Technical Volume

38th Indian Engineering Congress

December 27-29, 2023

Venue: Hotel Royal Orbit, Jabalpur

Theme

Reimagining Tomorrow: Shaping the Future through Disruptive and Interdisciplinary Technologies

Organised by

The Institution of Engineers (India)

8 Gokhale Road, Kolkata

Hosted by

Jabalpur Local Centre

The Institution of Engineers (India)

Notification for

R&D Grant-in-Aid

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TECHNICAL VOLUME

38th Indian Engineering Congress

27-29 December 2023, Jabalpur

theme

Reimagining Tomorrow: Shaping the Future through Disruptive and Interdisciplinary Technologies

The Institution of Engineers (India)
8 Gokhale Road, Kolkata 700020

The Institution of Engineers (India)
AN ISO 9001 : 2015 CERTIFIED ORGANISATION
(ESTABLISHED 1920, INCORPORATED BY ROYAL CHARTER 1935)
8 Gokhale Road, Kolkata 700 020

A Century of Service to the Nation

Er Shivananda Roy
President
The Institution of Engineers (India)

Message

As we stand on the threshold of the 38th Indian Engineering Congress, it is a matter of immense pleasure to note that a Technical Volume is being published on the occasion. This volume serves as a hallmark of the Congress's theme, 'Reimagining Tomorrow: Shaping the Future through Disruptive and Interdisciplinary Technologies.'

In an era defined by rapid technological evolution, this congress serves as a beacon for the engineering community to converge, exchange ideas, and chart the course for a future shaped by innovation and interdisciplinary collaboration. The theme aptly captures the essence of our collective journey—a journey propelled by disruptive technologies that fosters holistic solutions to complex challenges.

Within the pages of this Technical Volume, the collective efforts of our contributors manifest in meticulous research, analytical prowess, and an unwavering commitment to excellence. This collaboration transforms the volume into a repository of cutting-edge advancements in the expansive landscape of engineering. Original contributions, case studies, articles of professional interest, and review work collectively reflect the diverse and comprehensive nature of the shared knowledge within.

As we eagerly look forward to the inaugural session on December 27, 2023, when this compendium of knowledge will be unveiled, we warmly invite you to explore the narratives and transformative insights that delineate the current state of engineering excellence. This Technical Volume will serve not only as a source of inspiration but also as a dynamic platform for fostering collaboration. It stands as a compelling testament to the boundless possibilities that lie ahead in our collective journey of shaping the future through disruptive and interdisciplinary technologies.

(Shivananda Roy)

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A Century of Service to the Nation

Dr G Ranganath
Chairman, Technical Committee, 38th IEC
Chairman, Committee for Advancement of Technology and Engineering (CATE) &
President-Elect, The Institution of Engineers (India)

Message

It is with great pleasure I extend my heartfelt greetings to all participants of the 38th Indian Engineering Congress, hosted by the Jabalpur Local Centre from December 27-29, 2023. Under the compelling theme, "Reimagining Tomorrow: Shaping the Future through Disruptive and Interdisciplinary Technologies," this congress promises to be a crucible of innovation and transformative ideas.

The disruptive and interdisciplinary technologies will shape a future overcoming the current limitations for our future generation. I am confident that this congress will be a nexus for the exchange of knowledge, ideas, and collaborative spirit.

The challenges of our era demand collective ingenuity, and it is heartening to witness the diverse expertise converging here to address them. Interdisciplinary collaboration is not merely a choice but a necessity in navigating the complexities of our time. Together, we shall explore uncharted territories, challenge the status quo, and usher in an era where technology is a force for good.

This congress will serve as a crucible for forging new partnerships, fostering innovation, and incubating ideas that will define the future of engineering. I extend my gratitude to the Jabalpur Local Centre for hosting this momentous event and commend all participants for their dedication to advancing the frontiers of knowledge.

Wishing you an enlightening and fruitful congress as we collectively embark on the journey of "Reimagining Tomorrow."

With profound respect and best wishes,

(G Ranganath)

The Institution of Engineers (India)

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A Century of Service to the Nation

Er Rakesh Rathore
Organising Chairman
Organising Committee
38th Indian Engineering Congress
The Institution of Engineers (India)

Message

I am happy to host the 38th Indian Engineering Congress of The Institution of Engineers (India) at Jabalpur during 27-29 December 2023 on the theme Reimagining Tomorrow: Shaping the Future through Disruptive and Interdisciplinary Technologies.

The technology have a profound impact on the society and the economy, and their influence is only to set to grow, and we believe innovation and discovery are the way forwards towards a bright future for humanity.

The scope of the congress is to delve into the ever-evolving world of technologies and their impact on various aspects of our society. The congress will also explore the societal implications and impacts of technologies, including the future of the modern workspace, the role of government and policy, and the importance of human interaction in an increasingly digital world.

The congress aims to bring together researchers, academics, industry leaders to discuss the impact of technologies on traditional business models, markets, and the environment. Our goal is to foster a deeper understanding of the challenges and opportunities posed by technologies and to explore ways in which they can drive inclusive and equitable growth and mitigate sustainable development.

I congratulate and extend my greetings to all those who directly and indirectly involves in hosting such a grand event. I wish the event will be grand success.

With profound thanks & Regards,

(Rakesh Rathore)

The Institution of Engineers (India)

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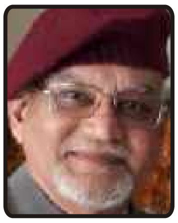
A Century of Service to the Nation



Brigadier V K Trivedi
Organising Secretary
Organising Committee
38th Indian Engineering Congress
The Institution of Engineers (India)

Message

It is a great honour to host the 38th Indian Engineering Congress of The Institution of Engineers (India) at Jabalpur during 27-29 December 2023. It is proud privilege to state that in the history over 100 years of The Institution of Engineers (India) that Jabalpur has got an opportunity to host the flagship event of IEI.

The rise of disruptive & Interdisciplinary technologies has resulted in a significant shift in the way businesses operate. Traditional business models and markets are being disrupted, leading to the emergence of innovative and often more sustainable alternatives. These emerging models are driven by new technologies and enabled by their unique capabilities. To evolve and move forward, we must examine the impact of these disruptive technologies on traditional business models and markets and explore strategies for adapting to them in a business context. Additionally, the ethical and social considerations that arise when adopting these technologies in a business setting are crucial to creating a human-centered environment that promotes livability and well-being.

It is a well known fact that the Engineers are the back bone of the infrastructure development, who gives shape to the developmental agendas of the nation and have played a very vital role in the nation building.

I congratulate and compliment to all our centres, council members, technical partners, knowledge partners, patrons, sponsors and members of The Institution of Engineers (India) as a whole for contributing and helping Jabalpur Local Centre for hosting such a big, historic and memorable event. I wish the event will be grand success.

(Brigadier V K Trivedi)

Technical Volume of
38th Indian Engineering Congress, 2023

President, IEI
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President-Elect, IEI
Dr G Ranganath

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Green Fabricated Iron-Oxide Nano-Adsorbent for Removal of Sulfur and Nitrate Ions from Wastewater of Dairy Processing Industry

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***Abstract**: Treatment of milk processing industry wastewater with an abundance concentration of hazardous organic contaminants is desirable for the sustainability of food processing industries, but it is challenging. This study aimed to develop a green synthesized iron-oxide nano-adsorbent using an eco-friendly ultrasonic assisted extract of the Catharanthusroseus flowers. Quality characteristics of wastewater determined and found huge effluent loads, including sulfate and nitrates. Characterization of the developed adsorbent revealed stable, non-spherical particles with a grooved surface and a face-centered cubic phase with a typical hematite spinal structure. An intermolecular H-bonding interactions and phytochemicals were found to be responsible for reducing ferric chloride hexahydrate into iron-oxide nanoparticles. The percent reduction efficiency of nitrate and sulfate with fabricated adsorbent was determined with a focus on the initial concentration of pollutants, pH, adsorbent dosage, and contact time. Prediction of process responses were made by artificial neural networks coupled with response surface methodology-based soft-computing technique. In a batch study, 88.08 and 86.36% of sulfate and nitrate were absorbed on adsorbent at optimized adsorption process parameters. Pseudo-second order, Freundlich, and intra-particle-diffusion models were the best fit to predict the adsorption capacity of a developed adsorbent. Most of the milk processing industry wastewater characteristics fell below the permissible limits of effluent standards, especially sulfate, and nitrate, resulting in 98.21 and 92.30% reduction efficiency. Hence, this novel green technology could be used in the milk processing industry for cleaner production and recycling wastewater.*

***Keywords**: Milk-processing, wastewater treatment, Catharanthusroseus, iron oxide, Nanoadsorbent*

INTRODUCTION

Environmental protection and freshwater conservation are the two main objectives of wastewater treatment. The milk processing industry (MPI) is the only industrial sector that runs continuously to process and develop milk and milk-based dairy products (Alimohammadi et al., 2017). MPI has been adopted physical, chemical, and biological treatment methods, including advanced sedimentation and flotation (Suman et al., 2018).

Adsorption could be used to solve the issues mentioned in the MPIW treatment techniques (Dinesha et al., 2022b). It is a phenomenon that occurs on surfaces and is a popular method for getting rid of all kinds of pollutants (El-sayed, 2020). In the recent decade, specifically for the treatment of MPIW using different nanoadsorbents such as chitosan, magnetic iron oxide, copper oxide, zinc oxide, titanium dioxide, chitosan zinc oxide, chitosan titanium dioxide, activated carbon, chitosan zinc-oxide coated sand filter beds were studied by various types of research (Al-Ananzeh, 2021; Dinesha et al., 2022a; Kushwaha et al., 2010; Thirugnanasambandham et al., 2014; Thirugnanasambandham and Sivakumar, 2016). For the treatment of industrial wastewater, iron oxide nanoparticles (IO-NPs) offer strong adsorptive and reductive characteristics. Herein, present work reported the green synthesis iron oxide nanoadsorbent (GSIO-NA) development using an optimized ratio of $FeCl_3.6H_2O$ (the precursor) and CRFE (the reducing agent).

MATERIALS AND METHODS

Green Synthesis of Iron Oxide Nanoadsorbent

C. roseus flower extract prepared according to method described by Kumar et al. (2020). Green synthesis procedure adopted according to method of Bibi et al., (2019).

Batch Adsorption Study

In accordance with the procedure outlined by Alimohammadi et al. (2016), a batch adsorption study for %RE of sulfate and nitrate was carried out using GSIO-NA. Initial GSIO-NA dosages of 10, 15, and 20 mg/L and initial sulfate and nitrate concentrations of 50, 100, and 150 mg/L were prepared in 100 mL of double distilled water in a conical flask. With 0.1M concentrated HCl and H_2SO_4, the pH (2, 6, and 10) of the prepared sulfate and nitrate solutions were adjusted. At varied time intervals (20, 70, and 120 min), the flasks consisting of the solutions were stirred at 200 rpm in an orbital shaker incubator that was kept at a temperature of 30 °C. Using a 10 mL syringe, samples from the batch adsorption tests were taken, filtered through a 0.45 um syringe filter, and then tested for nitrate and sulfate content. The outcomes of replicate studies were tabulated. The values of %RE of sulfate and nitrate were calculated using Eq. (1).

$$\% \text{ of RE of sulfate or nitrate } = \left[\frac{\text{Initial concentration} - \text{Final concentration}}{\text{Initial concentration}}\right] \times 100 \qquad (1)$$

RESULTS AND DISCUSSION

Table 1 displays the independent variable's coded and uncoded values together with the matching experimental and predicted values. Maximum %RE of sulfate by employing GSIO-NA was found to be 88.08% for Y_{Exp}, 60.05% for Y_{RSM}, and 88.13% for Y_{ANN} at sulfate concentration of 150 mg/L, 10 pH, GSIO-NA dose of 15 mg/L, and contact duration of 70 min., respectively (Run 8). The minimum %RE of sulfate by using GSIO-NA was found to be 3.16% for Y_{Exp}, 19.81% for Y_{RSM}, and 3.19% forY_{ANN} at an sulfate concentration of 50 mg/L, 6 pH, a GSIO-NA dose of 15 mg/L and, a contact duration of 20 min, respectively (Run 9). Additionally, it can be seen in the table that utilising GSIO-NA, the maximum %RE of nitrate was found to be 86.36% for Y_{Exp}, 85.84% for Y_{RSM}, and 86.18% for Y_{ANN} at nitrate concentration of 50 mg/L, 2 pH, a GSIO-NA dose of 15 mg/L and, a contact duration of 70 min, respectively (Run 1). The minimum %RE of nitrate by using GSIO-NA was found to be 55.75% for Y_{Exp}, 63.03% for Y_{RSM}, and 55.67% for Y_{ANN} at nitrate concentration of 100 mg/L, 6 pH, a GSIO-NA dose of 10 mg/L, and a contact duration of 20 min, respectively (Run 5). Effects of the interactions between the initial concentration, pH, dose, and contact time on the %RE of sulfate and nitrate were significant statistically at $p<0.05$. The findings of an adsorption study performed on a batch of GSIO-NA were compared with predicted values of Y_{RSM} and Y_{ANN} (Run 1 to 29).

Table 2 shows the variance analysis results and estimated coefficient values for sulfate and nitrate. The model's F-values of 2.61 and 3.90 are considered significant. Only a 4.19% probability of sulfate and a 0.79% probability of noise causing a significant "model F-value" exist. The model terms are considered significant when the "Prob > F" values are less than 0.05. The independent variables, such as concentration (X_1), pH (X_2), dosage (X_3), and contact time (X_4), are important model terms in both the%RE of sulfate and nitrate. The coded parameters X_1, X_2, X^2 and X_1, X_2, X_4, X_1^2, X_2^2 are model significant terms for %RE of sulfate and nitrate. The parameters were considered insignificant if p> 0.1. The "F-valueLack of Fit " of 54.15 and 55.16 denotes a significant lack of fit. An "F-valueLack of Fit" this large could only happen noise 0.08% of the time. If the "Pred R-Squared" value is negative, the overall mean is considered a more accurate predictor of response than the existing model. A ratio of at least 4 is preferable when measuring the signal-to-noise ratio using "Adeq Precision". A ratio of 6.17 to 7.78 indicates a strong enough signal. Hence, this model helped to find a better way around the design space.

Determination coefficients (R^2=0.722 and 0.795) showed a strong correlation between the predicted and experimental values. As a result, within the studied range, the resulting model accurately assessed the expected response. The optimized predictive quadratic model (in terms of coded factors) for %RE of sulfate and nitrate by using GSIO-NA is presented in Eq. 2 and 3.

%RE of sulfate = $72.23+13.87*X_1+20.52*X_2-0.67*X_3+7.33*X_4+14.58*X_1*X_2-18.69*X_1*X_3- 9.31*X_1*X_4-2.85*X_1*X_2-2.86*X_2*X_4-5.21*X_3*X_4-19.70*X_1^2-6.02*X_2^2- 11.41*X_3^2- 2.22*X_4^2$ … (2)

%RE of nitrate = $74.93-4.06*X_1-5.04*X_2+1.29*X_3+6.53*X_4+2.31*X_1*X_2-3.15*X_1*X_3+1.36*X_1*X_4+2.35*X_2*X_3-0.14*X_2*X_4+1.77*X_3*X_4+5.15*X_1^2-5.66* X_2^2-4.04*X_3^2-1.82*X_4^2$ ⋯ (3)

Table 1 Independent variables with values that have been encoded and uncoded, together with the matching experimental and anticipated values

Run	X_1 (mg/L)	X_2	X_3 (mg/L)	X_4 (min)	% reduction of sulfate			% reduction of nitrate		
					Y_{EXP}	Y_{RSM}	Y_{ANN}	Y_{EXP}	Y_{RSM}	Y_{ANN}
1	50(−1)	2(−1)	15(0)	70(0)	56.00	26.72	56.04	86.36	85.84	86.18
2	150(+1)	2(−1)	15(0)	70(0)	41.27	25.30	41.30	76.55	73.10	76.60
3	50(−1)	10(+1)	15(0)	70(0)	44.00	38.58	44.61	62.15	71.12	62.30
4	150(+1)	10(+1)	15(0)	70(0)	87.60	95.50	87.60	61.59	67.64	61.48
5	100(0)	6(0)	10(−1)	20(−1)	40.10	46.74	40.15	55.75	63.03	55.67
6	100(0)	6(0)	20(+1)	20(−1)	69.83	55.82	69.90	59.33	62.06	59.35
7	100(0)	6(0)	10(−1)	120(+1)	79.20	71.82	79.16	69.73	72.52	69.70
8	100(0)	6(0)	20(+1)	120(+1)	88.08	60.05	88.13	80.41	78.65	80.36
9	50(−1)	6(0)	15(0)	20(−1)	03.16	19.81	03.19	84.86	77.16	84.68
10	150(+1)	6(0)	15(0)	20(−1)	83.27	66.16	83.28	70.80	66.32	70.81
11	50(−1)	6(0)	15(0)	120(+1)	25.00	53.07	25.49	85.50	87.48	85.58
12	150(+1)	6(0)	15(0)	120(+1)	67.87	62.22	67.92	76.89	82.09	76.87
13	100(0)	2(−1)	10(−1)	70(0)	17.63	32.12	17.63	73.50	71.33	73.28
14	100(0)	10(+1)	10(−1)	70(0)	87.50	78.86	87.26	60.53	56.55	60.61
15	100(0)	2(−1)	20(+1)	70(0)	16.84	36.48	16.85	67.74	69.22	67.70
16	100(0)	10(+1)	20(+1)	70(0)	75.30	71.81	75.42	64.16	63.82	64.15
17	50(−1)	6(0)	10(−1)	70(0)	22.00	9.24	22.23	77.48	75.65	77.21
18	150(+1)	6(0)	10(−1)	70(0)	66.67	74.37	66.73	75.94	73.85	75.82
19	50(−1)	6(0)	20(+1)	70(0)	42.54	45.27	42.67	85.46	84.54	85.43
20	150(+1)	6(0)	20(+1)	70(0)	12.44	35.64	12.53	71.30	70.12	71.31
21	100(0)	2(−1)	15(0)	20(−1)	29.00	33.29	29.05	60.89	65.83	63.57
22	100(0)	10(+1)	15(0)	20(−1)	76.50	80.05	76.19	58.76	56.02	55.50
23	100(0)	2(−1)	15(0)	120(+1)	46.80	53.68	48.73	79.43	79.15	79.57
24	100(0)	10(+1)	15(0)	120(+1)	82.84	88.98	83.69	76.75	68.79	76.85
25	100(0)	6(0)	15(0)	70(0)	66.67	72.24	64.77	74.54	74.93	74.59
26	100(0)	6(0)	15(0)	70(0)	73.65	72.24	70.77	74.53	74.93	74.58
27	100(0)	6(0)	15(0)	70(0)	73.44	72.24	70.77	74.52	74.93	74.50
28	100(0)	6(0)	15(0)	70(0)	73.70	72.24	71.77	74.55	74.93	74.52
29	100(0)	6(0)	15(0)	70(0)	73.70	72.24	71.77	76.53	74.93	75.98
R^2						0.722	0.998		0.795	0.991
Adj-R^2						0.712	0.998		0.788	0.991
SSE						3816	27.34		351.7	18.28
RMSE						11.89	1.066		3.67	0.822

X_1- Initial concentrations of sulfate and nitrate (mg/L), X_2- pH, X_3- GSIO-NA dosage (mg/L), X_4- Contact time (min), Y_{EXP} - Experimental value, Y_{RSM} - Predicted by RSM model, Y_{ANN} - predicted by ANN model.

Process Parameters Optimization

Table 3 demonstrates the use of GSIO-NA to compare expected and actual responses for %RE of sulfate and nitrate. An optimized treatment combination for experimental and predicted values of %RE of sulfate using GSIO-NA was found to be 88.08 and 88.13% at pH of 6, initial sulfate concentration of 100 mg/L, contact duration of 120 min, and GSIO-NA dose of 20 mg/L. The combination of this optimized treatments had an R^2 value of 0.722, a %RD of -0.0019, and desirability of 0.999. Similarly, with a 2 pH, 50 mg/L of nitrate concentration, 70 min of contact period, and 15 mg/L of GSIO-NA dose. The optimal treatment combination for nitrate reduction utilizing GSIO-NA was reported to be 86.36% (experimental) and 86.18% (predicted). This combination of optimized treatments had an R^2 value of 0.795, a %RD of 0.071, and desirability of 0.953.

Table 2 Statistical parameters ofthe quadratic model

Source	%RE of sulfate				%RE of nitrate			
	Sum of squares	**Mean Square**	**F-value**	**p-value**	**Sum of squares**	**Mean Square**	**F-value**	**p-value**
Model	13758	982.71	2.61	0.0419 (S)	1724.32	123.17	3.90	0.0079 (S)
X_1	2307.97	2307.97	6.12	0.0268	197.97	197.97	6.27	0.0253
X_2	5051.2	5051.20	13.39	0.002600	305.32	305.32	9.66	0.0077
X_3	5.42707	5.43	0.01	0.9062	19.94	19.94	0.63	0.4402
X_4	644.307	644.31	1.71	0.2123	511.17	511.17	16.18	0.0013
X_1X_2	850.597	850.60	2.26	0.1554	21.39	21.39	0.68	0.4244
X_1X_3	1397.64	1397.64	3.71	0.0748	39.82	39.82	1.26	0.2805
X_1X_4	346.704	346.70	0.92	0.3539	7.43	7.43	0.24	0.6353
X_2X_3	32.547	32.55	0.09	0.7732	22.04	22.04	0.70	0.4176
X_2X_4	32.8329	32.83	0.09	0.7723	0.08	0.08	0.00	0.9617
X_3X_4	108.681	108.68	0.29	0.5998	12.60	12.60	0.40	0.5378
Residual	5279.91	377.14			442.30			
Lack of Fit	5241.19	524.12	54.15	0.0008 (S)	439.11	43.91	55.16	0.0008 (S)
Pure Error	38.7159	9.68			3.18			
Cor Total	19037.9				2166.61			

S– Significant

Table 3 Verification GSIO-NA process variables

	Pollutants	X_1	X_2	X_3	X_4	**% RE**	**%RD**	**Desirability**	R^2**-value**
Predicted Experimental	Sulfate	100	6	20	120	88.13 88.08	-0.0019	0.999	0.722
Predicted Experimental	Nitrate	50	2	15	70	86.18 86.36	0.0071	0.953	0.795

%RD– Percent relative deviation

CONCLUSION

Iron oxide NPs as a nanoabsorbent synthesized by employing flower extract of the C. roseus plant and characterized thoroughly for morphology and phase purity. Adsorption process variables on the %RE of sulfate and nitrate were optimized and predicted through RSM and ANN modeling approaches. Maximum %RE (experimental and predicted) values of sulfate (88.08 and 88.13%) and nitrate (86.36 and 86.18%) were found at initial sulfate and nitrate concentrations of 100 and 50 mg/L, pH of 6 and 2, GSIO-NA dosages of 20 and 15 mg/L, and contact times of 120 and 70 min, respectively. Thus, it is anticipated that the treated MPIW will be accepted for recycling, safe disposal, and irrigation. This integrated strategy offers effective wastewater treatment technologies for potential environmental benefits.

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Biomimicry in Architecture: The Synergistic Fusion of Nature's Wisdom and Artificial Intelligence for Sustainable and Aesthetically Alluring Energy-Efficient Structures

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***Abstract**: The realm of architecture is currently witnessing a groundbreaking paradigm shift, where Biomimicry, a design approach inspired by nature, converges with Artificial Intelligence (AI) to birth energy-efficient structures for sustainable living. This transformative synergy harnesses the intrinsic wisdom of the natural world and the computational dexterity of AI to transcend conventional architectural norms, crafting buildings that embody both efficiency and aesthetics. In the course of this investigation, we focus on avant-garde architectural organizations that have embraced this union, serving as emblematic pioneers of nature-inspired designs enhanced by cutting-edge technology. The study's overarching purpose is to comprehensively explore the fusion of Biomimicry and AI within architecture, unveiling the potential inherent in this amalgamation, with a specific emphasis on energy efficiency, sustainability, and aesthetic appeal. To this end, we delineate the foundational principles of Biomimicry, elucidate the role of AI in enhancing these principles, scrutinize select architectural projects that exemplify this synergy, and evaluate the multifaceted impacts of Biomimetic architectural design enriched by AI. Employing a multifaceted research methodology involving literature review, case studies, expert interviews, and data analysis, this study aims to provide a comprehensive perspective on the dynamic interaction between Biomimicry and AI in architecture. Nevertheless, it is essential to acknowledge the study's limitations, encompassing potential biases in case study selection and the ever-evolving landscape of AI applications in architecture. The social and practical ramifications of this fusion are profound, fostering eco-conscious architectural design that aligns with resource efficiency, ecological stewardship, and human well-being, ultimately harmonizing humanity's coexistence with the environment. Looking forward, the research's trajectory extends into the ongoing exploration of the evolving relationship between Biomimicry and AI, with a focus on quantifiable benefits, in-depth case study analyses, and emerging technological intersections, as it aspires to cultivate a novel architectural language that venerates both nature's wisdom and AI's intelligence, facilitating sustainable and harmonious living.*

***Keywords**: Biomimicry in Architecture, Artificial Intelligence (AI) in Architecture, Sustainable Building Design, Nature-Inspired Architecture, Energy-Efficient Structures*

INTRODUCTION

The realm of architecture is undergoing a transformative paradigm shift, marked by the convergence of Biomimicry and Artificial Intelligence (AI), unlocking new possibilities for the creation of sustainable and aesthetically appealing structures. This synthesis of nature's wisdom and computational prowess represents a groundbreaking approach to architectural design, reshaping the way we conceive, construct, and inhabit built environments. As we stand at the intersection of biological inspiration and technological innovation, this paper aims to delve into the profound implications and potentials of this symbiotic relationship, focusing on energy-efficient structures that embody both functionality and beauty.

Context for the Paradigm Shift in Architecture

Traditionally, architectural design has been informed by human-centric principles, often detached from the intricate ecosystems and efficiencies found in the natural world. However, a growing awareness of environmental challenges, coupled with advancements in scientific understanding, has catalysed a paradigm shift. Architects and designers are increasingly turning to nature for inspiration, recognizing the efficiency, resilience, and sustainability inherent in biological systems. This shift reflects a broader societal recognition of the need for environmentally conscious practices in the face of climate change and resource depletion.

Defining Biomimicry and its Role in Architectural Design: (Royall, 2010)

Biomimicry, as a design approach, draws inspiration from nature's patterns, processes, and systems to solve human challenges. This method transcends mere aesthetic imitation, seeking to emulate the underlying principles that govern nature's success. Architectural Biomimicry, therefore, involves not only mimicking natural forms but also integrating ecological principles and sustainable strategies into the built environment. By learning from the efficiency of a spider's silk or the resilience of a termite mound, architects can create structures that are not only visually appealing but also inherently sustainable and adaptive.

This integration of Biomimicry into architectural practices aligns with the ethos of sustainability, as nature has been optimizing its designs over millions of years of evolution. The potential benefits are manifold, from enhanced energy efficiency to the creation of structures that seamlessly integrate with their surrounding ecosystems. The use of biomimetic principles in architectural design also represents a departure from the conventional, linear approach to construction, embracing a more circular and regenerative model inspired by natural ecosystems.

Introducing Artificial Intelligence in Architecture: (Pena, 2021)

Simultaneously, the advent of Artificial Intelligence has introduced a new dimension to architectural innovation. AI, with its computational abilities, has the capacity to process vast amounts of data, simulate complex scenarios, and generate design solutions that might elude traditional human-centred approaches. Machine learning algorithms, generative design software, and parametric modelling tools empower architects to explore a multitude of design possibilities, optimizing structures for performance, resource efficiency, and user experience.

The role of AI in architecture extends beyond mere automation; it facilitates a collaborative partnership between human creativity and machine intelligence. AI tools analyse vast datasets on climate, materials, and construction techniques, informing architects about optimal design parameters for specific contexts. This fusion of human intuition and machine precision holds the promise of revolutionizing the architectural design process, transcending limitations and unlocking innovative solutions to complex challenges.

Significance of the Study and Objectives:

Against this backdrop, the significance of this study lies in unravelling the synergistic fusion of Biomimicry and AI within the field of architecture. By understanding and documenting this convergence, we aim to shed light on how it redefines the principles of sustainable building design, energy efficiency, and aesthetic appeal. The study seeks to go beyond surface-level exploration, delving into specific case studies, methodologies, and impacts, providing a comprehensive perspective on this transformative relationship.

Primary Objectives of this Study

- To Explore Foundational Principles: Examine the fundamental principles of Biomimicry in architecture, elucidating how it goes beyond superficial imitation to integrate ecological and sustainable elements.
- To Unveil AI's Role in Enhancing Biomimetic Principles: Investigate how AI complements and enhances Biomimicry, specifically focusing on the ways in which computational tools contribute to the optimization of architectural designs inspired by nature.
- To Analyse Exemplary Case Studies: Examine select architectural projects that epitomize the synergy between Biomimicry and AI. Evaluate these cases in terms of design innovation, energy efficiency, and aesthetic appeal.
- To Evaluate Impacts: Assess the multifaceted impacts of Biomimetic architectural design enriched by AI, considering environmental, social, and economic dimensions.
- To Provide a Comprehensive Methodology: Employ a multifaceted research methodology, including literature review, case studies, expert interviews, and data analysis, to offer a well-rounded understanding of the subject.

As we embark on this exploration, it is essential to acknowledge the inherent limitations, including potential biases in case study selection and the rapidly evolving landscape of AI applications in architecture. Through this study, we aim to contribute to the evolving discourse on sustainable architecture, paving the way for a future where the built environment harmonizes with both nature's wisdom and artificial intelligence.

BIOMIMICRY IN ARCHITECTURE: FOUNDATIONAL PRINCIPLES

Biomimicry, an innovative practice grounded in deriving insights from nature's ingenious solutions to complex challenges, signifies a profound paradigm shift in engineering and architectural design. At its core, this approach contends that nature, through the crucible of natural selection spanning billions of years, has effectively grappled with and resolved myriad issues confronting society. This article embarks on a comprehensive exploration of the principles underpinning biomimicry, with a pronounced emphasis on its pertinence in the realm of architecture. The ensuing discourse is complemented by a series of case studies meticulously curated to underscore the tangible application of biomimicry principles in real-world architectural projects.(Mathew, n.d.)

Principles of Biomimicry

The foundational precepts of biomimicry serve as the cornerstone for transmuting nature's brilliance into human engineering endeavours. This section meticulously examines these core tenets:

- Emulating Nature's Forms and Shapes: This necessitates a scrupulous observation and emulation of natural structures to inform the design of efficient and sustainable human-made edifices. Through discerning replication of nature's shapes, architects are poised to craft structures that not only satisfy aesthetic sensibilities but also coalesce seamlessly with the surrounding environment.
- Mimicking Biological Processes:A deep dive into the intricacies of processes such as photosynthesis and respiration yields invaluable insights for the development of innovative and sustainable technologies in architectural design. By assimilating and replicating these processes, architects can propel the creation of eco-friendly and energy-efficient structures.
- Learning from Ecosystems: Extending biomimicry beyond individual organisms, this principle delves into the study of interconnected natural systems. Its objective is to influence the design of resilient and sustainable human systems by drawing inspiration from the intricate yet efficient structures manifested in ecosystems.
- Optimizing Resource Use: As a linchpin for sustainability, this principle exhorts designers to derive inspiration from nature's efficient resource utilization. Such inspiration not only advances sustainability objectives but also curtails waste generation in architectural projects.
- Adaptation and Resilience: This principle accentuates the integration of adaptability and resilience into designs, mirroring nature's inherent capacity to withstand and recover from disturbances. Architectural structures, thus inspired, are poised to navigate environmental challenges with heightened efficacy.
- Use of Life-Friendly Chemistry: Underscoring the significance of sustainable materials and chemicals derived from the principles of life-friendly chemistry found in natural processes, this principle advocates for the incorporation of environmentally friendly and non-toxic elements in architectural constructs.

Rethinking Future: Historical Roots and Contemporary Examples

This segment delves into the historical antecedents of biomimicry in architecture, illuminating how nature-inspired design has subtly permeated human-built environments across different epochs. The enduring influence of the Golden Ratio, reflective of natural spirals, serves as an ancient architectural touchstone, yielding structures characterized by aesthetic harmony and proportion. Contemporary exemplars, such as the East Gate Centre in Harare, Zimbabwe, and the Beijing National Stadium, serve as living testaments to the seamless integration of biomimicry principles into expansive architectural projects, where functionality converges with aesthetics.

Case Studies

1. East Gate Center, Harare, Zimbabwe:(Emmanuel k. Bright, 2021)

- Inspiration: Biomimicry principles exerted a discernible influence on the design, drawing inspiration from natural shapes and patterns.
- Design Elements: The resultant undulating facade of the building mirrors dynamic patterns found in nature.
- Outcome: The integration of biomimicry principles yielded an architectural marvel that is not only aesthetically captivating but also environmentally congruent.

2. Beijing National Stadium, China:

- Inspiration: Biomimicry principles served as a guiding ethos in the structural design, drawing inspiration from the efficiency and strength observed in bird nests.
- Design Elements: The intricate lattice pattern, reminiscent of twigs woven in a nest, enhances both aesthetic appeal and structural integrity.
- Outcome: The "Bird's Nest" stands as an iconic exemplar of biomimicry in architecture, embodying a symbiosis of functionality and visual allure.

3. Ancient Egyptian Columns:

- Inspiration: Ancient Egyptian architecture, predating formal biomimicry studies, manifests early influences of nature-inspired design.
- Design Elements: Columns in structures like the Karnak Temple exhibit proportions reflecting the Golden Ratio inherent in natural spirals.
- Outcome: The application of biomimicry principles, albeit not explicitly labelled as such, contributed to visually pleasing and proportioned architectural designs.

These case studies collectively underscore the versatility and enduring influence of biomimicry across different historical epochs and cultural milieus. From the nuanced intricacies of ancient Egyptian columns to the contemporary grandeur of the East Gate Center and the Beijing National Stadium, biomimicry consistently emerges as a driving force in shaping architecture—offering sustainable, resilient, and aesthetically pleasing design solutions.

Biomimicry for Sustainable Innovation:(Leena N. Fukey, 2019)

Against the backdrop of burgeoning globalization, biomimicry emerges as a beacon of hope for the tenets of sustainable architecture. Coined to encapsulate the essence of mirroring nature's genius, biomimicry propounds a transformative paradigm for erecting a built environment that seamlessly harmonizes with the planet. This innovative approach epitomizes a steadfast commitment to ecological responsibility, heralding a promising trajectory for sustainable solutions.

Drawing inspiration from nature's efficiency and resilience, biomimicry stands at the vanguard of redefining architectural practices. It transcends mere conceptualization, serving as a potent catalyst for change—propelling sustainability into the very nucleus of global architectural discourse and ensuring a regenerative legacy for posterity.

Biomimicry for a Sustainable Future:

Biomimicry, a lodestar of sustainable innovation, aligns harmoniously with ecological principles to recalibrate our approach to design. By scrutinizing nature's blueprints, it advocates for biodiversity preservation, efficient resource utilization, and the establishment of closed-loop systems, thereby minimizing environmental impact.

The focus on adaptability and resilience within biomimicry mirrors the innate fortitude of ecosystems, steering the development of designs capable of withstanding the vicissitudes of environmental shifts. From carbon sequestration initiatives to water conservation strategies and habitat restoration endeavours, biomimicry proffers solutions deeply rooted in nature's efficiency. It not only elevates energy efficiency benchmarks but also serves as an inspirational wellspring for devising pollution prevention strategies. Moreover, it seamlessly integrates ecosystem services into urban planning, presenting a holistic paradigm where human innovation aligns seamlessly with the intrinsic wisdom of the natural world.

In the Face of Global Challenges

In confronting the contemporary challenges of climate change, resource depletion, and ecological degradation, biomimicry emerges as a robust framework for sustainable architectural innovation. Its multifaceted approach extends beyond conventional practices, offering a harmonious blend of functionality, aesthetics, and ecological integrity.

From Blueprint to Reality

Biomimicry, as an applied discipline, propels sustainable architecture from the realm of conceptualization to pragmatic reality. By leveraging nature's proven solutions, architects and designers are empowered to create structures that not only endure but actively contribute to the regeneration of the environment.

Looking Forward

As the architectural landscape evolves, biomimicry stands poised at the forefront, offering a transformative lens through which to envision and actualize a sustainable future. It is not merely a conceptual framework; it embodies a commitment to the seamless integration of human innovation with the intricate wisdom inherent in the natural world.

Legacy for Generations

The legacy of biomimicry in architecture transcends the immediate concerns of today. It heralds a paradigm shift that bequeaths to future generations a built environment that not only satisfies human needs but does so in concert with the regenerative principles of the natural world. In embracing biomimicry, we bequeath a legacy of sustainability—a gift that echoes through time.

In summation, biomimicry, converging innovation and ecological wisdom, emerges as a lodestar guiding the trajectory of architectural evolution. It is a testament to the transformative power of learning from nature, fostering a symbiotic relationship between human ingenuity and the enduring genius of the natural world.

ARTIFICIAL INTELEGENCE IN ARCHITECTURE: ENHANCING BIOMIMETIC PRINCIPLES

In the ever-evolving landscape of architectural design, the infusion of Artificial Intelligence (AI) has emerged as a transformative catalyst, reshaping conventional methodologies and ushering in an era marked by innovation and efficiency. This chapter intricately explores the multifaceted role of AI within the context of architectural design, with a specific emphasis on how it not only complements but significantly enhances the foundational principles of Biomimicry. We embark on an exploration of the symbiotic relationship between AI and Biomimicry, shedding light on the nuanced contributions of computational design, machine learning, and generative algorithms in the conception and realization of energy-efficient, sustainable, and aesthetically captivating structures.

Introducing AI in the Context of Architectural Design:(Pena, 2021)

The integration of AI into architectural processes represents a paradigm shift, transcending traditional design approaches. AI, in this context, encompasses an array of sophisticated technologies and methodologies that augment the creative process. Departing from reliance on human intuition alone, AI introduces computational capabilities that empower architects to analyse vast datasets, simulate intricate scenarios, and generate design solutions that extend beyond the limitations of manual exploration. Throughout the entire design lifecycle, AI becomes an active collaborator, offering profound insights, optimizing parameters, and suggesting innovative solutions.

This collaborative partnership goes beyond mere tool usage; architects are now active participants in a dynamic dialogue with AI tools, leveraging computational power to not only inform but fundamentally enhance their creative decisions. This synergy holds the promise of unlocking new dimensions in architectural expression while simultaneously addressing the urgent challenges posed by sustainability and efficiency in the built environment.

AI Complementing and Enhancing Biomimicry Principles:

At the heart of Biomimicry lies the quest for inspiration from nature's efficient and time-tested solutions. AI, as a powerful ally in this endeavor, amplifies Biomimicry principles and broadens the scope of design exploration. One pivotal aspect of AI's contribution to Biomimicry is its ability to analyze biological data. Machine learning algorithms, when fed vast datasets containing information about natural systems, excel at extracting intricate patterns and principles that can be directly applied to architectural design.

Consider the intricate network of veins in a leaf or the optimized structure of a bird's wing. AI can meticulously analyze these biological features, extracting underlying principles of efficiency and adaptability. Armed with this knowledge, architects can seamlessly integrate these principles into their designs, creating structures that not only mimic nature aesthetically but also functionally emulate its inherent efficiency.

Beyond this, AI facilitates a more rapid and iterative design process within the realm of Biomimicry. Generative algorithms, driven by machine learning, explore a myriad of design possibilities based on biomimetic principles. This not only accelerates the design phase but also allows architects to consider a broader spectrum of solutions, optimizing for various parameters such as energy efficiency, material usage, and structural integrity.

Role of Computational Design, Machine Learning, and Generative Algorithms in Architecture:(Caetano, 2020)

1. Computational Design: AI-driven computational design involves the application of algorithms to generate and evaluate design alternatives. This approach allows architects to traverse a vast design space, optimizing for different parameters and constraints. The iterative nature of computational design aligns seamlessly with the biomimetic process, mirroring nature's solutions that often result from continuous refinement over time.
2. Machine Learning: Central to the fusion of AI and Biomimicry is the role of machine learning algorithms. These algorithms play a pivotal role in the analysis of biological data, extracting actionable insights for architectural design. By learning from patterns in nature, machine learning contributes to the identification of biomimetic principles that can inform various aspects of a building's design, ranging from its overall form to the selection of materials.
3. Generative Algorithms: Leveraging computational power, generative algorithms autonomously produce design solutions based on predefined parameters and goals. In the context of Biomimicry, these algorithms explore biomimetic principles, generating designs that optimize for specific functions inspired by nature. This approach not only enhances the efficiency of the design process but also encourages novel solutions informed by the adaptability of biological systems.

In essence, the incorporation of AI into architectural design transcends mere automation; it evolves into an enabler of creativity, a catalyst for innovation, and a bridge between human intuition and computational precision. By amalgamating the principles of Biomimicry with the capabilities of AI, architects can envision and realize structures that not only pay homage to nature aesthetically but also embody its efficiency and resilience.

As we navigate the intricate interplay between Biomimicry and AI in architecture, it becomes increasingly apparent that their synergy extends far beyond a mere convergence of technologies. Instead, it signifies a paradigm shift in how we conceptualize, design, and construct the built environment. The collaborative dance between nature-inspired design principles and the computational prowess of AI empowers architects to envision and create structures that not only emulate the beauty of the natural world but also harness its inherent efficiency for sustainable, energy-efficient, and aesthetically captivating built environments.

This chapter serves as a foundational exploration, laying the groundwork for a deeper dive into exemplary case studies in subsequent sections. These case studies will provide tangible insights into the successful marriage of Biomimicry and AI, elucidating the concrete impacts and innovations arising from this transformative union.

CASE STUDIES: EXEMPLIFYING THE SYNERGY

In this comprehensive exploration, we delve into distinct case studies that serve as exemplars of the successful integration of Biomimicry and Artificial Intelligence (AI) within the realm of architectural projects. These case studies not only highlight the tangible manifestations of the symbiotic relationship between nature-inspired design principles and AI's computational prowess but also provide nuanced insights into the challenges faced and the innovative solutions that emerged throughout the design and implementation process.

The Eden Project – Cornwall, United Kingdom:(sriramoju, 2006)

Organization: Eden Project

The Eden Project, nestled in the picturesque landscape of Cornwall, United Kingdom, stands as a paradigm of architectural innovation, seamlessly marrying Biomimicry and AI. Conceived by Sir Tim Smit and designed by Sir Nicholas Grimshaw, this ambitious project drew inspiration from natural ecosystems, envisioning a series of biomes housing a diverse array of plant species. AI played a pivotal role in optimizing both the design and operational aspects of these biomes, ensuring a harmonious balance between sustainability, energy efficiency, and ecological preservation.

Analysis:

- Biomimicry Integration: The architectural vision of the biomes draws inspiration from the intricate geometry of geodesic domes, echoing the efficiency found in natural structures such as soap bubbles. This biomimetic approach not only enhances structural efficiency but also lays the foundation for the creation of a climate-controlled environment that mirrors the intricacies of diverse ecosystems.
- AI Contribution: AI takes center stage in the analysis of climate data, simulation of environmental conditions, and the optimization of the biome structures for energy efficiency. Machine learning algorithms continuously adapt to the dynamic interplay of environmental factors, ensuring optimal conditions for the flourishing plant life while minimizing energy consumption.
- Energy Efficiency: The integration of AI-driven climate control systems has led to a remarkable reduction in energy consumption. The system dynamically adjusts ventilation, heating, and cooling based on real-time environmental data, showcasing a harmonious synergy between Biomimicry-inspired design and AI-driven efficiency.
- Aesthetic Appeal: Beyond functionality, the architectural design contributes to a visually stunning landscape. The use of transparent ETFE panels allows natural light to weave through the biomes, creating a captivating play of light and shadows that enhances the overall aesthetic appeal and fosters a connection between visitors and the natural world.
- Challenges and Innovations: Challenges were encountered in fine-tuning AI algorithms to respond accurately to the complex and dynamic environmental conditions within the biomes. Innovations arose in the form of adaptive control systems, continuously learning from the ecosystem, ensuring a resilient and sustainable operation even in the face of unpredictable variables.

The Eastgate Centre – Harare, Zimbabwe:(Ansari, 2022)

Organization: Architect Mick Pearce and Arup Associates

The Eastgate Centre in the bustling city of Harare, Zimbabwe, stands as a testament to the successful integration of Biomimicry and AI, specifically tailored to address the unique challenges presented by the local climate. Architect

Mick Pearce, inspired by the ingenuity of termite mounds, envisioned a building that not only leverages natural ventilation principles but also incorporates AI to optimize and fine-tune its environmental performance.

Analysis:

- Biomimicry Integration: The building's ventilation system takes inspiration from the sophisticated design of termite mounds, utilizing passive cooling mechanisms through a series of strategically placed vents. This biomimetic approach ensures a comfortable indoor environment without heavy reliance on energy-intensive air conditioning systems.
- AI Contribution: AI is enlisted to analyze and predict weather patterns, occupancy data, and the efficiency of the termite-inspired ventilation system. Machine learning algorithms orchestrate real-time adjustments to the building's ventilation, optimizing indoor conditions based on external factors such as temperature, humidity, and occupancy.
- Energy Efficiency:The integration of Biomimicry and AI results in a building operating with significantly lower energy consumption compared to conventional structures. The reliance on natural ventilation not only reduces the need for mechanical cooling but also positions the Eastgate Centre as a shining example of sustainable architecture in a challenging climate.
- Aesthetic Appeal: The architectural design, influenced by the organic forms found in termite mounds, goes beyond functionality to contribute to the building's aesthetic appeal. The incorporation of natural elements creates a visually engaging and contextually responsive structure that harmonizes with its surroundings.
- Challenges and Innovations: Challenges included the adaptation of AI algorithms to the unique climatic conditions of Harare. Innovations emerged through predictive modeling, anticipating temperature fluctuations and enabling proactive adjustments to the building's ventilation system for enhanced efficiency.

The Beijing National Stadium (Bird's Nest) – Beijing, China:(Ann Rogers, 2008)

Organization: Herzog & de Meuron, Arup, and China Architecture Design & Research Group

The Beijing National Stadium, affectionately known as the Bird's Nest, is an architectural marvel that seamlessly weaves together Biomimicry and AI to create a visually striking and energy-efficient sports arena. Conceived for the 2008 Olympic Games, the stadium's form and structural principles draw inspiration from natural elements, while AI takes the stage in optimizing its energy usage and operational efficiency.

Analysis:

- Biomimicry Integration: The stadium's iconic lattice-like structure draws direct inspiration from the interwoven twigs of a bird's nest. This biomimetic approach not only contributes to the stadium's aesthetic appeal but also enhances its structural efficiency, mimicking the resilience found in nature.
- AI Contribution: AI plays a pivotal role in both the design and operation of the stadium. Computational design algorithms are employed to optimize the structural elements, ensuring each component contributes to the overall strength and stability. Furthermore, AI-driven building management systems are implemented to monitor and control energy usage in real-time.
- Energy Efficiency: The integration of Biomimicry and AI results in a structurally efficient stadium with optimized energy usage. AI-driven building management systems dynamically adjust lighting, HVAC, and other systems based on occupancy and environmental conditions, contributing to substantial energy savings.
- Aesthetic Appeal: Beyond functionality and efficiency, the biomimetic design of the Bird's Nest elevates the stadium to an aesthetic masterpiece. The lattice structure creates a sense of openness and transparency, allowing natural light to permeate the space and offering a visually engaging experience for spectators.
- Challenges and Innovations: Challenges were encountered in balancing the aesthetic vision of the architects with the structural and energy efficiency requirements. Innovations emerged through advanced computational simulations that fine-tuned the stadium's structural elements and AI algorithms that continuously optimize energy usage, particularly during high-occupancy events.

These case studies serve as illuminating illustrations of the successful synergy between Biomimicry and Artificial Intelligence within the field of architecture. Each project, while unique in its context and purpose, shares a common thread of harmonizing nature-inspired design principles with the computational precision afforded by AI. The analysis not only sheds light on the intricacies of this symbiotic relationship but also underscores the multifaceted successes in design innovation, energy efficiency, and aesthetic appeal.

As we navigate the complexities of the dynamic intersection between Biomimicry and AI in architecture, these case studies stand as beacons, guiding future architects and designers. They exemplify the possibilities of transformative and sustainable built environments, emphasizing the potential for a harmonious coexistence between nature's wisdom and artificial intelligence. In the subsequent sections, we delve deeper into the broader impacts and implications of this synergy, exploring the transformative potential it holds for the future of architecture and sustainable living.

IMPACTS OF BIOMIMETIC ARCHITECTURAL DESIGN ENRICHED BY AI(Doughan, et al., 2019)(Talanov, et al., 2015)(Jordi Vallverdu, 2016)

The integration of Biomimicry and Artificial Intelligence (AI) within architectural design represents a transformative synergy that extends its influence across diverse dimensions—environmental, social, and economic. This chapter meticulously examines the multifaceted impacts of this fusion, delving into its contributions to sustainability, enhancement of human well-being, and the potential drawbacks and challenges associated with the integration of Biomimicry and AI.

Environmental Impacts:

- Biodiversity Preservation: The infusion of AI into Biomimetic architectural design becomes a powerful tool for biodiversity preservation. This amalgamation allows architects to create structures that seamlessly blend into and contribute positively to local ecosystems. By mimicking natural forms and functions, these structures become ecological partners rather than disruptors, fostering a symbiotic relationship with the environment.
- Resource Efficiency: AI-driven design optimization significantly enhances resource efficiency in Biomimetic architectural projects. Inspired by the optimized systems found in nature, these designs are fine-tuned by sophisticated AI algorithms. The result is a reduction in overall resource consumption, spanning from energy-efficient climate control to sustainable material choices. This not only minimizes the environmental impact but also aligns with the global agenda of resource conservation.
- Adaptive Resilience: The fusion of Biomimicry and AI imparts a unique adaptive resilience to architectural structures. Drawing inspiration from natural ecosystems, these buildings can dynamically respond to changing environmental conditions. They exhibit a robustness akin to the adaptability found in nature, ensuring functionality and efficiency even in the face of unforeseen challenges such as climate fluctuations or extreme weather events.
- Carbon Footprint Reduction: AI's role in design optimization and material selection contributes significantly to the reduction of carbon footprints associated with construction and operation. Biomimicry principles, when integrated with AI, ensure that structures not only aesthetically imitate nature but are also inherently geared towards minimizing environmental impact. This convergence aligns with global efforts to mitigate climate change by curbing carbon emissions.

Social Impacts:

- Enhanced Human Experience: The marriage of Biomimicry and AI results in architectural spaces that transcend mere functionality, providing occupants with enhanced human experiences. The optimization of environmental conditions, incorporation of natural elements, and adherence to biophilic design principles collectively create spaces that are not only visually appealing but also conducive to well-being, comfort, and heightened productivity.
- Biophilic Design: Biomimetic architectural designs enriched by AI often embrace biophilic design principles, fostering a profound connection between occupants and the natural world. The deliberate exposure to natural

light, integration of greenery, and emulation of natural patterns contribute to improved mental health, reduced stress levels, and an overall positive impact on the psychological well-being of occupants.

- Community Engagement: These innovative architectural designs become focal points for community engagement. The integration of Biomimicry and AI turns these structures into educational hubs, attracting community interest and raising awareness about sustainable living practices. Public spaces inspired by nature and enriched by AI can catalyze community involvement and instill a collective sense of environmental responsibility.
- Inclusive Accessibility: AI-driven features in Biomimetic designs can serve as a catalyst for inclusive accessibility. Smart building technologies, guided by Biomimicry and AI, have the potential to adapt spaces to accommodate various needs, ensuring that architectural designs prioritize inclusivity and cater to a wide range of users. This inclusivity becomes an integral aspect of socially responsible design.

Economic Impacts:

- Long-term Cost Savings: While the upfront investment in Biomimetic architectural design enriched by AI may be higher, the long-term economic benefits are noteworthy. Energy-efficient structures result in reduced operational costs over time, and the durability of adaptive designs minimizes maintenance expenses. This financial sustainability contributes to the long-term viability of these structures, making them economically attractive.
- Innovation and Industry Growth: The integration of Biomimicry and AI fosters a culture of innovation within the architectural industry. Architectural firms at the forefront of this synergy position themselves as leaders in sustainable design, attracting clients and contributing to the evolution of construction practices. This innovation-driven growth not only benefits individual firms but also propels the entire architectural industry forward into a new era of sustainable practices.
- Job Creation: The demand for professionals skilled in both Biomimicry and AI within the architectural sector creates opportunities for job creation. As the industry embraces this transformative synergy, a skilled workforce becomes essential for the conception, design, and implementation of these cutting-edge projects. This not only contributes to employment growth within the sector but also fosters the development of expertise in a rapidly evolving field.

Sustainability and Human Well-being:

- Symbiotic Coexistence: The fusion of Biomimicry and AI signifies a harmonious coexistence between human-made structures and the natural environment. By emulating nature's efficiency, adaptability, and resilience, these structures contribute to sustainable coexistence. This alignment with the broader goals of ecological stewardship is a testament to the potential of this synergy to reshape the relationship between the built environment and the natural world.
- Occupant Health and Productivity: The focus on creating environments that mimic nature positively impacts occupant health and productivity. Daylight optimization, air quality control, and the incorporation of natural elements contribute to a healthier indoor environment. This, in turn, fosters well-being and enhances cognitive performance among occupants, establishing a direct link between the architectural environment and human flourishing.
- Resilient and Regenerative Design: Biomimetic architectural designs enriched by AI go beyond mere sustainability; they embody regenerative principles. Drawing inspiration from ecosystems, these designs seek not only to minimize negative impacts but also to contribute positively to the surrounding environment. This regenerative approach creates a cycle that aligns with the core principles of Biomimicry, promoting a holistic and regenerative approach to design.

Drawbacks and Challenges:

- Technological Dependency: Excessive reliance on AI may lead to technological dependency, potentially diminishing the role of human intuition and creativity in the design process. Striking a balance between technological precision and human ingenuity is essential to ensure that the fusion enhances rather than replaces

the creative aspects of architectural design. Architects and designers must consciously navigate this challenge to maintain a harmonious balance.
- Ethical Considerations: The integration of AI raises ethical considerations, particularly concerning data privacy and responsible technology use. Architects and designers must navigate the ethical implications of AI-driven design processes, ensuring transparency, accountability, and responsible decision-making. This becomes crucial to address potential concerns related to privacy and the responsible use of data, establishing a framework that upholds ethical standards in the industry.
- Initial Costs and Accessibility: The upfront costs associated with implementing Biomimetic architectural designs enriched by AI may pose a barrier to widespread adoption, limiting accessibility to certain demographics or regions. Striking a balance between innovation and cost-effectiveness is crucial for ensuring inclusivity in sustainable design practices. This challenge calls for innovative financial models and strategies to make these advanced design practices accessible to a broader audience.

The fusion of Biomimicry and AI within architectural design leaves an indelible mark on the environmental, social, and economic landscape. As we navigate this transformative synergy, the positive contributions to sustainability, human well-being, and economic growth are evident. However, a nuanced understanding of potential drawbacks and challenges is imperative to navigate the evolving landscape of technology and design. Striking a harmonious balance between nature's wisdom and artificial intelligence holds the key to creating a built environment that not only reflects the efficiency of natural ecosystems but also nurtures the well-being of its inhabitants in a regenerative and inclusive manner.

CONCLUSION

The convergence of biomimicry and AI: Transforming the future of architect:

The convergence of Biomimicry and Artificial Intelligence (AI) in architecture represents a significant paradigm shift, profoundly impacting the theoretical and practical aspects of designing and constructing the built environment. This seamless integration of nature-inspired principles with the computational prowess of AI empowers architects to create structures that not only resonate with the beauty of the natural world but also harness its inherent efficiency and resilience. This symbiotic relationship holds the promise of revolutionizing architecture, ushering in a more sustainable, energy-efficient, and aesthetically pleasing future.

This research has demonstrably shown that the impacts of Biomimicry and AI integration extend far beyond the realm of aesthetics. It has the potential to:

- Enhance biodiversity preservation: Biomimetic architectural designs, informed by nature's intricate systems, can evolve into ecological partners, fostering a harmonious relationship with the environment rather than serving as disruptors.
- Improve resource efficiency: AI-driven design optimization minimizes material waste and energy consumption, contributing to a more sustainable and responsible built environment.
- Optimize performance and comfort: AI-powered building management systems continuously monitor and regulate environmental conditions, ensuring optimal comfort for occupants while minimizing energy usage.
- Enhance architectural expression: Biomimetic design principles, coupled with AI's generative capabilities, unlock a new dimension of architectural expression, leading to innovative and aesthetically captivating structures.
- Promote social well-being: Biomimetic architecture, drawing inspiration from nature's interconnectedness, can foster a sense of community and belonging, contributing to improved social well-being.

Despite these transformative benefits, some challenges remain:

- Ethical considerations: The integration of AI raises ethical questions regarding data privacy, bias in algorithms, and potential job displacement within the architectural profession.
- Accessibility: The cost of advanced AI technology may limit its accessibility, particularly for smaller architecture firms or developing nations.

- Adaptability: AI algorithms require continuous training and adaptation to remain effective, necessitating ongoing investment and expertise.

Overcoming these challenges necessitates a collaborative effort from architects, engineers, technologists, and policymakers. By fostering ethical standards, promoting open-source technology, and investing in training and education, we can ensure that the benefits of Biomimicry and AI remain accessible and equitably distributed.

In conclusion, the fusion of Biomimicry and AI presents a remarkable opportunity to reshape the future of architecture. By learning from nature's wisdom and leveraging the power of AI, we can build a more sustainable, responsible, and aesthetically captivating world. Embracing this transformative synergy, we embark on a journey towards a future where the built environment harmonizes seamlessly with the natural world, serving as a testament to the ingenuity of both nature and technology.

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AEROSPACE ENGINEERING DIVISION

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Numerical Simulation of a Jet in Cross Flow in a Constant Area Duct

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Abstract *: Understanding of mixing of two different jets is required to design and optimize the scramjet engine for hypersonic and other aerospace applications. The injection of a subsonic jet in a supersonic flow generates the shock waves which travel through the 2D duct. The enhancement in mixing flow can reduce combustor length substantially and thereby reduce the weight of the engine. Here in this paper, an attempt has been made to simulate the mixing of Mach 0.5 jet of air with Mach 2 air flow in a 2D duct using commercial simulation software. The pressure at which the subsonic jet was introduced was varied to analyze the effect of pressure. The simulation was run until the steady state solution was found. The results provided good insight into the flow pattern and mixing of the flows inside the duct. Overall, the understanding of jet in a cross flow was improved to pursue further research in this field.*

Keywords*: Hypersonic; Scramjet; Jet; Cross Flow; Combustor.*

INTRODUCTION

A fundamental phenomenon in engineering and aerodynamics, the interaction between a jet and cross flow is especially useful in the design and optimization of combustion systems and hypersonic flows[1]. The complex dynamics of a jet in cross flow inside a 2D constant area duct have been examined in this research work, with an emphasis on how they relate to combustor performance [2]. Through numerical simulations and careful examination of the resulting data, a more profound comprehension of the underlying physical processes and the influence of different factors on the flow behavior have been obtained [3].

The intricate relationship between jets and cross flows is crucial in the scramjet engine as it affects the overall performance of the engine.

A simplified but useful framework for analyzing these interactions is provided by the particular geometry of a 2D constant area duct (**Figure 1**). We can concentrate on the key elements of jet-cross flow interactions in the constant area duct because it provides a controlled environment, free from the complexities caused by different geometries. When examining these flows, numerical simulations provide an economical and highly adaptable method that permits in-depth examination of the underlying physics in a variety of scenarios.

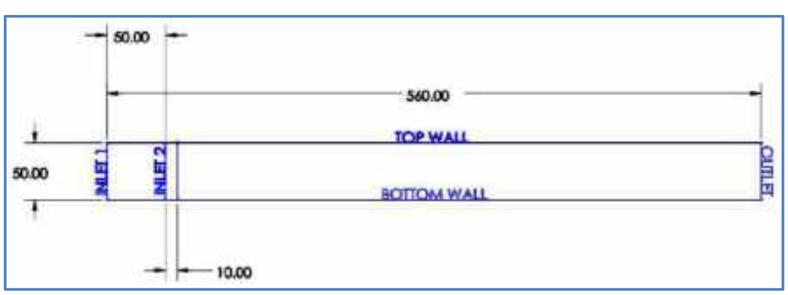

Figure 1 Geometry with Boundary Condition

Efficient mixing is pivotal in aerospace applications. With the use of commercial simulation software[4]. Varying the pressure at which the jet is introduced is a focal point, as it directly affects mixing. The study of mixing continues until a steady-state solution is reached, providing valuable insights into the flow patterns within the duct. This exploration is a significant step towards enhancing our understanding of jet-in-cross-flow phenomena, with promising implications for the advancement of aerospace engineering [5].

SIMULATION METHODOLOGY

To comprehend the vehicle's internal and external flow fields, computational fluid dynamics is a useful tool. For this kind of work, commercial simulation software like Ansys is quite helpful. Applying the proper boundary conditions and grid size will yield results that could then be utilized in the design and development of the hypersonic vehicle. The appropriate units were used when constructing the 2D geometry. Since the nozzle design is a straightforward 2D constant area duct, Ansys Workbench Grid Generator could be used to create the structured grid with ease. Before accepting the simulation’s results, the grid independence test is required to be conducted. The number of grid points was adjusted in both the directions. For any analysis, the simulation results are required to be acceptable irrespective of the mesh/grid size. Both axially and radially, the mesh's grid sizing was altered to 500, 600, and 700 and to 50 respectively. Further analysis was performed when the results were independent to the grid points. The variation in Mach number along the direction of the flow is depicted in the accompanying figure. It is evident that the variation for the existing grid points has not changed significantly. In a similar manner, radial variations were made to the grid points. **Figure 2** illustrates the plot for the fluctuation in Mach number in the lateral direction of the nozzle exit.

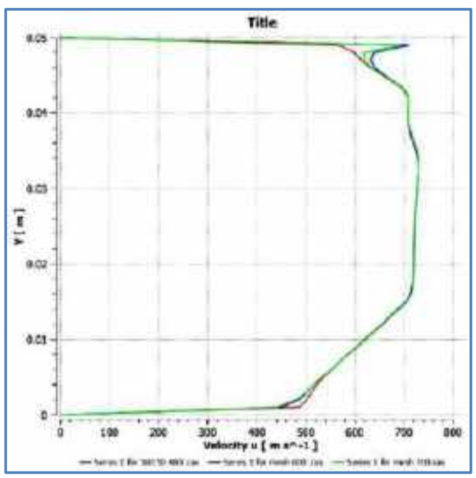

Figure 2 Grid Independency Test

The simulation was carried out with the appropriate boundary conditions. The conditions employed at the inlet and outlet were velocity inlet and pressure outlet respectively. The test section and nozzle surfaces were classified as walls specified for no-slip boundary conditions (**Table 1**). The temperature of the flow was 300K while the density was 1.225 kg/m^3. The analysis was performed using an SST-K turbulence fluid dynamic model.

Table 1 Boundary conditions

Zone	Boundary type	P (atm)	M (Mach No)	M (kg/m-s)
Air-Inlet 1	Pressure Far field	1	2	1.789401e-05
Air-Inlet 2	Pressure Far field	5	0.5	1.789401e-05
Mixture outlet	Pressure Outlet	0	-	1.789401e-05
Wall_1	Wall	-	-	-
Wall_2	Wall	-	-	-

The convergence criteria for various parameters were set to IE−6 and the solution converged to that limit. Simulations were conducted using the implicit Roe-Flux Difference Splitting Method (Roe-FDS), which provided good boundary layer resolution and is effective at accurately capturing contact discontinuity. The mass flux imbalance was examined once the simulation was finished to ensure there was no substantial mass accumulation in the domain. Therefore, more analysis can be performed using the converged solution.

RESULTS AND DISCUSSION

The 2D duct flow field was revealed by the simulation outcomes. Analyses of the flow field have been conducted using Ansys, a commercial simulation software. The grid independency tests have been carried out and results have been analyzed.

Shockwaves are created which travel towards the outlet of the duct when the two flows contact. As the shockwave approaches the outlet, it becomes less intense, as shown in **Figures 3** and **4** respectively. Shockwave formation also results in pressure differences and variations in velocity.

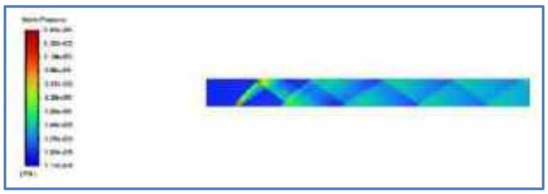

Figure 3 Pressure Contour

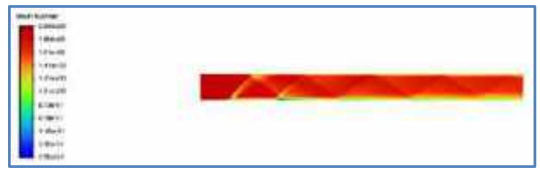

Figure 4 Mach Number Contour

The boundary layer creation on the walls and the significantly larger fluctuation in pressure and velocity change in the locations where the shockwaves make contact with the duct walls are also visible in **Figures 3** and **4** respectively. Boundary layer separation due to shockwave impingement was also observed on the walls of the combustor. The results are useful to estimate the length of the duct required for adequate mixing of the flow at the exit plane.

CONCLUSION

The mixing of flow in a 2-d constant area duct has been analyzed. The results from the simulation provided the vital information about the mixing of fluids as different pressures and velocities and its effects on the flow field. In future, the simulation will be carried out with different temperature and gas to improve the understanding about the effects of the same on jet in a cross flow.

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Study of Coordinate Acquisition Accuracy, Error and Latency of the Head Tracker based on Distance and Ambient Light

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Abstract: *The range of the head motion box, light intensity, tracker latency, and transmitter-receiver distance affect the optical tracker's 6-DoF data acquisition. Comparing optical data to Polhemus Fasttrak electromagnetic tracker data, which is more accurate and has less latency, provides more precise data. The optical tracker was used in this investigation. Performance of the optical tracker was assessed in four areas. These include coordinate acquisition accuracy, benchmarked data error, tracker component distance, light intensity, and delay. The tracker was tested with different transmitter and receiver positions and light intensities. As the distance between transmitter and receiver increases, it is generally observed that accuracy and error percentages become more refined. An examination of distances between 25 cm and 100 cm shows that accuracy percentages range from 86% to 96% and 78% to 89% respectively. Consequently, it stands to reason that the optical tracker operates at optimal capacity when distanced from the receiver. Optimal tracker performance requires adequate lighting, with higher light intensities - like 165 Lux - having a positive impact on accuracy. Lower error percentages accompany these more intense light settings. The latency of the tracker exhibits a similar pattern over various distances and light intensities, with an average range of 9.1 ms to 9.8 ms. This exemplifies the tracker's capacity to sustain a low latency, hence guaranteeing prompt responsiveness in real-time tracking.*

Keywords: *Augmented Reality; Virtual Reality; Head-Mounted Displays; Head Tracking; Optical Tracking; Degree of Freedom*

INTRODUCTION

Head tracking technology in head-mounted displays (HMDs) enhances VR and AR immersion. The following article discusses HMD head tracking applications and importance. Head tracking maintains the validity of virtual or augmented content by detecting the user's head movements and synchronizing the display with their perspective. Creating a more believable and immersive HMD experience requires head tracking. This technique improves spatial awareness and reduces motion sickness, making digital interactions easier. This technology has several medical, gaming, and training simulation applications, as well as design applications.

Various tracking technologies, including optical, electromagnetic, and inertial sensors, are utilised by HMDs. The optical tracker stands out in comparison to the others. It is precise and has low latency. Additionally, it is not readily disrupted by external factors. It monitors the position and orientation of the user's cranium via cameras and markers. This is the reason for its precise results. Unquestionably, this would be beneficial for surgical simulations, architectural design, and training simulations as well. When developing this technology, they had no competitors in mind in terms of precision. This abstract will discuss some of the fundamental principles underlying head tracking in HMDs as well as its advantages over other methods such as electromagnetic or inertial, which can be unreliable and inaccurate at times due to environmental interference.

In the domain of virtual and augmented reality, the effectiveness of optical head trackers is dependent on their accuracy, their capacity to minimise errors, and their latency, particularly when they are confronted with varied distances and different levels of ambient light. For the purpose of shedding light on the complexities of optical head tracking systems, this in-depth investigation dives into the intricate dynamics of these factors.

The precision of optical head trackers is dependent on a number of elements, the most important of which are the quality of the optical sensors, the resolution of the camera, and the effectiveness of the tracking algorithms. When there is a greater distance between the optical sensors and the item that is being monitored, there is a tendency for the accuracy to decrease. Calibration techniques have emerged as crucial mechanisms for minimising systematic mistakes. These procedures ensure that the virtual representation aligns with the user's motions in the actual world with an outstanding level of precision.

The tracking errors that occur within optical head trackers can be attributed to a variety of different sources. One of the most common factors is occlusion, which occurs when one or more environmental features or objects block the line of sight between the optical sensors and the item that is being tracked. There is a possibility that errors will be introduced by fluctuations in the ambient light levels, which would challenge the tracker's ability to properly detect features. One possible source of systematic errors is the presence of flaws in the calibration process or in the optical properties of the environment in which the tracking is performed. For the purpose of addressing these inaccuracies, it is necessary to design complex algorithms, real-time correction approaches, and the optimisation of sensor settings in order to improve the overall tracking precision.

The time gap that exists between a user's movement and the accompanying virtual reaction is referred to as latency. Latency is an essential component of the user experience in virtual and augmented reality settings. It is the goal of optical head trackers to reduce latency as much as possible in order to facilitate a seamless and immersive engagement. The computational complexity of the tracking algorithms, the pace at which data is processed, and the communication delay that exists between the tracking system and the rendering device are all factors that influence the latency factor. Because of the amount of time it takes for light to travel and go through processing, increased distance increases the amount of latency that is introduced. It is of the utmost importance to effectively manage and effectively mitigate latency in order to avoid motion sickness and to guarantee a natural and responsive user experience.

The tracking performance is substantially influenced by the distance that exists between the optical sensors and the item that is being tracked. Longer distances magnify measurement mistakes, which in turn affects both the accuracy and the latency of the measurement. At the same time, variations in the ambient light conditions provide issues, since sudden shifts or environments with low light levels may hinder the optical sensors' ability to accurately detect features. The deployment of adaptive algorithms that are able to dynamically react to changes in distance and ambient light is required in order to effectively address these difficulties. The durability and dependability of optical head tracking systems are strengthened as a result of this adaptability, which guarantees consistent tracking performance over a wide range of environmental circumstances.

RELATED WORK

The scientists compared projected head motion correction and motion tracking utilizing Active NMR field probes and a Moiré phase tracking camera system with an optical marker. Both tracking devices tracked humans simultaneously. A gradient echo sequence and MP2RAGE were used to compare prospective head motion correction. Three subjects' motion tracking trajectories were also examined and their correlation and deviance analyzed[1].The objective of the proposed review was to furnish an exhaustive and intricate synopsis of electromagnetic and optical tracking systems, encompassing their operational mechanisms, error sources, and validation procedures. Furthermore, the paper elaborated on clinical applications and commercial and research-oriented solutions for both technologies. In conclusion, a critical comparative analysis of the current state of the art was presented, elucidating the strengths and weaknesses of each monitoring system in the context of medical applications[2].A fuzzy Kalman filter (AKF) was proposed by the authors in this work. The inclusion of an adaptive observation noise coefficient in the proposed AKF is the result of an analysis of the error distribution of the estimation model and the user experience of the head tracker. This adjustment has the potential to dynamically mitigate the smoothness of the curve. Extensive experimental trials demonstrated the viability and efficacy of the proposed system, which attained an industry-leading level of performance[3].

A rapid online calibration procedure for OST-HMD was suggested by the authors, which utilised an optical monitoring system. During this process, two three-dimensional datasets were acquired: the virtual points that were displayed before the observer's eyes, and the corresponding points in optical tracking space. By resolving the transformation between these two three-dimensional coordinates, the link between virtual and physical space was established. This methodology facilitated the development of an augmented reality (AR) surgical navigation system, which was subsequently employed for experimental validation and clinical testing[4].

The authors assessed neural networks, support vector machines, and decision trees in this study in order to determine the optimal optical vector and centre of the ocular using the pupil ellipse as input. As input, the authors examined both solitary ellipses and window-based approaches. Evaluations were conducted with respect to precision and execution time. The assessment provided a comprehensive summary of the anticipated overall precision across various models and quantities of input ellipses. To facilitate the generation of training and evaluation data, a simulator was implemented. To conduct a visual assessment and advance the field of optical vector estimation, real data were utilized to implement the most effective model[5].

The authors examined the foundational theories of vision and perception, in addition to the most recent developments in display engineering and tracking technologies, in this state-of-the-art report. They begin by providing an overview of the fundamentals of light and image formation. The authors then described the fundamentals of visual perception through the lens of the human visual system. The authors presented two systematic synopses of the most recent developments in near-eye display and the tracking technologies that are integral to these displays. In conclusion, they delineated unresolved research inquiries with the intention of stimulating the investigations of subsequent generations[6].

In recent years, head-mounted displays (HMDs) and virtual reality (VR) have been widely implemented. The integration of eye-trackers into these systems could provide an evaluation of the user experience and computational efficacy. However, alongside visually induced motion sickness (VIMS), ocular fatigue has become more prevalent both during and after the viewing experience, underscoring the need for quantitative evaluation of the adverse consequences. Due to the lack of a universally accepted measurement method for ocular fatigue induced by HMDs, the authors identified parameters associated with optometry tests. An innovative computational methodology was put forth by the authors to estimate eye fatigue through the provision of multiple verifiable models[7].

The researchers investigated the effects of erroneous focus signals on user productivity, visual fatigue, and burden during the execution of an augmented reality (AR)-guided manual task using the Microsoft HoloLens, a cutting-edge over-the-head (OTT) device. Comparing the performance of twenty participants on a connect-the-dots task with and without augmented reality (AR) was the objective of this experimental study. The following assessments were designed: binocular and monocular with augmented reality guidance, and binocular and monocular using the natural eye. Every trial was assessed in terms of its precision in dot-connecting. A NASA Task Load Index and Likert scale-based assessment was conducted to determine the level of visual comfort and burden[8].

A method was proposed by the authors that enables the concurrent classification, segmentation, and monitoring of object instances within a video sequence. The approach, denoted as MaskProp, implemented a mask propagation branch to transfer frame-level object instance masks from a given video frame to every other frame in a video recording, thereby adapting the well-known Mask R-CNN to video. As a result, the system was capable of forecasting instance tracks at the clip level in relation to the object instances that were segmented in the clip's middle frame. Clip-level instance tracking, which is densely generated for each frame in the sequence, is ultimately aggregated to generate segmentation and classification of video-level object instances. The experimental results indicated that the approach was resilient to object occlusions and motion distortion in video due to the clip-level instance segmentation[9].

A low-cost, accurate, and robust remote eye-tracking system was delineated by the authors. This system operates on an industrial prototype smartphone that incorporates both an infrared camera and illumination system. The advantageous application of eye-tracking technology has been demonstrated in a variety of fields, including automotive safety, advertising evaluation, pilot training, and neurological and neuropsychiatric testing. Smartphone-based remote eye-tracking has the potential to facilitate a substantial expansion in the implementation of applications within these fields. A 3D gaze-estimation model was implemented in the proposed system, allowing for precise point-of-gaze (PoG) estimation while the user's head and device were in motion. In order to achieve precise identification of the input eye features, namely the pupil centre and corneal reflections, the system implemented a novel center-of-mass output layer in conjunction with Convolutional Neural Networks (CNNs)[10].

METHODOLOGY

Errors in the 6-DoF head coordinates may occur due to factors such as extraneous light interference or head movement outside the specified range of the head motion box. Horizontally and vertically, the head motion box in the cockpit is restricted to 120 mm and 70 mm, respectively. A number of variables influence the acquisition of 6-DoF coordinate data for the cranium. Optical tracking data acquisition is influenced by the number of sensors utilized, hardware latency, light intensity, distance between the transmitter and receiver, and prediction algorithm. Errors in 6-DoF data acquisition in electromagnetic tracking are caused by hardware latency, the number of transmitting sensors utilized, and interference from ferromagnetism that results in data corruption or loss. **Figure 1** illustrates the diverse head movements that transpire during the process of monitoring coordinated head movements.

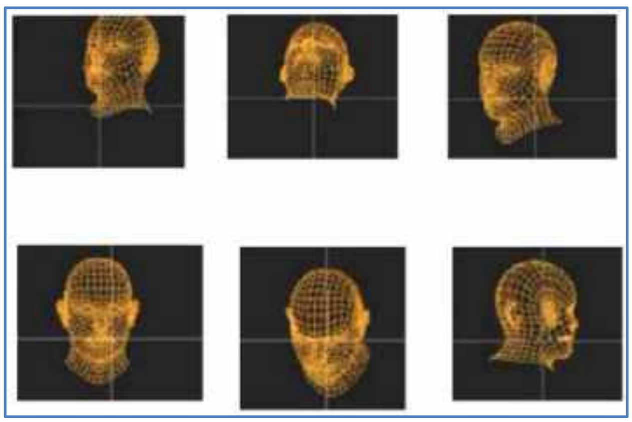

Figure 1 Diverse head movements during 6-DoF motion

Optical Tracker Latency

The duration between a head movement and the tracker receiving the head's coordinates is referred to as latency. The duration between the tracker detecting a change in the head's position or orientation and the change occurring has a detrimental effect on the simulation. It ought to be kept to a minimum extent. The rate at which coordinates are acquired is affected by the distance between the transmitter and the receiver, its position and orientation in the cockpit, and these factors collectively contribute to latency. In this section, the latency of various optical detectors is examined. **Figure 2** illustrates the overall hardware latencies of five different trackers, which influenced the choice of optical tracker implemented in this study. Track IRTM 5 is the most cost-effective optical tracker with the shortest latency, measuring 10 milliseconds in optical delay. The outcomes of utilizing optical trackers to quantify latency in three separate sets of missing data are presented in **Figure 3** and **Figure 4**. Missing data refers to the quantity of head coordinates that were not collected due to external interferences or other circumstances, such as the head sensor moving outside the HMB range.

Optical Tracker Errors

The acquisition of 6-DoF positional error using an optical tracker is additionally affected by the range of the head motion box (HMB), the intensity of the light, the latency of the optical tracker, and the distance between the transmitter and receiver. The presence of missing head coordinate instances resulted in nearly perfect positional inaccuracy, as the missing values were represented by the letter "0." **Table 2** presents the results of an assessment of the optical tracker's efficacy across a range of light intensities and transmitter and receiver positions. The accuracy plot of the optical tracker is illustrated in **Figure 3**, showcasing its performance across various light intensities and transmitter and receiver placements.

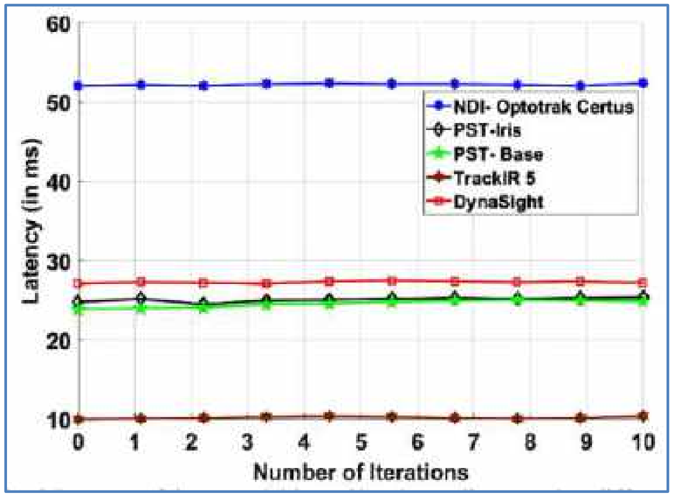

Figure 2 Latency of data acquisition of head coordinates using different optical trackers

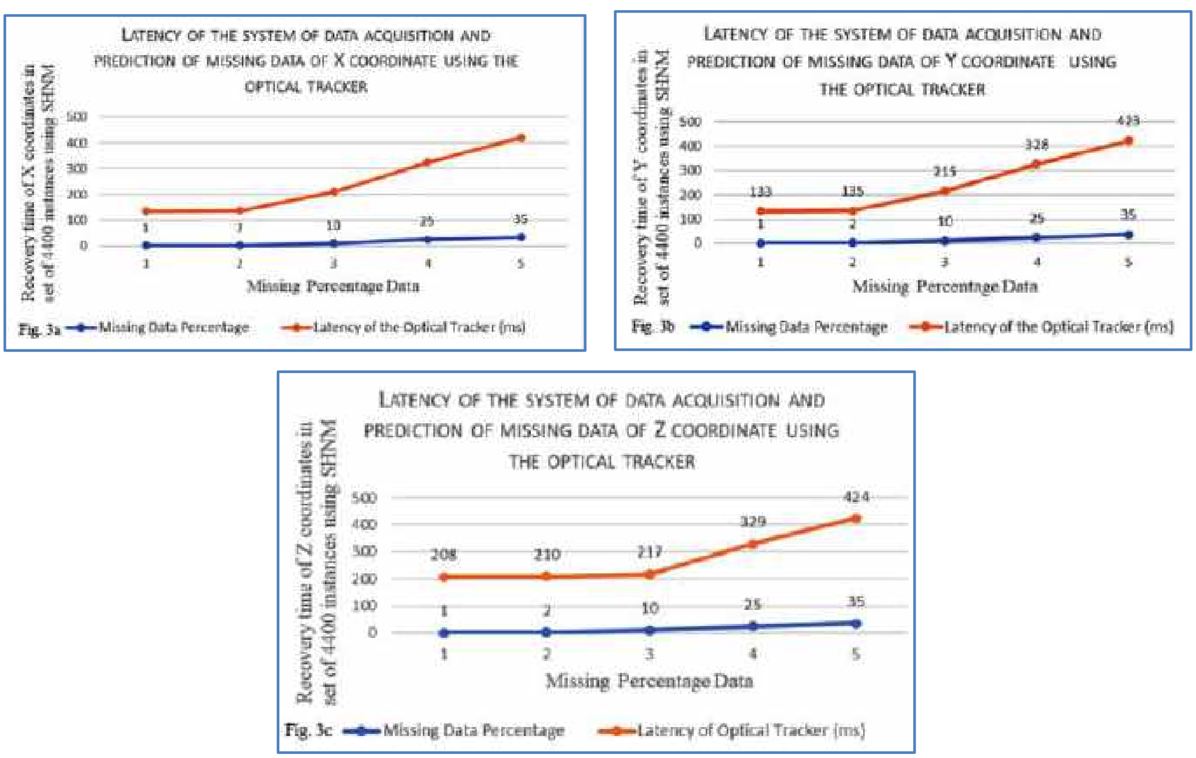

Figure 3 Latency of the Translational Coordinates of the system of data acquisition and prediction of missing data employing optical tracker

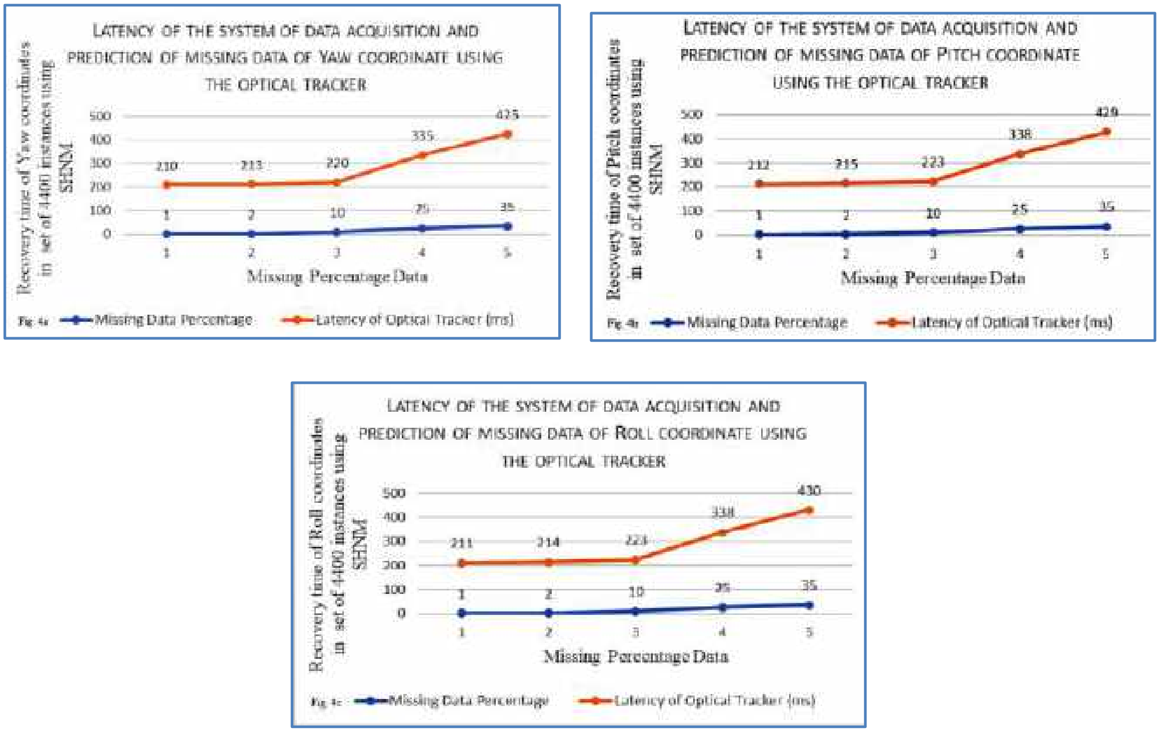

Figure 4 Latency of the Rotational Coordinates of the system of data acquisition and prediction of missing data employing optical tracker

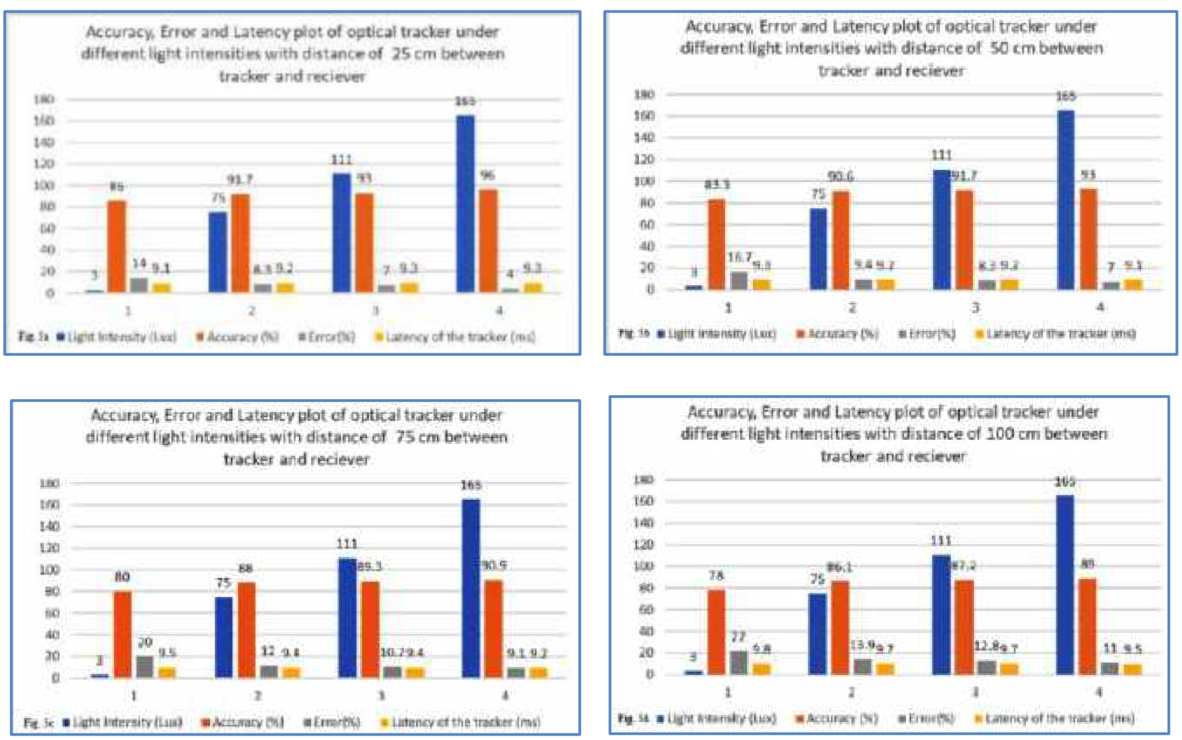

Figure 5 Evaluation of optical tracker: Varying light intensities and placements - transmitter and receiver

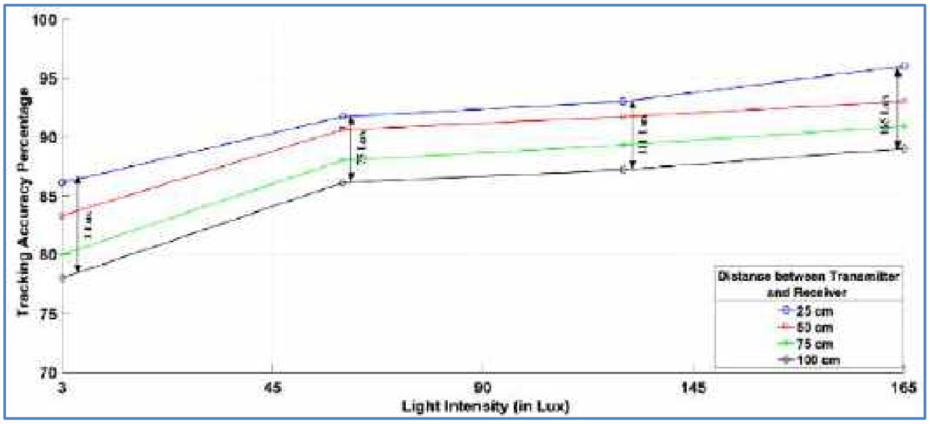

Figure 6 Accuracy plot of optical tracker under varying light intensities and placements of transmitter and receiver.

CONCLUSION

The accuracy, error resilience, and latency of optical head trackers are tightly intertwined with the intricacies of distance and the circumstances of the ambient light. It is very necessary to take a holistic approach, which includes the use of cutting-edge sensor technology, thorough calibration procedures, adaptive algorithms, and real-time corrective mechanisms. It is crucial to use this multidimensional technique in order to provide a tracking experience that is not only accurate but also resilient and responsive across a wide range of dynamic and diverse environments.

ACKNOWLEDGMENT

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Aeroelastic Stability of Composite Sandwich Panels with Hexagonal Honeycomb MRE Core for Unmanned Aerial Vehicle Components

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***Abstract**: Present paper deals with dynamic analysis of laminated composite sandwich beam with hexagonal honeycomb MRE core layer subjected to different types of external forces. The governing equations are derived from energy principles. An interactive simulation tool is developed to predict the natural frequencies, critical aerodynamic pressure points as well as the dynamic response of the structure with various boundary conditions. To access the aerodynamic stability of the system, the critical aerodynamic pressure is computed with supersonic flow conditions in addition to the external blast loads are applied, and the dynamic response characteristics for different boundary conditions are reported. Parametric analysis is conducted by considering honeycomb layer thickness, unit cell lengths, angle, and thickness ratio of the core as input variables to predict natural frequency and critical aerodynamic pressure at different magnetic field intensities.*

***Keywords**: Aeroelastic Stability; Magnetorheological Elastomer; Sandwich Composites; Flutter*

INTRODUCTION

Today, new advanced materials are prominent in aircraft and space vehicle components due to several requirements. The usage percentage of Sandwich materials in aircraft structures is rising year by year from 1930's and its application increased in essential components such as fuselage, wings, blades, rudder, elevators, and other secondary components. Sandwich materials possess a special mechanical property to withstand the aero-thermoelastic effects and other environmental conditions. Many research works are found on the sandwich materials to enhance the mechanical properties. Wang et al. [1] developed fire protected composite lattice sandwich structure. Zhao et al. [2] developed the novel auxetic honeycomb core and analyzed sandwich beam energy absorption and bending response. Zhang [3] investigated multilayer curved aluminum honeycomb sandwich beams under low velocity impact. Xin and Kiani [4] investigated the characteristics of arbitrary thick sandwich beam with metal foam core resting on elastic medium.

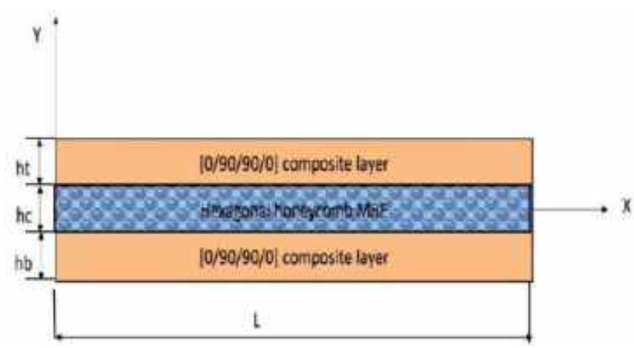
The aeroelastic behavior of sandwich structure is very crucial in the design. Predicting the flutter zone is crucial since it can lead to catastrophic failures. The aeroelastic stability behavior of sandwich panels with honeycomb cores in supersonic airflow was examined by Zhou et al. [5] for simply supported boundary.In supersonic airflow and thermal load conditions, Karimiasl and Alibeigloo [6] investigated by nonlinear aeroelastic instability of a composite sandwich panel. Ni et al. [7] analyzed the aeroelastic characteristics of laminated plates with honeycomb core under acoustic load for various boundary conditions in supersonic flow. Saidi et al. [8] examined the flutter of honeycomb sandwich trapezoidal wings under supersonic airflow.

Magnetorheological elastomers (MRE) are smart materials that change stiffening properties when exposed to a magnetic field.MRE was used in many applications as a core material to increase the damping of the structure. Selvaraj and Ramamoorthy [9] numerically and experimentally examined a three-layered sandwich beam with thin orthotropic skins and a multiwall carbon nanotube reinforced magnetorheological elastomer core. Sharif et al. [10] experimentally studied the sandwich beam with aluminum face sheets and the 3D printed hexagonal honeycomb core, which is filled with magnetorheological elastomer layer. Similar study was done by Eloy et al. [11] wherethe 3D printed structure is rectangular and face sheets are made up of composite material.When subjected to a base excitation load, Li et al. [12] investigated how well the magnetorheological elastomer (MRE) multifunctional grille composite sandwich plate (MRE-MGCSP) suppresses vibration when the magnetorheological effect creates a multi-regional magnetic field inside the structures.

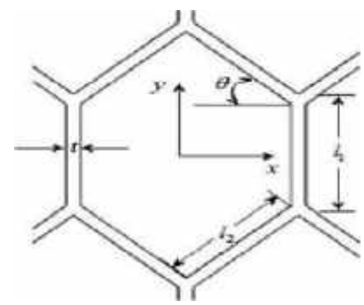
According to the available literature, several aeroelastic stability studies on honeycomb sandwich beams have been performed, but none of them used MRE as the core material. In the present work, aeroelastic characteristics of hexagonal honeycomb MRE core composite sandwich beamsare investigated in supersonic airflow conditions.The effect of hexagonal unit cell thickness and orientation angle on critical aerodynamic pressure and fundamental frequency are illustrated. Further, the transient dynamic response of the beam subjected impact loads is also performed. The work therefore focused on the parametrization part to identify important design parameters impacting the dynamic characteristics.

MATHEMATICAL FORMULATION

The sandwich beam with length L, width b, consists of a composite face layer of thicknesses h_t and h_b for top and bottom layers respectively. The core layer consists of hexagonal honeycomb magnetorheological elastomer of thickness h_2 as shown in the **Figure 1(a)**. The unit-cell of the hexagonal honeycomb core is seen in **Figure 1(b)**. The lengths of the honeycomb are$l_1$and l_2 ,the angle of the honeycomb is θ and the wall thickness is t.



(a) (a)Layers of sandwich bem



(b) Unit cell

Figure 1 Sandwich beam with hexagonal core and unit cell

The equivalent characteristics of the honeycomb core are considered from the Gibsonet al. [13] and it is given as

$$\overline{G} = \frac{\cos\theta}{\emptyset+\sin\theta}\gamma G \tag{1}$$

$$\rho = \frac{(2+\emptyset)\gamma}{2\cos\theta(\emptyset+\sin\theta)}\rho_c \tag{2}$$

Where $\gamma = t/l_2$ is the dimensionless cell thickness' $\emptyset = l_1/l_2$ is the internal aspect ratio. G is the shear modulus of the MRE,ρ_c is the density of core material. The strain energy (U) of composite sandwich beam for top and bottom layers at any instant can be obtained as

$$U = \frac{1}{2}\int_0^L b * \left[\left(A_{11}^t\left(\frac{\partial u_t}{\partial x}\right)^2 + A_{11}^b\left(\frac{\partial u_b}{\partial x}\right)^2\right)dx + \left(D_{11}^t\left(\frac{\partial^2 w}{\partial x^2}\right)^2 + D_{11}^b\left(\frac{\partial^2 w}{\partial x^2}\right)^2\right)dx + Gh_c\left[\frac{d}{h_c}\frac{\partial w}{\partial x} - \frac{(1+e)}{h_c}\right]^2 dx\right] \tag{3}$$

The terms $A_{11}$and D_{11} are the extensional and bending stiffness components given as:

$$(A_{11}, D_{11}) = b\sum_{k=1}^{n} \overline{Q}\int_{h_{k-1}}^{h_k}(1, z^2)dz \qquad (4)$$

The suffixes t, b, c indicates the top, bottom and core layer respectively. Also, $d = h_c + 0.5(h_t + h_b)$, $G=G'(1+i\eta)$ is the complex shear modulus with G'as the storage shear modulus and η as loss factor.In present work, following expressions of storage modulus and loss factor are considered in terms of magnetic field intensity B [14].

$$G' = -6.9395\, B^6 - 9.1077\, B^5 + 71.797\, B^4 - 93.422\, B^3 + 38.778\, B^2 + 2.43\, B + 2.7006 \qquad (5a)$$

$$\eta = -5.3485\, B^6 - 17.787\, B^5 + 22.148\, B^4 - 12.185\, B^3 + 2.3522\, B^2 + 0.1526\, B + 0.228 \qquad (5b)$$

The kinetic energy (T) of the sandwich beam is obtained as

$$T = \frac{1}{2}\int_0^L(\rho_t A_t + \rho_c A_c + \rho_b A_b)\left(\frac{\partial w}{\partial t}\right)^2 dx + \frac{1}{2}\int_0^L(\rho_t I_t + \rho_b I_b)\left(\frac{\partial^2 w}{\partial x\, \partial t}\right)^2 dx + \frac{1}{2}\int_0^L\left(\rho_t A_t\left(\frac{\partial u_t}{\partial t}\right)^2 + \rho_b A_b\left(\frac{\partial u_b}{\partial t}\right)^2\right)dx + \frac{1}{2}\int_0^L \rho_c I_c\left[\frac{d}{h_c}\frac{\partial^2 w}{\partial x\, \partial t} - \frac{(1+e)}{h_c}\frac{\partial u}{\partial t}\right]^2 dx \qquad (6)$$

where ρ is the density and A is the area of the cross section I is the moment of inertia.The suffixes t, b, c indicates the top, bottom, and core layer respectively.

The quasi-steady first order piston theory can be employed for supersonic airflow regime,. Therefore, the work done by such aerodynamic load can be expressed as:

$$W = b\int_0^L \Delta p\, w(x,t)dx \qquad (7a)$$

$$\Delta p = -\frac{\rho_a V_\infty^2}{\sqrt{M_\infty^2 - 1}}\left[\frac{\partial w}{\partial x} + \frac{M_\infty^2 - 2}{M_\infty^2 - 1}\frac{1}{V_\infty}\frac{\partial w}{\partial t}\right] \qquad (7b)$$

where ρ_a, V_∞ and M_∞denote the air density, velocity, and Mach number of the free stream respectively. Non-dimensional aerodynamic pressure term adopted for the analysis defined as$\lambda = \frac{\rho_a V_\infty^2}{\sqrt{M_\infty^2 - 1}}\frac{L^3}{E_1 h^3}$

In order to test the dynamic response of the beam against normal MRE core composite sandwich beam, impact loads are applied over the surface. External loads applied over the beam such as sine load, triangular load and blast load which can be expressed as

$$q(t) = \begin{cases} \begin{Bmatrix} 1 - t/t_i, & 0 \le t \le t_i \\ 0, & t > t_i \end{Bmatrix} & \text{traingular load} \\ \begin{Bmatrix} \sin\left(\pi t/t_i\right), & 0 \le t \le t_i \\ 0, & t > t_i \end{Bmatrix} & \text{Sine load} \\ \begin{Bmatrix} \exp(-\lambda t), & 0 \le t \le t_i \\ 0, & t > t_i \end{Bmatrix} & \text{Blast load} \end{cases} \qquad (8)$$

t_i is the incident time and t being the final time.

The external force is given as

$$F = F_0 q(t) \tag{9}$$

All energy equations described above are substituted in the Hamilton's equation given below to obtain the governing equation of the beam.

$$\delta \int_{t_1}^{t_2} (T - U + W) dt = 0 \tag{10}$$

The governing equations in matrix form for the dynamic system using finite element solution for the honeycomb sandwich beam are as follows:

$$[M]\{\ddot{X}\} + [C]\{\dot{X}\} + [K]\{X\} = \{F\} \tag{11}$$

Where [M], [K] and {F} represents mass, stiffness matrices and force vectors. Assuming the hormonic motion, the Eq.(11) is transformed into eigenvalue problem and solved for eigenvalues (Ω) in the complex form. The natural frequency ω and modal loss factor η of the three-layer sandwich beam can be obtained as follows:

$$\omega = \sqrt{Re^2(\Omega) + Im^2(\Omega)},\ \eta = \frac{-Im(\Omega)}{\sqrt{Re^2(\Omega)+Im^2(\Omega)}} \tag{13}$$

The non-dimensional aerodynamic pressure, λ is normally used to obtain the flutter boundary. One can determine the instability boundary by graphing the loss factor for various non-dimensional aerodynamic pressures. When the loss factor shifts from a positive to a negative value, instability will be reached [14].

RESULTS AND DISCUSSION

Using the present formulation, frequencies and the critical nondimensional aerodynamic pressure of the composite MRE sandwich beam are obtained using a computer program developed in Matlab software. The results of present model are verified with the available literature for sandwich beam. All the geometric and material properties are considered from the reference [14].

Table 1 Validation using natural frequencies

Natural frequencies (Hz)				
Mode↓	**Reference [14]**		**Present**	
BC→	**CC**	**CF**	**CC**	**CF**
1	309.3	59.1	299.32	59.13
2	717.42	324.71	712.64	328.42
3	1210	782.76	1226	798.21
4	1746.7	1312.2	1751.23	1358.6

For the present analysis, the material properties of the sandwich beam are taken as follows: (i) graphite-epoxy composite face layer equivalent properties E_1= 131GPa, E_2=10.34GPa, G_{12}=6.895GPa ν_{12}=0.22, and face layer density ρ_f=1627 kg/m^3; (ii) MRE core layer density ρ_c=3500 kg/m^3. The geometrical properties considered for the investigation are length = 400 mm, width = 30 mm, and thickness of face layer is 1mm and the core layer is 5mm.The layup configuration for both top and bottom face layers are $[0/90]_s$. The geometrical parameters of hexagonal cells are θ= 45^o,γ=0.2, and ϕ=1. These properties are used throughout the analysis.

Natural frequencies of the composite MRE sandwich beam with hexagonal core for various boundary conditions is given the **Table 2**.

Table 2 Natural frequencies for various boundary conditions

Natural frequencies (Hz)			
Mode	**CC**	**CF**	**SS**
1	54.848	20.36	37.69
2	133.35	70.10	97.82
3	245.62	145.55	190.53
4	396.03	255.26	320.10
5	583.13	403.18	490.83

Effect of Unit Cell Thickness

The ratio of the thickness to the length of unit cell (γ) is varied from 0.1 to 0.4, while remaining other parameters are maintained constant when magnetic field is increased. Results are depicted in the **Table 3**. For this clamped-clamped condition is considered.

Table 3 Effect of unit cell thickness ratio on fundamental frequency(Hz)

Magnetic field B (Tesla)	Unit cell thickness ratio			
	0.1	**0.2**	**0.3**	**0.4**
0	54.88	54.848	54.77	54.678
0.1	56.45	57.252	57.685	57.935
0.2	58.84	60.833	61.978	62.698
0.3	61.10	64.164	65.925	67.045
0.4	62.8	66.616	68.805	70.201

It is observed that as the cell thickness ratio increases, the natural frequency decreases slightly as it can be seen in row-1. When the magnetic field is increased, natural frequency increases. A reverse trend is followed by the beam when magnetic field is acting on it.

Effect of Unit Cell Angle

The effect of unit cell angle θ for different magnetic field intensity on the fundamental frequency is considered. The obtained values are listed in the Table IV for the clamped-clamped boundary condition.

Table 4 Effect of unit cell angle on natural frequencies (Hz)

Magnetic field B (Tesla)	unit cell angle			
	15^o	**30^o**	**45^o**	**60^o**
0	53.29	55.31	54.85	51.19
0.1	55.45	57.69	57.25	53.39
0.2	58.67	61.24	60.83	56.67
0.3	61.69	64.54	64.16	59.74
0.4	63.92	66.98	66.62	61.99

Natural frequencies rise as the unit cell angle increases up to 30^o later gradually decreases when further unit cell angle increases. Similar trend also observed even at the higher the magnetic field intensity values.

Aeroelastic Analysis by Varying Unit Cell Parameters

To determine the aeroelastic stability of the sandwich beam, non-dimensional aerodynamic pressure is increased and plotted against the natural frequencies and loss factors as shown in the **Figure 2**. It is observed that first mode of the loss factor value changes the sign from positive to negative and the critical aerodynamic pressure is determined. Similarly, the natural frequencies of modes one and two try to coalesce. The MRE sandwich beam will be stable till the critical aerodynamic point. The critical aerodynamic point is determined by varying various parameters of the hexagonal unit cell to know the stability of the beam. The results are depicted in the **Figure 3** and **Figure 4** for the clamped-clamped end conditions. From the **Figure 3**, it can be observed that as the angle decreases, the critical aerodynamic pressure increases up to 45^{o} and later-on, it is decreasing. As the Unit cell ratio of lengths increases the critical aerodynamic pressure decreases.

It is observed from the **Figure 4** that unit cell thickness ratio and the core thickness are directly proportional to critical aerodynamic pressure. Both the values raise as the critical aerodynamic pressure increases

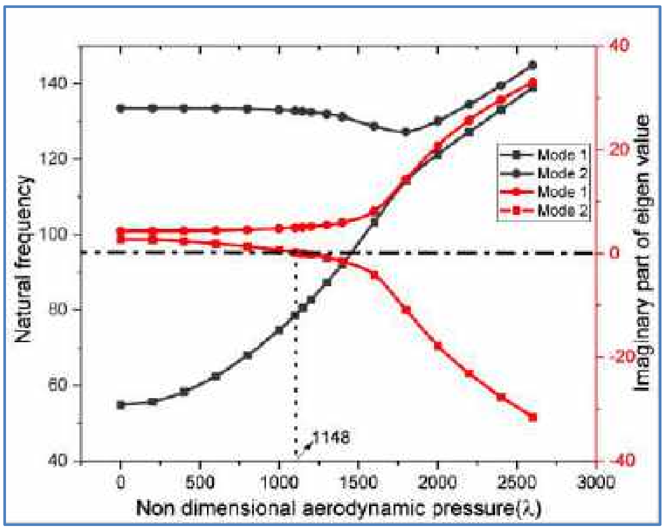


Figure 2 Aeroelastic stability of the sandwich beam

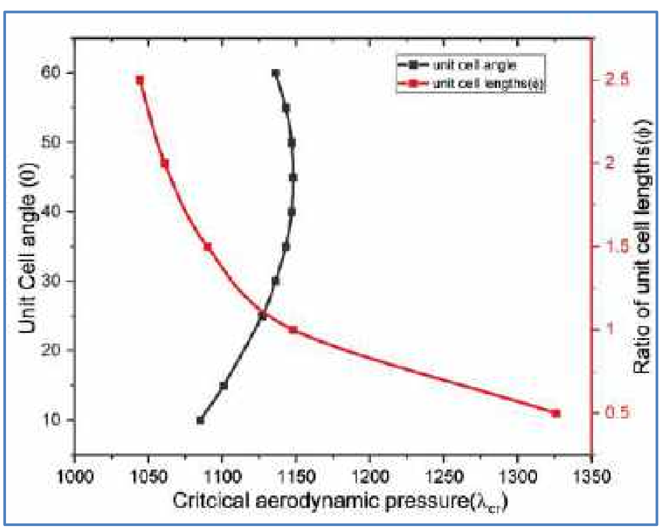


Figure 3 Influence of unit cell angle and lengths on the stability of the sandwich beam

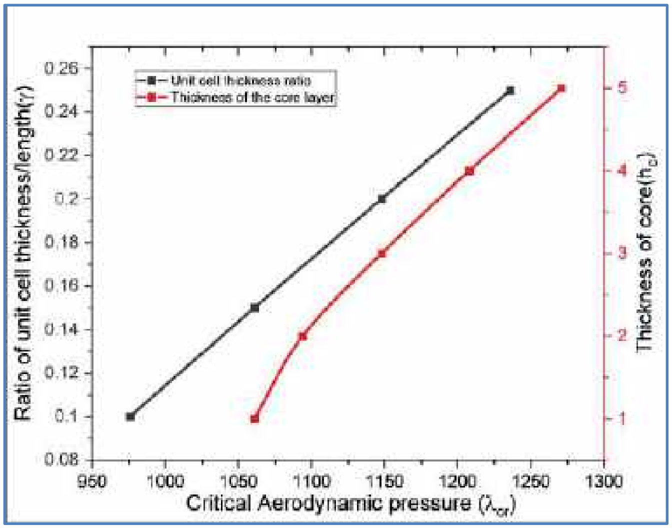


Figure 4 Influence of unit cell thickness and core layer thickness on the stability of the sandwich beam

Dynamic Response of the Beam

The vibration responses of composite MRE hexagonal core sandwich beam under various external loads with other parameters for clamped-clamped beam are investigated. Loads are acted for the 0.3 seconds and the response is noted for the 0.6 seconds. The results are presented in the **Figure 5** when a load amplitude of 100 N is acting over it and the response is noted at the mid-span of the beam.

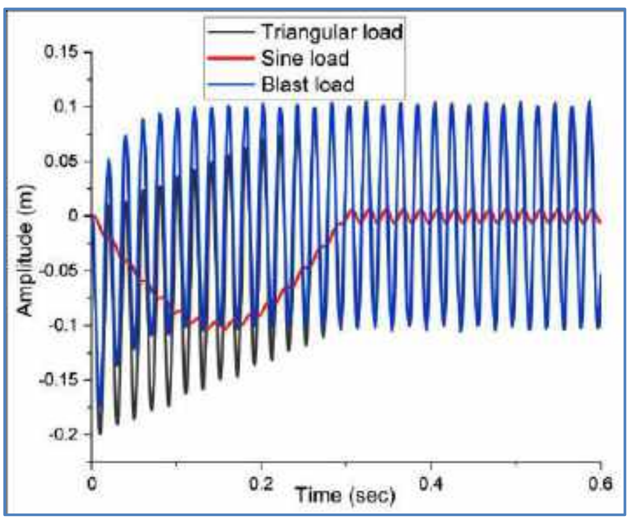


Figure 5 Dynamic response of the sandwich beam subjected to external loads

It is seen from the **Figure 5** that maximum deflection is occurring when the blast load acts over it.

CONCLUSION

The dynamic analysis and aeroelastic stability of hexagonal MRE core composite sandwich beam was presented in this article. Using the Hamilton's principle and finite element method, the dynamic analysis has been presented. The influence of various hexagonal unit cell parameters on the natural frequency and the critical aerodynamic pressure was studied. The results show that, in the absence of a magnetic field, natural frequency drops as unit cell thickness decreases; however, this relationship is reversed in the presence of a magnetic field. As unit cell angle increases both natural frequency and the critical aerodynamic pressure increases first and later it decreases. Unit cell thickness ratio and core layer thickness are directly proportional to critical aerodynamic pressure. In addition, the dynamic response of the beam with impact loads was measured. As the natural frequency and critical aerodynamic pressure are influenced by the unit cell parameters, an optimization work can be taken up in future to obtain their optimum values to improve the aeroelastic stability.

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CHEMICAL ENGINEERING DIVISION

CH_IEC 2023 TV 065

Polyvinyl Alcohol/Polyvinyl Pyrrolidone Based Hydrogel for Cartilage Application

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***Abstract**: Researchers have recognized Poly (vinyl alcohol) (PVA) hydrogel as a material of significant interest, considering it a highly intriguing and promising option for replacing articular cartilage. The primary drawback associated with PVA hydrogels is their challenge in meeting the mechanical requirements essential for replicating the characteristics of articular cartilage. In this study, we synthesized blend hydrogels of PVA and poly (vinyl pyrrolidone) (PVP) through repeated freezing and thawing techniques. These hydrogels exhibited a comparable internal three-dimensional structure and water content, approximately 70%, to that found in natural articular cartilage. The study delved into the examination of mechanical properties, revealing that alterations in these properties within PVA/PVP hydrogels were notably contingent on both the PVP content and the number of freezing-thawing cycles. The blend hydrogel containing 1 wt.% PVP demonstrated the most favourable mechanical characteristics. The storage modulus significantly exceeded the loss modulus, indicating a prevalence of elasticity akin to that of cartilage. Furthermore, the PVP blended PVA hydrogel did not show any notable antimicrobial activity against bacterial species, including Escherichia coli (E. Coli) and Staphylococcus aureus (S. aureus). Moreover, the in vitro biocompatibility response with Human Mesenchymal Stem Cells (hMSC) after a 72-hour culture period confirms that PVA/PVP hydrogels hold promise as advanced alternatives for future-generation cartilage substitutes.*

***Keywords**: Hydrogel, Tissue engineering, Biomaterial and Cartilage*

INTRODUCTION

Articular cartilage, found on the ends of long bones in the body, serves as a remarkably smooth surface that minimizes friction. It also excels at enduring significant mechanical pressures while evenly distributing these loads across the underlying bone, thereby preventing the formation of concentrated stress points. Due to its lack of blood vessels and nerves, articular cartilage possesses limited natural healing abilities or self-repair capacity[1]. When the articular cartilage undergoes damage, it initiates a gradual onset of osteoarthritis, ultimately resulting in the loss of joint function[2]. Surgical methods like microfracture and autologous chondrocyte implantation have gained widespread use for alleviating pain and restoring tissue function through regeneration[3].However, these techniques fail to fully restore the natural function of cartilage. The utilization of suitable implants to replace damaged cartilage is regarded as a promising avenue for cartilage replacement, captivating the interest of biomaterial scientists for many years [4].Hydrogels have the capability to capture huge quantities of water or biological liquids while maintaining great strength in physiological circumstances [5].In the preparation of stable hydrogels, researchers can employ several crosslinking methods, including physical, chemical, and radiation techniques, or a combination of diverse methods [6].While the chemical method (involving a chemical agent) remains the most common system for hydrogel synthesis, physical crosslinking techniques have garnered significant attention nowadays due to their non-toxic nature, particularly for biomedical applications[7].There is an ongoing interest in polymer hydrogel development due to their remarkable qualities such as penetrability, hydrophobicity, and viscoelasticity. These characteristics raise high expectations for hydrogels with exceptional performance. Hydrogels have found utility in various applications, including pharmaceutical, biological, and everyday care [8]. These applications encompass serving as carriers for drug delivery, facilitating immunoassays, enabling implantable artificial muscles, crafting eye contact lenses, and producing wound dressings, among others [9]. Polymer researchers are using hydrogels, which are among the most promising polymer types for new material development. These polymeric materials do not dissolve in water at physiological temperatures or pH levels but undergo significant swelling in an aqueous medium [10].

Poly (vinyl alcohol) (PVA) stands as a hydrogel biomaterial with a long and effective track record in human applications[11]. Its successful utilization includes the production of embolic bodies, immobilizing enzymes, transforming biomass cells, and creating implants to prevent postoperative tissue collapse, among other notable examples[12]. By absorbing an adequate amount of water, PVA can be easily transformed into a PVA hydrogel, usually at the cost of its strength and mechanical properties [13]. This synthetic polymer exhibits biodegradable properties in natural environments[14]. Additionally, PVA possesses outstanding thermal and chemical stability, non-toxicity, enduring pH and temperature resistance, remarkable film-forming capabilities, and high biocompatibility with biological tissues, rendering it a notable polymer for drug delivery. However, pristine PVA hydrogels are inherently fragile, thus overcoming this limitation by integrating them into an interpenetrating polymeric network (IPN) hydrogel through combinations with other polymers [15]. This approach effectively addresses their fragility using diverse methods encompassing both chemical and physical means. PVA has been amalgamated with various polymers to create a broad spectrum of hydrogels, with poly (vinyl pyrrolidone) (PVP) notably aligning with this category. PVP stands out due to its hydrophilicity, biodegradability, low chemical toxicity, biocompatibility, excellent solubility in water and most organic solvents, and its excretion through both renal and hepatic pathways. Consequently, PVP finds multifaceted applications in industrial and biomedical domains, spanning beverages, pharmaceuticals, cosmetics, detergents, adhesives, paints, bioengineering, and electronic materials. Moreover, PVP's capacity to absorb up to 40% of its weight in water positions it as an ideal medium for efficiently dispersing poorly soluble drugs [16][17][18].Poly(vinylpyrrolidone) (PVP), acting as a reliable proton receptor, contains ample carbonyl groups capable of forming hydrogen bonds with hydroxyl groups in the PVA chain. The properties of these two-component hydrogels can be adjusted accordingly[19].

This study introduces an innovative synthesis technique for PVA/PVP hydrogels, showcasing their promising prospects in biomedical applications and evaluate influence of PVP in PVA hydrogels. The hydrogels showcased adjustable porosity, swelling behaviour, and viscoelastic traits, rendering them apt for drug delivery and tissue engineering. Porosity examinations unveiled interconnected pores, aiding drug diffusion and cell infiltration. Swelling assessments details hydrophilicity of the hydrogel, while viscoelastic analyses illustrated adaptable mechanical properties. Compression tests revealed heightened resilience compared to pure PVA hydrogels. Cytotoxicity investigations affirmed the hydrogels' biocompatibility, positioning them as promising contenders for biomedical use.

MATERIALS AND METHODS

Polyvinyl alcohol with a molecular weight spanning from 60,000 to 125,000 Da was procured from Himedia Ltd. Polyvinyl pyrrolidone K30 was acquired from Loba ChemiePvt. Ltd. in Mumbai, India. The HMSC cell lines were sourced from Sigma Aldrich, while all other chemicals were utilized in their initially received form.

Hydrogel Sample Preparation

In a brief, the development of PVA/PVP-based hydrogels involved a freeze and thaw process. Initially, 10 grams of PVA was dissolved in 100ml of distilled water using a hotplate magnetic stirrer set at 90°C with a stirring speed of 400rpm. Simultaneously, in a separate beaker, varying concentrations of PVP (0%, 1%, 2% and 3wt%) were dissolved in distilled water using a magnetic stirrer at 30°C.subsequently, both polymers were combined and stirred for a duration of 2 hours to achieve a homogeneous mixture of the PVA/PVP blend. Once the blend's uniformity was confirmed, it was poured into a petri dish and subjected to a freeze and thaw process. During this process, the PVA/PVP blend was frozen at -24°C for 10 hours and then thawed for 6 hours at room temperature. This freezing and thawing cycle was repeated a total of 5 times. The developed hydrogel used for various characterizations.

Characterization

Morphology Evalution

The characterization of gel samples' morphology was conducted using a JEOL JSM-6380LA Japan scanning electron microscope operating at 20kV for secondary electron imaging subsequent to gold coating via a sputter coater.

Evaluation of Swelling, Porosity and Contact Angle of the Hydrogels

To conduct the swelling study, the weights of lyophilized hydrogels were initially recorded as the initial weight (Wi) before immersion in deionized water. Subsequently, the hydrogel weights were measured at regular intervals (every 2 hours) while immersed in deionized water until reaching an steady state to determine the final weight of the sample. Swelling ratio calculated using equation 1 and the evaluation of the hydrogel's porosity was performed as described elsewhere. In summary, the samples underwent a 12-hour immersion in ethanol, and the weight after immersion (W2) was measured. Subsequently, the samples were removed, and the initial weight (W1) was determined by lyophilizing the swollen hydrogel. The porosity of the hydrogel evaluated by using equation 2.

$$\text{Swelling ratio} = \frac{(W f - Wi)}{W f} \times 100 \qquad (1)$$

$$\text{Porosity} = \frac{(W2 - W1 - W3)}{(W2 - W3)} \qquad (2)$$

Where, W3 represents the weight of the residual ethanol remaining after extracting the swollen hydrogel sample.

To assess the surface wettability of the hydrogel, we determined the angle formed between a liquid droplet (PBS) and the solid surface. A droplet of the liquid was carefully positioned on the flat surface of the swollen hydrogel, and after reaching equilibrium, we measured the contact angle. We conducted these measurements in triplicate and reported the average value.

Mechanical Characterization of the Hydrogel

We conducted compression tests and cyclic loading-unloading compression tests. The samples employed were cylindrical, with dimensions of 10 mm in diameter and 7mm in height. During the tests, we recorded the breaking stress and strain values.

We assessed the rheological characteristics of the swollen hydrogel using a Rheometer (MCR 702, Anton Paar) set at a temperature of 37.5ºC. The experiments were conducted on thin hydrogel discs measuring 20 mm in diameter and 1 mm in thickness. We evaluated the storage modulus (G') and loss modulus (G") over a range of angular frequencies from 0.1 to 100 rad/sec, maintaining a constant strain rate of 1%.

Biocompatibility Evaluation

The biocompatibility and cell viability of the PVA (PP-0) and PVA/1%PVP (PP-1%) hydrogels were evaluated using the MTT protocol detailed in the article[20]. This process also allowed us to verify the toxicity behavior of the hydrogels.

RESULT AND DISCUSSION

Morphological Evaluation of the Hydrogels

Figure 1 describes SEM images of cross-sectional view of hydrogel scaffolds. These images reveal interconnected porosity present across all the hydrogels. This interconnected porosity is vital for facilitating nutrient transport and the removal of metabolic wastes within cartilage scaffolds in biological systems[21]. **Table 1** outlines the average porosity of the PVA/PVP hydrogel at different concentrations. It is also observed that as the concentration of PVP increases, there is a decrement in the porosity. This decrease might be due to the polymer chains within the blend increasingly intertwining, forming a tighter network. Consequently, this tighter structure impedes pore formation during phase inversion, ultimately yielding a hydrogel with fewer pores.

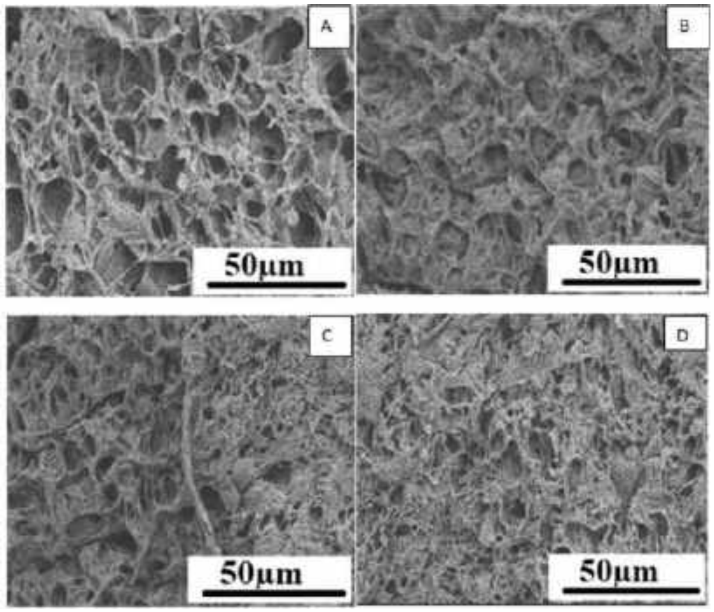


Figure 1 Morphology of PVA/PVP composite hydrogel. A) Pure PVA, B) PVA/1%PVP,C)PVA/2%PVP and D) PVA/3%PVP

Table 1 PVA and PVA/PVP hydrogel swelling ratio, contact angle and average porosity

Hydrogel	Swelling ratio	Contact angle	Average Porosity
PP-0%	233.07±3.75	66.14±1.13	92.34±0.87
PP-1%	209.03±4.95	64.96±0.94	84.77±0.41
PP-2%	183.27±3.81	56.30±0.31	73.11±0.13
PP-3%	163.03±4.17	50.27±0.97	67.06±1.12

Swelling Behavior of the Hydrogels

Swelling analyses serve as initial in vitro assessments for hydrogels, examining both Pure PVA and PVA/PVP blends with varying compositions of PVP. Swelling strength stands as a critical metric for biomaterials, especially in applications related to tissue engineering. The Porosity and their connectivity significantly impact the absorption of bodily fluids, the transportation of nutrients, and the exchange of metabolites. Moreover, swelling enlarges the pore volume, consequently augmenting the inner surface area-to-volume ratio and enhancing the potential for cell infusion from the exterior to the interior. Previous research suggests that “The swelling behavior of PVA/PVP hydrogels is significantly impacted by the concentration of PVP incorporated within the composite hydrogel. As the PVP concentration in the PVA hydrogel increases, the swelling ratio exhibits a decreasing trend. This phenomenon is attributed to the inherent hydrophilicity of PVP, which surpasses that of PVA. Consequently, the presence of PVP leads to a reduction in the availability of water molecules capable of swelling the PVA chains. Additionally, the incorporation of PVP enhances the crosslinking density of the hydrogel, resulting in a less porous and less water-absorbent network structure [22][23].

Mechanical Behavior of Hydrogel

Compression behavior of PVA and PVA/PVP Composite Hydrogels

Figure 3 illustrates the stress-strain relationship of hydrogel materials, showcasing characteristics akin to viscoelastic solids. The compression behavior of hydrogels is significantly impacted by their polymer structure, resembling the response of cartilage under compression. As a polymeric hydrogel undergoes loading, it absorbs the load, leading to a reorientation of its polymeric chains. This reorientation prompts the flow of interstitial fluid out of the hydrogel. Throughout this process, the initial load induces notable deformation. With continued application of the load, the reorientation process brings about uniformity, while friction generated by interstitial fluids results in the solidification of the gel-like material, demanding increased effort to further augment the strain. Incorporating 1 wt% PVP into the hydrogel yielded an optimal compressive strength of 1.27 MPa, as shown in **Figure 3**. This value falls within the range of compression strength observed in healthy cartilage, which typically ranges from 0.1 to 2 MPa[24]. However, hydrogels containing more than 1% PVP exhibited a decline in compressive strength. This decrease could be attributed to an increased concentration of PVP within the PVA, leading to a smoother hydrogel that is more prone to early failure.

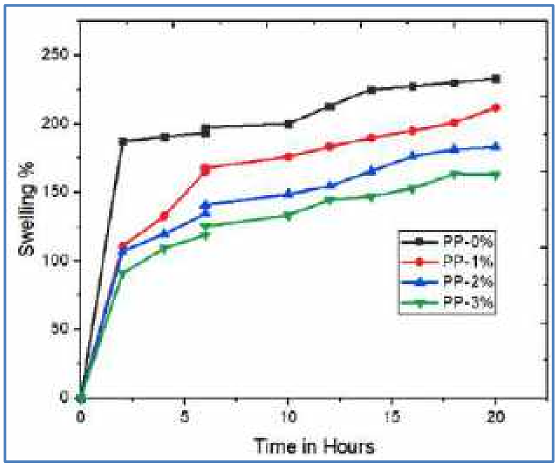


Figure 2 Swelling behavior PVA/PVP composite hydrogel. A) Pure PVA, B) PVA/1%PVP,C) PVA/2%PVP and D) PVA/3%PVP

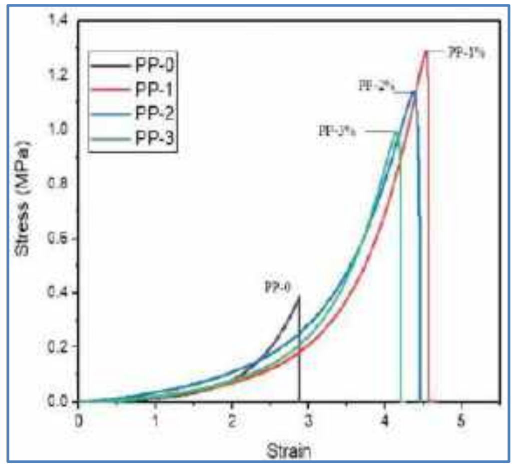


Figure 3 Compression behaviour of PVA/PVP composite hydrogel.

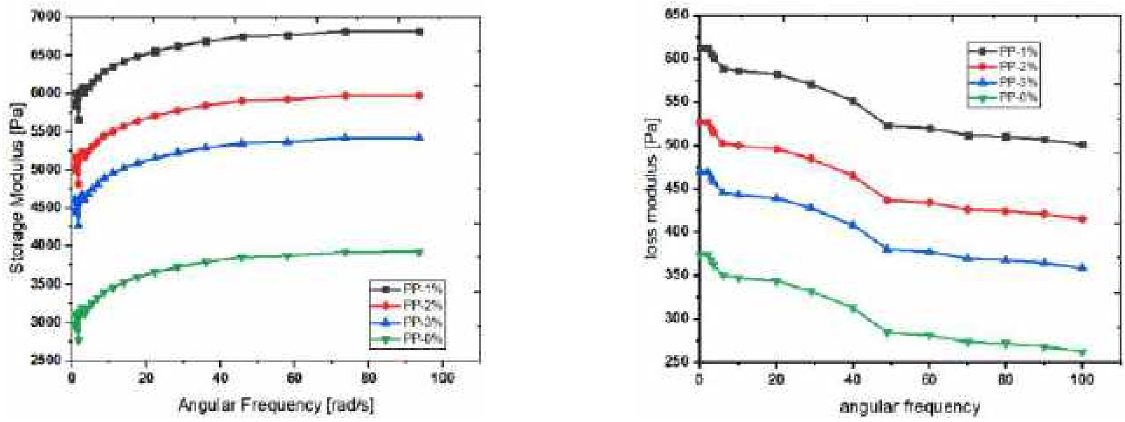
Viscoelastic behavior of PVA and PVA/PVP Hydrogels

The viscoelastic properties of PVA and PVA/PVP hydrogels were examined via an oscillatory frequency sweep using the MCR-702 Anton Paar rheometer. Figure 4 illustrates the storage and loss moduli of the hydrogels across varying PVP concentrations. The storage modulus represents the sample's elasticity, storing energy due to elasticity, while G″ indicates energy loss during processes. **Figure 4a** displays the storage modulus of both hydrogels, showcasing that the composite hydrogel, particularly at 1% PVP, exhibits a dominant storage modulus meeting the requirements for applications like cartilage. Additionally, an increase in PVP concentration within the PVA network leads to a reduction in the storage modulus, attributed to PVP over-accumulation. **Figure 4b** showcases the hydrogels' loss modulus, indicating lower energy dissipation in the graph.

BIOCOMPATIBILITY STUDY

Cytotoxicity and Cell Viability of PVA and PVA/PVP Hydrogels

The MTT assay method was used to investigate the in-vitro toxicity of the PVA/PVP-based composite hydrogel on the hMSC cell line. Compared to the negative control (cell control), the positive control showed three times higher cell viability than the minimum, as shown in **Figure 5**. The cell viability of the PVA and PVA/1%PVP hydrogels was 89.71% and 94.32%, respectively. Interestingly, the PVA hydrogel displayed only a marginal increase in cell viability compared to the composite hydrogel (PVA/1%PVP). Adhering to biocompatibility evaluation standards, the composite hydrogel exhibited no detectable toxicity to hMSC cells, maintaining a cell viability of over 70%. After 72 hours of incubation, robust cell culture and proliferation were observed in the culture plate, indicating healthy growth and development of all cells.



(a) (b)

Figure 4 Visco elastic behavior of PVA and PVA/PVP composite hydrogels. (a) Storage modulus VS angular frequency, (b) loss modulus VS angular frequency.

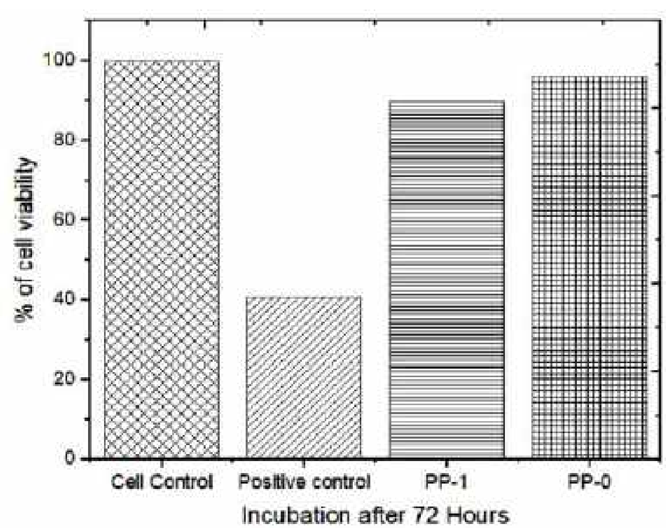


Figure 5 Cell Viability of PVA and PVA/1%PVP hydrogel after 72 h cell culture

CONCLUSION

Hydrogel blends of PVA and PVP, crafted through a repetitive freezing-thawing technique, could serve as promising materials for regenerate damaged articular cartilage. When specifically enriched with PVP, these blends exhibit enhanced mechanical properties for 1% PVP concentration attributed to stronger inter-chain hydrogen bonding compared to pure PVA. Furthermore, they mimic the distinctive viscoelastic behavior observed in articular cartilage. All the created hydrogels exhibited a porous structure with interconnected porosity, a crucial characteristic for cartilage scaffolds. The swelling capability of the hydrogel surpasses that of articular cartilage, showcasing excellent hydrophilic properties. Notably, a significant enhancement in mechanical properties, particularly in compression strength, was observed in composites containing 1 wt% of PVP. However, as the PVP content exceeds 1 wt%, there's a decline in compressive strength, potentially attributed to the excessive accumulation of PVP within the PVA structure. The storage modulus significantly surpassed the loss modulus, showcasing a predominance of elasticity. Moreover, as the concentration of PVP increased to 1 wt%, the storage modulus exhibited a corresponding rise. The trend suggests that the composites exhibit primarily elastic behavior similar to soft tissues in mammals. The cell viability of the composite hydrogel was good, showing no toxicity to h MSCs, with over 75% viability after 72 hours of culture. Overall, considering prior findings and discussions, the PVA/1%PVP composites emerge as an excellent option across a range of potential physical and mechanobiological properties.

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Reimagining Tomorrow through Dismantling the Conventions – A Professional's Way of Optimizing Resource Utilization through Engineering Logic

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***Abstract**: Great Chinese Scholar Confucius has said "Change is Inevitable". It's now an established fact that those who rapidly adopt the changes in line with the times are emerging the winners in the race and are setting the way forward for developmental goals. India is no different and we are witnessing changes at national and state level in every sphere. Organizations are not untouched by this paradigm shift in adopting changes in their spheres at a fast pace to sustain profitability and contribution to the national development. In this background it is imperative for all the practicing field level Technical Professionals too to contribute their best for organizational development and in-turn to national economy by optimizing resources utilization through questioning the Status-Quo and dismantling the conventions in some of the existing practices in Hydrocarbon Sector with the help of sound Engineering Concepts, Logical Reasoning, and Technical Standards, and Codes.*

Through this case study, author would like to share the experience of successful reasoning supported by good Engineering concepts incorporating Blow Down Time Calculations, Dispersion Modelling using ALOHA Software at one of the Hydrocarbon Pipeline installation while reasoning out the Technical observations raised by Third Party audit Teams during an external safety audit which otherwise could have cost valuable time and resources, had the observations been accepted without questioning the existing practices.

Blowdown valves and piping systems are installed around the mainline Sectionalizing valve in a gas transmission piping system in order to evacuate gas from sections of pipeline in the event of an emergency or for maintenance purposes. The case study pertains to the requirement of providing minimum of one third of Main Pipeline size for Vent Lines in Sectionalizing Valve Stations in a cross-country hydrocarbon pipeline which required modifications, shutdowns on an operational hydrocarbon pipeline. The audit observation was closed after presenting the engineering reasoning based on blow-down time calculations coupled with Dispersion Modelling for continuing with existing vent lines without carrying out any modifications which saved lot of Energy, Shutdown Time, reduction in Methane Emissions, and also enhanced Safety.

***Keywords**: Blow Down Time, Dispersion Modelling, Sectionalizing Valve, Methane Emission*

INTRODUCTION

High Pressure Natural Gas Pipelines transporting Natural Gas from one place to the other are considered to be the most economic means of transporting Energy. These High Pressure Pipelines supply Natural Gas to Important Industries like Power Plants, Fertilizer Plants, Industries and also several City Gas Distribution Networks. Hence ensuring the safe operation, reliability and availability of these Hydro Carbon Pipelines is of utmost importance to the concerned engineering professionals.

As these pipelines pass through rural and urban areas and operate in public space, the safe operation of these pipeline installations is of utmost importance. Hence the Pipeline Operators attach utmost importance to Safety aspects in Operation and Maintenance of these Installations. Regular Internal and External safety audits are carried out and the audit observations are complied with utmost priority. Oil Industry Safety Directorate (OISD) and Petroleum and Natural Gas Regulatory Board (PNGRB) are the government bodies entrusted with the monitoring of the safety aspects in these installations through regular inspections / audits during the Commissioning and Operations Phase. On some occasions, the external safety auditors raise the observations which may require substantial modifications to the existing installations.

The Gas Pipelines in India are designed and constructed in accordance with ASME B31.8, OISD Standards and PNGRB Regulations and hence are considered to be of pool-proof design. Once constructed and put into operation, the gas Pipelines supply the important energy feedstock in the form of natural gas to several industries and hence availing shutdowns for any modification job on the pipeline involves lot of venting of valuable natural gas, increasing the CO2 emissions, and also shutdown of several downstream industries affecting many people dependent on the downstream industries and affecting the economic activity. Despite such huge resource requirement, pipeline operators normally carry out the required modifications to comply with the safety observations if the same are considered to be enhancing the safety of the installations. However in certain cases, it is observed that the compliance to the Audit observations, despite carried out at huge resource utilization and expenditure of resources, may not enhance any additional safety. In such cases, the Professional associated with the Operation and Maintenance should reason out with the authorities based on sound engineering logic and question the conventions in practice which may not have any sound basis.

Through the Present Paper , author would like to share the experience of successful reasoning supported by good Engineering concepts incorporating Blow Down Time Calculations, Dispersion Modelling using ALOHA Software at one of the 18”dia,140 Km long Hydrocarbon Pipeline installation while reasoning out the Technical observations raised by Third Party audit Teams during an external safety audit regarding the vent Pipe Size, which otherwise could have cost valuable time and resources to the organization, Shutdown of Downstream Industries affecting several people dependent on those facilities, had the observations been accepted without questioning the existing practices. It is pertinent to mention here that India is a developing country and valuable resources including financial resources are required to be utilized for the right causes so as to yield the optimum results for the utilized resources.

A BRIEF ABOUT NATURAL GAS PIPELINES

Natural Gas Pipelines are mostly made of carbon steel and are laid normally at a depth of 1 to 1.5 meters depending on the earth profile. Sectionalizing Valve (SV) Stations are used for underground pipelines for isolating a part of the Pipeline Section for any maintenance or evacuation requirement. Intermediate Pigging (IP) Stations are the facilities intended for cleaning / inspection Pigging. Pig Launcher / Receiver are installed at IP Stations. Launcher for Launching the Pig into the downstream pipeline section and Receiver for Receiving the Pig Launched from the Other IP Station. Based on the Population density, the Distance between Two SV Stations varies from 8 Km to 32 KM. The IP Stations are installed as per the design and the distance between two IP stations shall not Exceed more than 200 KM. Blowdown valves and piping systems are installed around the mainline Sectionalizing valve in a gas transmission piping system in order to evacuate gas from sections of pipeline in the event of an emergency or for maintenance purposes.

THE SAFETY OBSERVATION BY THIRD PARTY AGENCY

The third Party Audit team raised an observation regarding the sizing of the Vent Lines used at 5 SV Stations of the 140 Km, 18” Dia Pipeline. The Observation was – The Vent line is 4”Size which should be minimum one third of main pipe size of 18” which should be minimum 6”size.

CONCERNS IN COMPLYING WITH THE AUDIT OBSERVATION

The Compliance to the audit observation required cutting and welding of New Vent Lines at 5 Locations along the length of the Pipeline. As the 140 KM Pipeline is in operation, feeding several industries, a Major Power Plant and an Important State Capital City Gas Distribution network and CNG Vehicle Network, availing complete shutdown on the operational pipeline for a minimum period of 4-5 days was practically not possible. The Shutdown also would have required venting of natural gas inventory in the 18”, 140 Km Pipeline operating at 30 Kg/Cm^2 Pressure, which is not only an unwanted expenditure but was also increasing the CO2 emissions by almost------- kg into the atmosphere.

APPLICATION OF ENGINEERING LOGIC

As the compliance to audit observation was requiring modification jobs and availing shutdowns, it is considered prudent to analyze the requirement of Blowdown Lines for Natural Gas Pipelines by referring to the ASME Codes and PNGRB regulation.

QUOTE :

ASME B31.8 CODE

Clause no. 846.2.1.c The sizes and capacity of the connections for blowing down the line shall be such that under emergency conditions the section of line can be blown down as rapidly as is practicable.

PNGRB REGULATION - TECHNICAL STANDARDS AND SPECIFICATIONS INCLUDING SAFETY STANDARDS FOR NATURAL GAS PIPELINES (T4S) REGULATIONS-2009

Sectionalizing Valve (s) station shall have blow down or vent line connection to evacuate the isolated pipeline section in case of an emergency and / or repair. The size of the connections for blowing down the mainline line shall not be less than 1/3rd of the mainline size.

UN-QUOTE

From the above the following are observed.

i. Natural Gas Pipeline Design Code – ASME B31.8, which was also referred in PNGRB T4S regulation, does not mention the sizing of the blow down connection.
ii. The PNGRB Regulation & OISD Standard 226 mention about having a vent line of size not less than 1/3rd of the main line size.
iii. The ASME Code ,T4S regulation and OISD standard mention that the vent connection is primarily meant for evacuating the section of pipeline between two sectionalizing valves and the codes and standards does not refer to the vent sizing as a safety requirement.

BLOW DOWN TIME CALCULATION

As the Vent lines are meant for blowdown of a section of Pipeline, and since the audit observation was to replace the existing lower sized vent lines with higher sized vent lines by carrying out required modifications, it is considered prudent to carry out the blow down time calculations for the Existing Vent Connections and the Higher Size Vent Connections (as per the PNGRB T4S requirement.) so as to assess the enhanced safety factor achieved out of the modification.

The Blow Down time for a Pipeline Section of length 24 KM between two Sectionalizing valves is considered for calculation of the blowdown time based on the American Gas Association (AGA) equation using [1] as below.

$$T = (0.0886P_i^{1/3}G^{1/2}D^2LF_c)/d^2$$

Where,

T Blow Down Time in Minutes
P_i Initial Pressure in the Pipeline which is to be vented.

G   Gas Gravity (Natural Gas – 0.6)
D   Pipe Inside Diameter in mm
L   Length of Pipe Section
d   Inside diameter of Vent Line.
F_c Choke Factor

For this paper, a sample Pipeline Section of 32 KM with parameters as mentioned in **Table 1** are considered.

Table 1 Pipeline and Operational Parameters Considered

Sl.No.	Description of Parameter	Unit	Value
1.	Length of P/L Section	KM	24
2	Diameter of the Pipeline	Inches	18
3	Diameter of the Actual Vent Line	Inches	4
4	Wall Thickness of the Pipeline	mm	7.1
5	Diameter of the required PNGRB Vent Line	Inches	6
6	Initial Pressure (Design Pressure)	Kg/Cm^2	72
7	Wall Thickness of the Vent line	mm	7.1
8	Final Pressure	Kg/Cm^2	1
9	Temperature	Deg.C	30
10	Natural Gas Gravity		0.6
11	Choke Factor		1.8

Using the above AGA equation, the blowdown time is calculated for the existing vent line of 4 Inches and PNGRB T4S stipulated $1/3^{rd}$ Vent Line. The Blowdown times so calculated are provided in the following table for a 32 KM Section.

Table 2 Blow down Time with Different Vent Line Sizes

Sl.No	Description of Parameter	Blow Down Time in Minutes
1	Blow Down Time with Existing 4 Inch Vent Line	127
2	Blow Down Time with PNGRB required $1/3^{rd}$ Vent line i.e.6 Inches	317

From the above, it is established that the Blow-Down time using AGA equation with 6 Inch Pipeline (meeting PNGRB requirements) is 169 Minutes and using a lower size 4 Inch Vent Line is 423 Minutes for evacuating a 32 KM Pipeline Section.

DISPERSION MODELLING USING ALOHA SOFTWARE TOOL

ALOHA (Areal Locations of Hazardous Atmospheres) is a modeling program [3] that estimates threat zones associated with hazardous chemical releases, including toxic gas clouds, fires, and explosions. ALOHA is developed by Office of Emergency Management EPA & Emergency Response Division NOAA, USA. As the existing vent line size (4 Inch) is lower than the PNGRB required vent size (6 Inch) the dispersion modelling was also carried out using ALOHA Software available in Public Domain so as to assess the threat zones. The Pipeline Details as mentioned in **Table 1** were used for the ALOHA Simulation with Both the Vent Lines. The Dispersion Modelling threat Zones with 4 Inch Vent Line is presented as **Figure 1** and with 6 Inch Vent Line is presented as **Figure 2.**

From the above dispersion modelling, the threat zone for 4 inch Vent Line during pipeline evacuation with 60% LEL extends up-to 1 Kilometer and with 100% LEL extends up-to 784 meters from the point of venting.

Similarly From the above dispersion modelling, the threat zone for 6 inch Vent Line during pipeline evacuation with

60% LEL extends up-to 1.5 Kilometer and with 100% LEL extends up-to 1000 meters from the point of venting.

LEL refers to Lower Explosion Limit and is an indication of the threat zone. From the above threat zone modelling, the threat zones for 4 and 6 inch Vent Lines are given in **Table 3**.

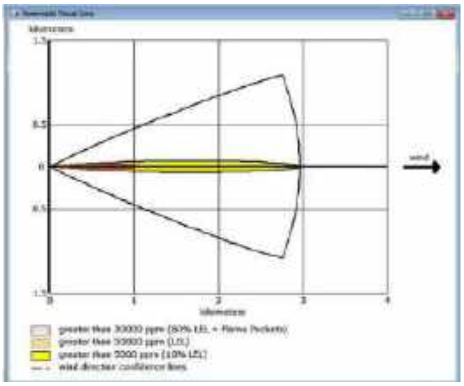

Figure 1 Threat Zone with 4 Inch Vent Line.

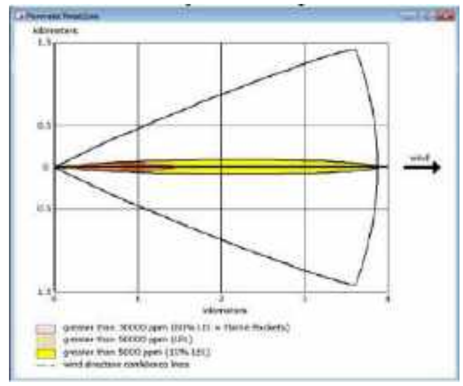

Figure 2 Threat Zone with 6 Inch Vent Line.

Table 3

Sl.No.	LEL	Threat Zone with 4"Vent	Threat Zone with 6"Vent
1	60%	1000	1500
2	100%	784	1000

From the above dispersion modelling, the threat zone i.e the spread of ignitable hydrocarbon mixture is extending to a larger distance in higher size 6" vent line than a lower 4" vent line. This is understandable as the venting of gas through a higher sized pipe results in evacuation of more inventory within a given time than a smaller vent line.

DISCUSSION

I).Operation of Vent Line Valves for Evacuation

The Sectionalizing Valve (SV) Stations in a natural Gas Pipeline are located in far-off or remote places from the Control Centres or the Pipeline Work Centres. The Valves in the Vent Lines are manual valves as the remote operation of the Vent Line valves was not envisaged in the ASME Code or OISD Standard /PNGRB regulation. As the SV Stations are located at a distance from the base stations, the vent line operation always requires time as the teams have to reach the terminal for operating the valves. The time required for reaching an SV Station varies from 1 -2 hours depending upon the SV station remoteness.

II).Blow Down Time

From the Blowdown time calculations, for the same diameter and length of Pipeline , the Blow Down Time with Lesser Size vent line is more than the higher sized vent, as mentioned in the table 2. However, the blowdown time in either case extends beyond 2 hours.

III).Vent Line Consideration for Blow Down

While the ASME Code does not mention about the no. of vent connections, the PNGRB regulation refers to one

Vent Connection. However in practice Each SV Station is provided with one Vent Connection for the same pipeline. Hence effectively, a Pipeline can be evacuated using two vent lines which reduces the actual blow down time than required by PNGRB or OISD.

IV). Rupture of the Pipeline

When a Pipeline ruptures completely, the inventory inside the pipeline is vented into atmosphere from the both ends of the pipeline at the point of rupture. Such evacuation lasts few minutes only, refer [2] and hence during such emergency exigencies, the time to reach the SV Station and operate the Manual Vent Valves for evacuation of the Pipelines from remote places takes significant time and by the time vent line valves are operated, the Pipeline already exhausts its inventory from the point of Rupture.

In view of I, II , III & IV above, the provision of a vent connection at SV station cannot be considered as a primary safety provision as the blowdown time using vent lines extends beyond several minutes or even hours even with a Higher sized vent line. Hence any Vent connection at SV station is to be treated as a means for evacuating the pipeline for planned maintenance activities only and shall not be treated as enhancing safety measures.

CONCLUSION& RECOMMENDATION

1. From the blowdown time calculations, it is observed that the time required for evacuating a pipeline section using vent lines at both sectionalizing valve stations is also significant and runs into several minutes or even hours. Even after carrying out the modifications and replacing the existing Blow Down Lines the Blow Down times shall still be nearly running into several minutes or even an hour and blow down time of 10-15 minutes could never be achieved. Hence, the Vent lines at SV stations in a Natural Gas Pipeline Network are to be considered as evacuation means for planned maintenance activities which can also be used during exigencies / breakdowns.

2. From the dispersion modelling, the LEL contours are observed to be less for lower sized vents, however since venting is always a controlled operation, the significance of Lesser LEL Contour with lower Vent Size should not be considered a factor for Vent line sizing and the OISD guidelines / PNGRB regulations need to be adhered to in all construction jobs.

3. Whenever a technical requirement for modification arises for complying with the prevailing guidelines / standards, an effort may be made to reason out with the concerned agencies for acceptance of the systems based on engineering logic so as to optimize the resource utilization in cases where the modifications does not enhance the safety and involves considerable expenditure and availing shut-downs of downstream industries . Such Resource optimization is essential for developing countries like India where those optimized resources can be utilized for other important activities.

4. For an 18”,140 KM, Pipeline Section, such an attempt to reason with OISD teams was made which resulted in accepting the continuation of existing vent lines by OISD without any modifications saving nearly 4,59,686 Standard Cubic Metres of Methane Emissions and also resulted in reduction of CO_2 emission by 8734 Tons approximately.

ACKNOWLEDGEMENT

An effort has been made in this paper to share the experience of the author in technically evaluating the vent line sizing using Blowdown time calculations and dispersion modelling which were used to convince the external auditors for continuing with the existing vent provisions without carrying out significant modifications. Using [4] the blowdown times were calculated for a specific pipeline for representing to the concerned officials. (The Calculations presented in this paper are based on a sample case and does not refer to the actual report.)

The author acknowledges the support from Senior officials at GAIL – Sh.K P Remesh,(retd.) Sh.KVS Rao, Sh.Anubuselvan & Sh.B N Rao in reviewing the concept and extending required cooperation for successful presentation of the case for consideration of agencies like OISD. The author acknowledges the consent from Oil & Gas Journal team for using their article. The author also acknowledges the positivity with which the reasoning based on Engineering logic was accepted by OISD team.

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COMPUTER ENGINEERING DIVISION

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Optimizing Heart Disease Prediction Models through Hyperparameter Tuning

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***Abstract**: This study focuses on optimizing heart disease prediction models through hyperparameter tuning. Heart disease, specifically heart attacks, is a critical health issue caused by the blockage of Lack of blood supply to the heart as a result of coronary artery plaque buildup. Early detection and accurate prediction of heart disease are vital to prevent life-threatening situations. To achieve this, study utilized a kaggle dataset comprising 303 rows and 14 columns, including features - age, sex, cholesterol levels etc. Logistic Regression, Random Forest, KNN, Decision Tree and SVCdifferent MLclassifiers were employed to predict heart disease.*

The models were initially evaluated using train-test split accuracy Subsequently to validate model performance, k-fold cross-validation (k=10) was applied based on the CV results, the best-performing models were selected and further fine-tuned using GridsearchCV and RandomsearchCV for hyperparameter optimization. The final results demonstrated improved performance: Logistic Regression achieved an accuracy of 91.80% on test data with an AUC-ROC score of 0.92, RF exhibited exceptional accuracy of 100% , AUC-ROC 1.00. SVC achieved an accuracy of 93.44%, AUC-ROC 0.93.This study highlights the importance of hyperparameter tuning in optimizing heart disease prediction models, with RF and SVC showing promising results for accurate heart disease prediction.

***Keywords**: Heart Attack Prediction, ECG, Machine Learning, k-fold Cross Validation, Hyperparameter Tuning, AUC-ROC*

INTRODUCTION

Heart Attack

A heart attack happens when the blood circulation to the heart is severely restricted or blocked. The deposition of fat, cholesterol, and other substances usually causes clogging of the heart's (coronary) arteries. The fatty, cholesterol-containing formations are known as plaques. The process of plaque accumulation is known as atherosclerosis.

Rarely, a plaque may rupture, resulting in the formation of a clot and the obstruction of blood flow. An area of the heart muscle that receives less blood flow may become damaged or even destroyed.

When an artery carrying blood and oxygen to the heart is clogged, a heart attack happens. Plaques are created when fatty, cholesterol-containing deposits accumulate over time in the arteries of the heart. Whenever a plaque breaks, a blood clot may result.

A heart attack may result from the clot's ability to obstruct arteries. The heart muscle tissue dies during a heart attack due to a lack of blood flow. A Myocardial Infarction is another name for a heart attack. To avoid mortality, a heart attack requires prompt treatment.

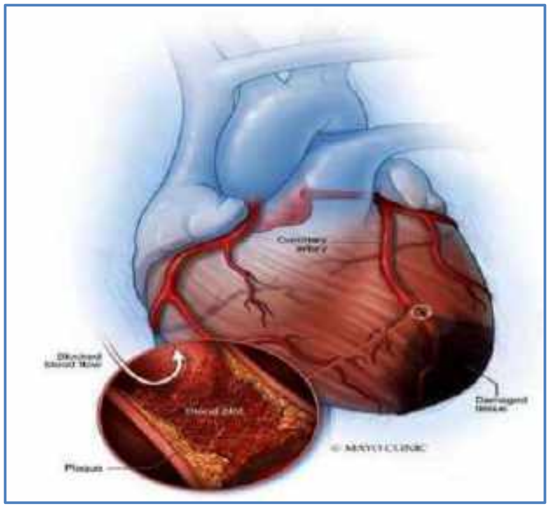

Figure 1 Heart Attack Causes

Heart Attack Early Signs

Heart attack symptoms can vary. Some people experience mild symptoms. Others exhibit severe symptoms. Some people don't exhibit any symptoms. chest discomfort that may feel painful, tight, achy, squeezing, or pressured, spreading pain or discomfort to the upper belly, shoulder, arm, back, neck, jaw, or occasionally teeth.

- A dry sweat
- Weariness
- Acid reflux
- Dizziness or unexpected lightheadedness
- Vomiting
- Breathlessness

Sharp or sudden neck, back, or arm pain might be unusual symptoms in women. Sudden cardiac arrest can occasionally be the first symptom of a heart attack. Unexpected heart attacks are possible. However, many people present symptoms and warning indications hours, days, or even weeks in ahead. Angina is characterized by persistent chest discomfort or pressure that persists even with rest and occurs due to temporary decline in the blood supply to heart muscles.

Chest Pain Types

1. Angina: Chest pain or discomfort known as angina is brought on by a decrease in blood flow to the heart muscle, often due to narrowed or blocked coronary arteries. A pressure or squeezing sensation on the chest is how angina feels. It happens when the heart isn't receiving enough blood. Additionally, a person's shoulder, back, neck, arms, and mouth may hurt.

2. Typical Angina: Typical angina is a specific type of chest pain characterized by a tight, squeezing sensation in the chest it often happens after physical effort or emotional stress and is treated with nitroglycerin or rest.

3. Atypical Angina: Atypical angina refers to chest discomfort or pain that doesn’t fit the classic pattern of typical angina. It may have different qualities and may not always be triggered by exertion or respond to nitroglycerin.

4. Non-Anginal Pain: Non-anginal pain is chest discomfort or pain that is not related to coronary artery disease. It can have various causes, such as musculoskeletal issues, gastrointestinal problems, anxiety, or lung conditions.

5. Asymptomatic: Asymptomatic means having no noticeable symptoms. In the context of chest pain, it implies that there is no chest discomfort or pain present.

ECG

ECG - An electrocardiogram (ECG) is a test that captures the electrical activity of the heart in order to detect various cardiac problems. To record the electrical impulses that propel heartbeat, electrodes are placed on the chest. On a linked computer monitor or printer, the signals are shown as waves.

Figure 2 ECG ST Depression

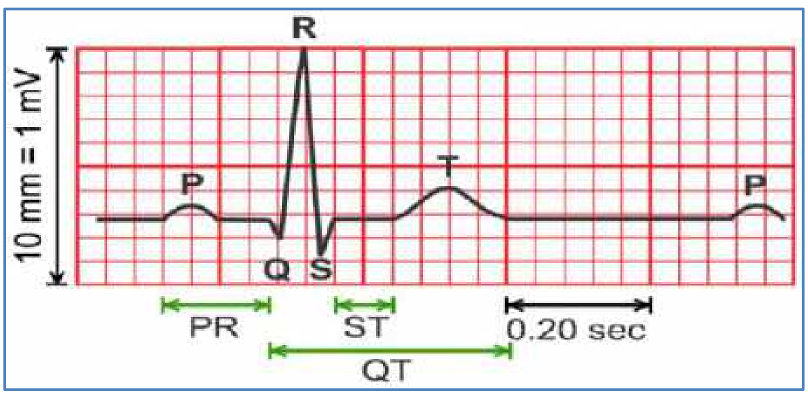

Figure 3 ECG Trace with Grid

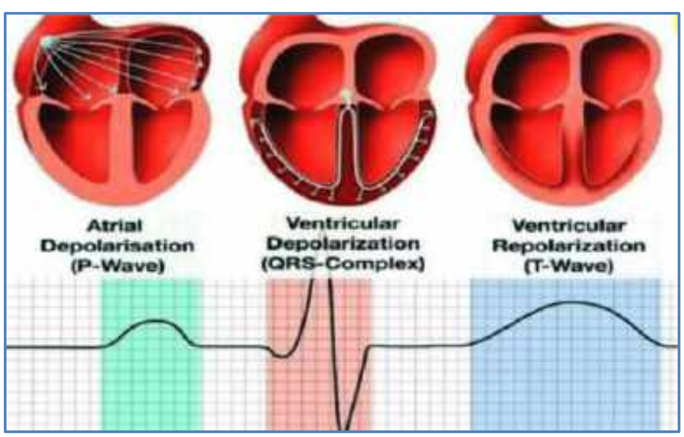

Figure 4 Representation of P-Wave QRS-Complex and T-Wave

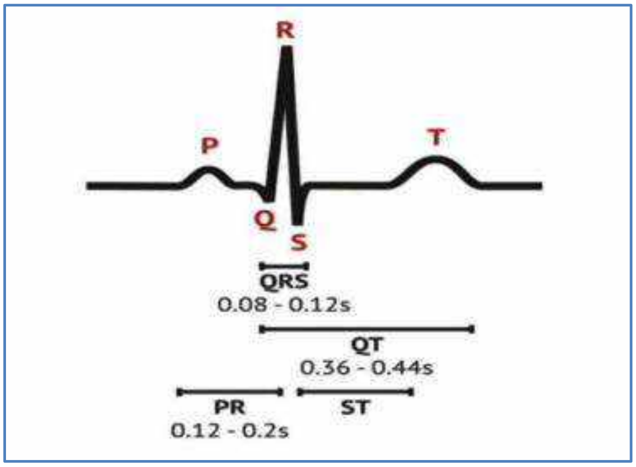

Figure 5 P-Wave QRS-Complex and T-Wave Duration

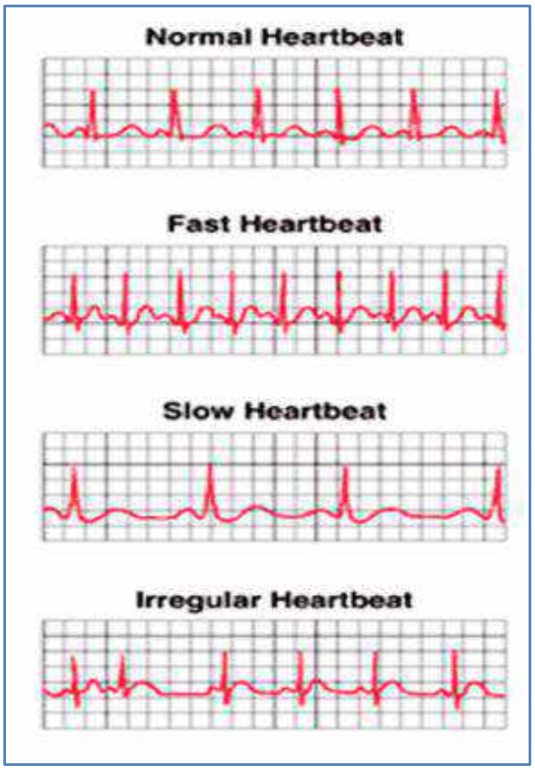

Figure 6 Various Heart Beats on ECG

MACHINE LEARNING

Artificial intelligence (AI) has a subfield called machine learning that empowers computers to learn and make decisions or forecasts based on data without explicit programming. It encompasses various techniques, but the three primary types are:

1. Supervised Learning: Algorithms are trained in supervised learning using labelled datasets, which pair input data with intended results. The objective is to discover a mapping between inputs and outputs that will allow the model to generate precise predictions for brand-new, unforeseen data.

2. Unsupervised Learning: Unsupervised learning operates on unlabeled datasets, and its goal is to discover patterns, structures, or relationships within the data. Common tasks include clustering similar data points or reducing the dimensionality of the data.
3. Reinforcement Learning: Reinforcement learning focuses on training algorithms is to train computers to select actions that will maximize overall rewards over time. The environment is used to teach the model new things, and it receives feedback in the form of incentives or punishments based on its activities.

Machine learning contributes to AI by enabling systems to enhance their performance over time through experience. There are two main types of tasks in machine learning:

1. Classification: Classification, a form of supervised learning, involves assigning input data points to specific categories or classes. The model learns to map input data to predefined output classes, making it suitable for tasks where the output variable is categorical.
2. Regression: Regression, also a type of supervised learning, aims to predict continuous numerical values based on input data. In regression tasks, the model learns to establish a relationship between the input features and the output variable, making it useful for tasks where the output variable is continuous.

Given the nature of the AHD Column in Dataset "heart.csv", the appropriate approach to solve this problem is Classification. In proposed work following Machine Learning Classification Algorithms are used –

(i) Logistic Regression
(ii) Random Forest Classifier
(iii) K Neighbors Classifier
(iv) Decision Tree Classifier
(v) Support Vector Classifier

CROSS VALIDATION

k-fold Cross Validation

Train-test splitting has its disadvantages. Firstly, it can result in high variability in performance evaluation because the choice of data points in the training and testing sets is random. This randomness means that the performance of a model can vary significantly between different train-test splits, making it challenging to draw consistent conclusions about how well a model generalizes to unseen data. Additionally, train-test splitting can lead to data wastage, especially when the dataset is small. A portion of the data is reserved for testing, which reduces the amount of data available for training. Less training data may result in models that are less robust or more prone to overfitting, which is especially problematic when working with limited data.

To address these issues, k-Fold Cross-Validation is employed. This technique partitions the data into k subsets or folds and iteratively uses each fold as both a training and testing set. By averaging the performance across these iterations, it provides a more stable and representative estimate of a model's generalization ability. Moreover, cross-validation ensures efficient data utilization, as each data point gets an opportunity to be part of both the training and testing sets. This is crucial, particularly when data is scarce. Cross-validation is also instrumental in model selection and hyperparameter tuning, enabling reliable comparisons between different models or parameter settings, making it a robust approach for assessing and improving machine learning models.

Hyperparameter Tuning

The process of systematically searching for the perfect hyperparameter combination is known as hyperparameter tuning, often referred to as hyperparameter optimisation for a machine learning model to achieve optimal performance. Hyperparameters are external configuration settings that govern how a machine learning algorithm learns and generalizes from the training data. Unlike model parameters, which are learned from the data during training (e.g., weights in a neural network), hyperparameters are set by the data scientist or machine learning practitioner before training begins.

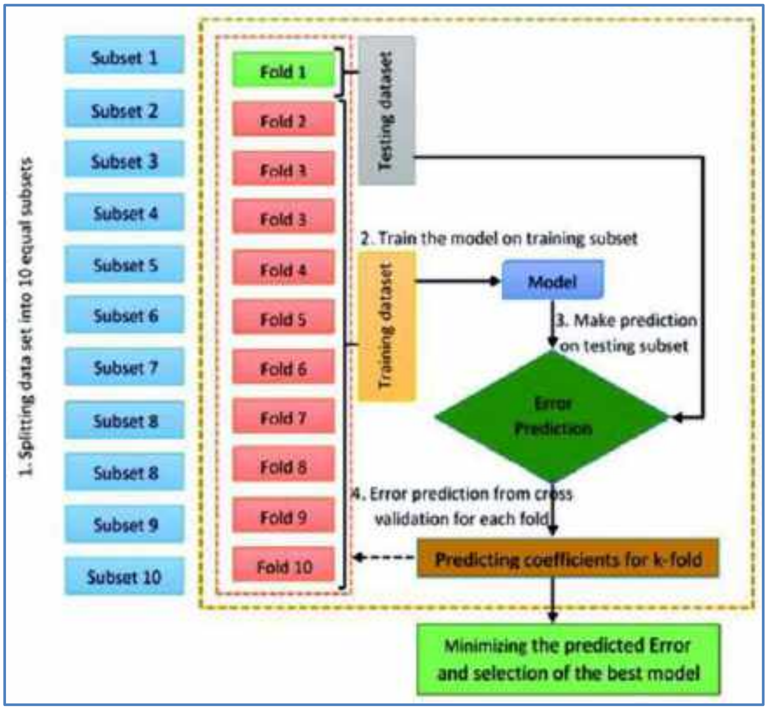

Figure 7 k-fold Cross Validation

The objective of hyperparameter tuning is to find the hyperparameter values that result in the best model performance, such as maximizing predictive accuracy, minimizing error, or achieving a specific performance metric. This process typically involves trying different values or ranges for hyperparameters, training the model with each set of hyperparameters, and evaluating the model's performance on a validation dataset. Techniques for hyperparameter tuning include grid search, random search, Bayesian optimization, and more, depending on the complexity of the problem and available computational resources. The ultimate goal of hyperparameter tuning is to fine-tune the model, prevent overfitting, and improve its generalization ability to make accurate predictions on unseen data. GridsearchCV and RandomizedSearchCV are two popular techniques for hyperparameter tuning in machine learning. They both aim to find the best combination of hyperparameters for a model, but they use different strategies for exploring the hyperparameter space.

GridSearchCV (Grid Search Cross-Validation)

GridsearchCV is an exhaustive search technique that evaluates the model's performance for all possible combinations of hyperparameters within a predefined range or set. It creates a grid of hyperparameter values and trains and validates the model for each combination. This method is systematic and ensures that you test every specified combination of hyperparameters. It can, however, be computationally expensive, particularly when working with a lot of hyperparameters or a wide range of values.

RandomSearchCV (Randomized Search Cross Validation)

On the reverse hand, RandomizedSearchCV adopts a more random strategy. It randomly selects a predetermined number of hyperparameter configurations from the hyperparameter space rather than analysing every possible combination. This randomness makes it more computationally efficient, especially when the hyperparameter space is extensive. RandomizedSearchCV can quickly explore a wide range of hyperparameters, potentially finding good configurations faster than GridsearchCV. However, there's a chance it may miss the optimal combination due to its randomized nature.

LITERATURE REVIEW

Dataset for this project was obtained from Kaggle. There are 303 instances in the collection overall, each with one of 13 attributes.

Data element	Description	Type	Range	Remarks
Age	-	Num[a]	29-77	Average is 54.37
Sex	-	Bi[b]	0: Female 1: Male	32% Female 68% Male
Cp	Chest pain level	Nom[c]	0/1/2/3 0: Asymptotic 2: non-anginal pain 3: Typical angina	Majority have 0 pain
Trestbps	Rest blood pressure	Num	94-200	Average is 131.6
Chol	Cholesterol level	Num	126-564	Average is 246.3
Fbs	Fasting blood sugar level	Bi	0: Level below 120 1: Level above 120	-
Restecg	Resting electrocardiographic results	Nom	0/1/2 0: Showing probable or definite left ventricular hypertrophy. 2: Abnormal	-
Thalach	Maximum heart rate achieved	Num	71-202	-
Exang	Exercise induced angina	Bi	0: None 1: Produced	-
Oldpeak	ST depression induced by exercise relative to rest	Num	0-6.2	Right skewed data, majority of population is between 0 and 0.5
Slope	The slope of the peak exercise ST segment	Nom	0: Unsloping 1: Flat 2: Down-sloping	-
Ca	Number of major vessels	Nom	0/1/2/3/4	-
Thal	Defect type	Nom	1: Fixed defect 2: Normal 3: Reversable defect	There is one outlier of category 0
Target	Diagnosis of heart disease	Bi	0: No disease 1: Disease	-

Figure 8 Heart Disease Dataset Description

Because the quality of the data used to create a machine learning model has a significant impact on how well it works, data preprocessing is essential. In addition to converting, resampling, and performing feature selection, Data pretreatment involves removing anomalies, damaged data, and missing data points from the data and corrupted or missing data points.

Attributes	Outlier values
Age	None
Chol	417, 564, 394, 407, 409
Trestbps	172, 178, 180,180, 200, 174, 192, 178, 180
Thalach	71
Oldpeak	4.2, 6.2, 5.6, 4.2, 4.4

Figure 9 List of Outliers

Only the extreme outliers were eliminated because the moderate outliers helped determine the final diagnosis. The interquartile range (IQR), a measure of the data's dispersion, and the lower and higher quartiles, respectively, are used in (1) and (2) to identify the extreme outliers.

(75% Q3) + 3 IQR (1)

(25% Q1) - 3 IQR (2)

The data points above the first expression were eliminated. The data points below the second expression were similarly eliminated. Thus, 2 of the 303 instances were eliminated.

The abbreviation "IQR" stands for "Interquartile Range." The spread or dispersion of data points within a dataset is evaluated statistically using the interquartile range. It is determined as the gap between the first and third quartiles (Q1 and Q3).

The interquartile range (IQR) can be calculated using the following formula: IQR = Q3 - Q1

Where:

• The first quartile, or Q1, represents the data's 25th percentile.

• The third quartile, or Q3, represents the data's 75% percentile.

IQR is a useful measure for understanding the variability of the middle 50% of the data. It is often used in conjunction with box plots and outlier detection methods to identify Potential Outliers;are data points that considerably deviate from this center range.

In the context of the provided information, the IQR is used to determine thresholds for identifying extreme outliers in specific attributes of the dataset, as described in the earlier response[1].

The work centred on applying machine learning methods, particularly Support Vector Machine (SVM) and K-Nearest Neighbour (KNN), to predict heart problems in individuals. This study's main objective is to identify the patients who are most prone to develop heart disease based on various medical features, such as chest pain, extracted from their medical records. This prediction is essential for early intervention and treatment.

The dataset used for this research is obtained from Kaggle.

Since the dataset contains no missing values, outliers, or categorical data, the only preprocessing step performed is feature selection.

Libraries Consulted: Several Python libraries are utilized, including the Math Library, NumPy, Pandas, Plotly, and Matplotlib, for various purposes such as data manipulation, visualization, and calculations.

Ec: In the context of forecasting heart disease, this figure shows the number of samples that were anticipated to be categorised as positive.

Enc: This is the proportion of samples that were predicted to be negative (having no evidence of cardiac disease)[2].

The primary goal is to employ machine learning, specifically the Random Forest algorithm, to accurately predict the likelihood of heart disease, a critical concern in modern healthcare. Dataset: Age, type of chest pain (Cp), resting blood pressure (Trestbps), cholesterol levels (Chol), fasting blood sugar (Fbs), maximum heart rate (Thalach), exercise-induced angina (Exang), ST depression caused by exercise relative to rest (Old Peak), and Thalassemia type (Thal) are among the patient attributes included in the dataset. It also includes a “Target” column indicating the presence (1) or absence (0) of heart disease.

Total Samples = 103	Output		
	Expected output	Ec	Enc
	c=55 positive	41	14
	nc = 48 negative	3	45

Figure 10 Result & Analysis of SVM

Total Samples = 257	Output		
	Expected output	Ec	Enc
	c=123 positive	101	22
	nc = 134 negative	13	121

Figure 11 Result & Analysis of KNN

Algorithm	Accuracy %	Miss rate %	Precision %	Recall %	F1 Score %
KNN	86	14	84	90	87
SVM	83	16	76	94	84

Figure 12 Result & Analysis of KNN, SVM

Algorithm: The chosen machine learning algorithm is the Random Forest, recognized for its ability to handle both regression and classification tasks efficiently. It operates by creating an ensemble of decision trees and aggregating their outputs to enhance predictive accuracy. Training and Testing Splitting: To evaluate the model's performance, Two subsets of the dataset are created: a training set, which typically constitutes 70% of the data, plus a testing set comprising the remaining 30%. To train the model to make predictions, utilize the training set, while the testing set is reserved to assess the model's accuracy and generalization to new, unseen data.

Accuracy: The emphasis throughout the work is on achieving high performance and accuracy rates. The accuracy of the prediction model depends on various factors, including the number of decision trees in the Random Forest. By combining multiple classifiers, the algorithm strives to increase accuracy while avoiding overfitting[3].

Disease prediction systems are highlighted as valuable tools for avoiding human errors in disease diagnosis and assisting in early disease prevention. The research focuses on developing intelligent heart disease prediction systems. This work used the well-known Cleveland heart disease dataset, which was obtained from the UCI machine learning library. 303 items in all containing info on heart disease, this dataset offers a comprehensive set of 76 attributes, each providing unique insights into various patient health-related factors. However, to focus specifically on heart disease prediction, the research selects a subset of 14 attributes deemed most relevant for the task. These attributes encompass a diverse range of information, including patient age, gender, chest pain type, blood pressure, cholesterol levels, and more. The dataset contains a mix of data types, including integers, real numbers, and discrete values, reflecting the varied nature of health-related information. Crucially, the "num" attribute within the dataset serves as the output label, with "num=0" indicating normal health and "num=1" signifying the presence of heart disease.

Platforms, including Weka, Rapid Miner, Mahout, and MATLABResults –

Decision Trees: 80.4%
Neural Networks: 85.68%
Naïve Bayes: 86.12%

Hybrid Neural Network with Genetic Algorithm:

Training dataset accuracy: 96.2%
Test dataset accuracy: 92%
Validation set accuracy: 89%

Robust Intelligent Heart Disease Prediction System (RIHDPS):

RIHDPS accuracy rate: 91.26%
Naïve Bayes accuracy value: 89.32%
Logistic Regression accuracy value: 84.47%
Neural Networks accuracy value: 90.2%
K-Means Clustering and Artificial Neural Network (ANN) Hybrid Model[4]: 93.5%

Thestudy focused on the diagnosis and prediction of heart-related diseases using machine learning algorithms. The introduction highlights the significance of the heart in living organisms and the importance of accurate diagnosis and prediction of heart-related diseases due to the potential life-threatening consequences. The primary goal of the seek is to create a system for cardiac disease prediction using machine learning techniques to raise awareness about these diseases. Data Collection: A dataset from the UCI repository is used in the investigation, which is widely recognized and verified. Attribute Selection: Various attributes from the dataset are chosen for the prediction system, such as age, gender, chest pain type, resting blood pressure, serum cholesterol, fasting blood sugar, etc.

Data Preprocessing: It is mentioned as a crucial step to achieve accurate results from machine learning algorithms. It includes handling null values and converting categorical variables into numerical form using dummy encoding (0 and 1).Machine Learning Algorithms: The paper evaluates the effectiveness of several machine learning algorithms at forecasting cardiac disease, Decision Tree, Linear Regression, K-nearest Neighbour (KNN), Support Vector Machine (SVM)[5]:Support Vector Machine: 83% ,Decision Tree: 79%, Linear Regression: 78%, K-nearest Neighbor: 87%

This research is to develop a predictive model for heart disease using Machine Learning techniques. Cleveland Heart Disease Dataset from the UCI Repository was the dataset used in this study. It contains a total of 14 attributes (features) related to heart health. Here are the attributes: Age in years, Sex (Male or Female), Chest pain type (Angina, abnormal angina, typical angina, asymptomatic), Resting Blood Pressure in mm Hg, Serum Cholesterol in mg/dL, Fasting blood sugar (1 if >120 mg/dL, 0 if <120 mg/dL), Electrocardiographic Results, Highest Heart Rate observed, Angina induced by exercise (0 for no, 1 for yes), Exercise-induced ST depression Exercise-induced ST depression, Slope of the ST segment, Number of major vessels ranging from 0 – 3 colored by fluoroscopy, Heart status, Target Output Class (1 for tested positive for the disease, 0 for tested negative for the disease). The dataset contains 1025 instances in total. It’s important to note that the dataset also had missing values, which were addressed through data preprocessing techniques. The dataset was divided into two portions: The training dataset included 80% of the total data. The testing dataset was made up of the remaining 20% of the data.

The research methodology involved several key steps: Data Collection: The Cleveland Heart Disease Dataset was obtained from the UCI Repository. Data Preprocessing: Missing values in the dataset were handled by replacing them with the mean of the respective column. The dataset was also transformed to ensure compatibility with Machine Learning techniques. Model Building: The predictive model was developed using the Weka Data Mining Tool, which offers various standard data mining tasks. For this work, four ML models — Random Forest, Support Vector Machine (SVM), Naive Bayes, and Decision Tree — were used. These models' effectiveness was evaluated using a number of criteria, such as precision, recall, accuracy, and ROC Area[6].

Model	Precision	Recall	ROC Area
SVM	0.995	0.995	0.995
Random Forest	0.997	0.997	1.00
Decision Tree	0.851	0.848	0.889
Naïve Bayes	0.904	0.904	0.966

Figure 13 Performance Measure of Models

METHODOLOGY

Heart Disease Data Source

IDE - Google Collaborator / Python–Python 3

Applied Binary Classification Problem on Data

Dataset : https://www.kaggle.com/datasets/zhaoyingzhu/heartcsv

File Size : 19KB

Dataset Size: 303 rows × 14 columns

Table 1 Dataset Attributes

Sr.No.	Feature	Description	Detailed Description
1	age	The person’s age in years	Type: Numerical Range: 29-77
2	sex	The individual's sex (1 is M, 0 is F)	Type: Binary 68% Male, 32% Female
3	cp:	kind of chest discomfort	Asymptomatic is value 0, while atypical angina is = 1, Non-anginal pain = 2, Standard angina = 3
4	trestbps:	At the time of hospital admission, the patient's resting blood pressure (mm Hg). Dataset Value:94-200	There are two forms of blood pressure that are measured in millimetres of mercury (mmHg): Systolic pressure is the force your heart exerts to force blood out. The pressure that exists between heartbeats is known as diastolic pressure. Normal Range: 90-120
5	chol:	The individual's cholesterol level in mg/dl Dataset Value: 126- 564	The common unit of measurement for cholesterol is milligrammes (mg) per deciliter (dL) of blood. Healthy cholesterol ranges from 125 to 200 mg/dL.
6	fbs:	The subject's fasting blood sugar Dataset Value: (1 = T; 0 = F; > 120 mg/dl)	Normal fasting blood glucose levels are predicted to be between 70 mg/dL to 100 mg/dL.
7	restecg:	electrocardiogram readings at rest: 0, 1, 2	Value 0: indicating left ventricular hypertrophy in accordance with Estes' criterion. Value 1: Regular, T wave inversions, as well as ST elevations or depressions of more than 0.05 mV, are ST-T wave abnormalities is a value 2.
8	thalach:	reached the person's highest heart rate Values: 71 –202	Normal: 60 to 100Per Minute
9	exang:	Exercise induced angina (1 = yes; 0 = no)	Chest Pain after Exercise
10	oldpeak:	ST depression caused by exercise compared to rest. 1 Block Size – 1mm* 1mm Block Inside Block – 0.2 mm	
11	slope:	The angle of the ST section of the peak workout	A slope of 0 degrees is downward, a slope of 1 degree is horizontal, and a slope of 2 degrees is upward.
12	ca:	Major Vessels (0–3) in Number Blockage Severity 0/ 1/ 2/ 3	Blood channels called coronary arteries provide the heart muscle with blood.
13	thal:	Thalassemia Value 0: NULL is a blood condition. Prior to being removed from the dataset Value: 1 / 2/ 3	Thalassemia is an inherited blood condition that results in lower-than-normal haemoglobin levels in your body. When haemoglobin cannot transport oxygen. Value 1: Fixed defect (part of the heart not receiving blood flow). Valuation 2: regular blood flow Value 3 indicates a reversible deficit (blood flow is visible but abnormal).
14	AHD	Heart condition	1 = no, 0= yes

As All Values of AHD Column are either 0 or 1 Thus, it is a Classification Problem.

Implementation

1. Importing Libraries
2. Drive Mount&Data Collection
- Reading CSV file (heart.csv) using pandas
3. Data PreprocessingStarts
- Printing dataframe df / data Exploration to obtain information about a DataFrame
4. Check forNull Values :
- Checking for missing values in the dataframe using df.isnull().sum().
- Fill Null Values with Mean
5. Data Preprocessing (Continued):
- Seperating the Dataset Featues into features (x) and target (y).
- get the Unique Values of Columns
- Plot Pie Chart for target (y)
- Standardization is used to bring features onto a common scale
- Use train_test_split,80 percent of the data will be used for training and 20 percent for testing.
6. Model Creation:
- Five Classification models are created on Training – Testing Data and evaluated using Confusion Matrix. The models are:
  - Logistic Regression Model
  - Random ForestClassification Model
  - K Neighbors Classifier Model
  - Decision Tree Classifier Model
  - Support Vector Classifier Model
7. Cross Validation
  - K Fold Cross Validation over (x,y) data is Applied on the Models
8. Hyperparameter Tuning
  - Based on Cross Validation Accuracy, Selected Best Models then applied GridsearchCV andRandomsearchCV for Hyperparameter Tuning
9. Finally Tested Models with Best Parameters
10. Model Evaluation
  - By Confusion Matrix
  - By Calculating AUC-ROC Score
11. Model Evaluation
  - By Confusion Matrix&By Calculating AUC-ROC Score

RESULT SUMMARY

Final Model Creation with Best Parameters

Logistic Regression Model

Accuracy on Test Data: 0.9180327868852459

Confusion Matrix:

[[30 3]

[2 26]]

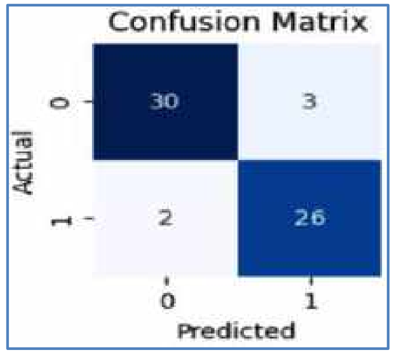

Figure 14 Confusion Matrix for LR Model with Best Parameters

Random Forest Classification Model

Accuracy on Test Data: 1.0

Confusion Matrix:

[[33 0]

[0 28]]

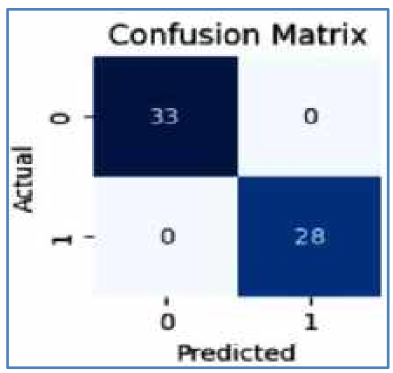

Figure 15 Confusion Matrix for RF Model with Best Parameters

Support Vector Classifier Model

Accuracy on Test Data 0.9344262295081968

Confusion Matrix:

[[31 2]

[2 26]]

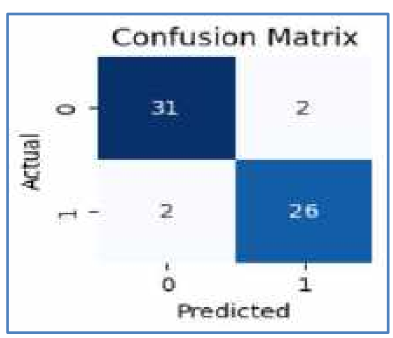

Figure 16 Confusion Matrix for SVC Model with Best Parameters

Classifier Models	**Train Test Split**	**Cross Validation CV=10**		**GridsearchCV / RandomsearchCV**
Logistic Regression	Accuracy - 0.9180327868852459	[0.90322581 0.80645161 0.80645161 0.96666667 0.83333333 0.7 0.86666667 0.9 0.73333333 0.86666667]	mean_accuracy_lr 83.828	Best Hyperparameters from Grid Search: {'C': 0.1, 'penalty': 'l2'} Best Accuracy: 0.8449462365591398 Best Hyperparameters from Random Search: {'penalty': 'l2', 'C': 0.1} Best Accuracy: 0.8449462365591398
Random Forest	Accuracy – 0.8852459016393442	[0.90322581 0.83870968 0.87096774 0.93333333 0.9 0.8 0.7 0.83333333 0.73333333 0.83333333]	mean_accuracy_RF 83.4624	Best Hyperparameters from Grid Search: {'max_depth': 10, 'n_estimators': 200} Best Accuracy: 0.8281720430107526 Best Hyperparameters from Random Search: {'n_estimators': 200, 'max_depth': 10} Best Accuracy: 0.8281720430107526
KNeighbour	Accuracy - 0.6721311475409836	[0.70967742 0.64516129 0.48387097 0.66666667 0.6 0.5 0.66666667 0.7 0.53333333 0.73333333]	mean_accuracy_KNC 62.3871	
Decision Tree	Accuracy - 0.819672131147541	[0.77419355 0.87096774 0.77419355 0.86666667 0.76666667 0.76666667 0.76666667 0.76666667 0.7 0.73333333]	mean_accuracy_DT 77.8495	
Support Vector	Accuracy - 0.8688524590163934	cv_score_svc [0.87096774 0.80645161 0.83870968 0.96666667 0.83333333 0.7 0.86666667 0.9 0.70.9]	mean_accuracy_svc 83.828	Best Hyperparameters from Grid Search: {'C': 0.1, 'kernel': 'linear'} Best Accuracy: 0.8447311827956989 Best Hyperparameters from Random Search: {'kernel': 'linear', 'C': 0.1} Best Accuracy: 0.8447311827956989

Table 2 Accuracies of Different Models

After Applying Best Parameters on Model					
Machine Learning Model		**Trained & Tested On**	**Confusion Matrix**	**Accuracy on Test Data**	**AUC-ROC Score**
1.	Logistic Regression	fit(x,y), Predict(x_test)	[[30 3] [2 26]]	0.9180327868852459	0.92
2.	Random Forest	fit(x,y), Predict(x_test)	[[33 0] [0 28]]	1.0	1.00
3.	Support Vector Classifier	fit(x,y), Predict(x_test)	[[31 2] [2 26]]	0.9344262295081968	0.93

AUC-ROC Score to Evaluate Model Performance

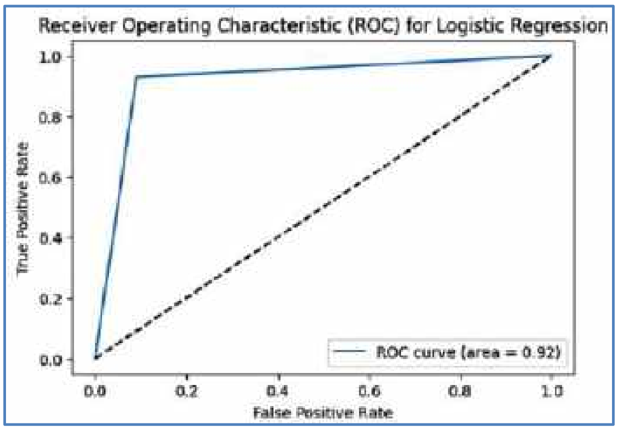

Figure 17 ROC for Logistic Regression Model

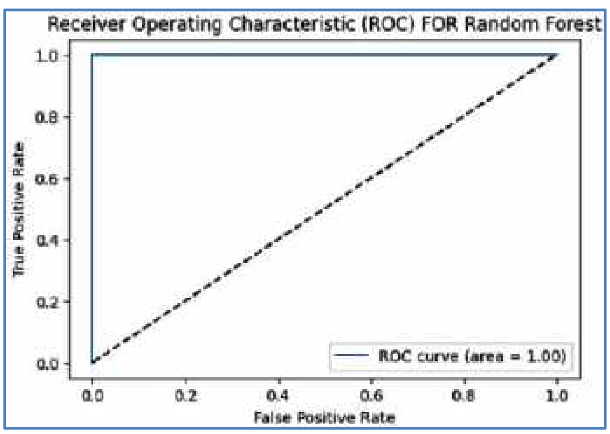

Figure 18 ROC for Random Forest Model

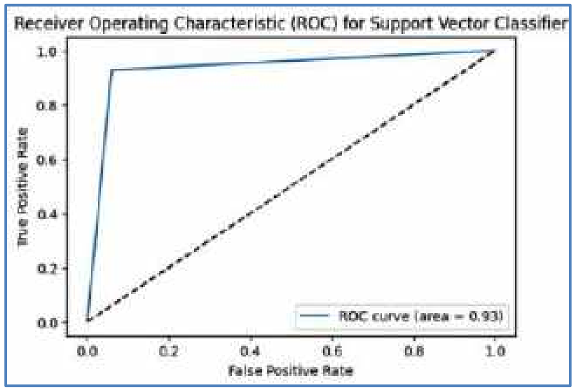

Figure 19 ROC for Support Vector Classifier Model

CONCLUSION& FUTURE WORK

Conclusion

In this study, we thoroughly assessed how well several machine learning algorithms predicted cardiac disease. We employed a systematic approach that involved train-test splitting, k-fold cross-validation (CV=10), and hyperparameter tuning using GridsearchCV and RandomsearchCV. The results provided valuable insights into the effectiveness of these techniques in optimizing model performance.

Train-Test Splitting: We partitioned the dataset into an 80-20 train-test split, where the models were trained using 80% of the data, and their prediction skills were tested using the remaining 20%. This approach ensured that the models were assessed on unseen data, helping to gauge their generalization performance.

Cross-Validation: We utilized k-fold cross-validation with k=10, i.e., the dataset was split into 10 smaller groups. The subsets were rotated through as a validation set while the other 9 subsets were utilised for training, and the models were trained and evaluated ten times. This robust cross-validation approach provided a more accurate estimate of the models' predictive accuracy. The reported mean accuracy values for each model provided a comprehensive assessment of their performance across diverse validation sets.

Hyperparameter Tuning: GridsearchCV and RandomsearchCV were applied to fine-tune the model hyperparameters. The best hyperparameters for each algorithm were identified through an exhaustive search, optimizing their performance. The best accuracy scores resulting from hyperparameter tuning were recorded for each model.

The best model after hyperparameter tuning, based on the highest accuracy, was the Random Forest model. After applying the best hyperparameters {'max_depth': 10, 'n_estimators': 200}, the Random Forest on the test dataset, the model had a 100% accuracy rate. This indicates that, among the models evaluated in your research, the Random Forest model performed the best after hyperparameter tuning, with perfect accuracy on the test data.

Future Work

1. Ensemble Learning: Explore ensemble learning techniques, such as bagging and boosting, to combine the strengths of multiple models. Ensemble methods like AdaBoost or Gradient Boosting can potentially further improve prediction accuracy.
2. Feature Engineering: Investigate more advanced feature engineering techniques to create new relevant features or reduce dimensionality. Consider feature selection algorithms and domain-specific feature engineering to enhance model performance.

3. Data Augmentation: Gather a larger and more diverse dataset to improve model generalization. Expanding the dataset could help the models perform even better and handle a broader range of patient profiles.
4. External Validation: Validate the models using external and independent datasets from different healthcare institutions or regions to ensure that the models generalize well beyond the initial dataset.
5. Real-time Monitoring: Develop a real-time monitoring system that continuously updates the models with new data, allowing them to adapt to changing patient demographics and evolving medical practices.
6. Patient Education: Develop educational tools or applications to inform patients about their risk factors for heart disease based on the predictions made by the models. Encourage proactive healthcare behaviors and lifestyle changes.
7. Other Algorithms: Explore other machine learning algorithms or deep learning architectures to see if they can outperform the current models. Experiment with more advanced techniques like neural networks or gradient-boosted trees.

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K-means Clustering with FCM for Segmentation of Human Brain Tumor Identification

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***Abstract**: The process of partitioning into different objects of an image is segmentation. In different major fields like face tracking, Satellite, Object Identification, Remote Sensing and majorly in medical field segmentation process is very important to find the different objects in the image. To investigate the functions and processes of human boy in radiology magnetic resonance imaging (MRI) will be used. MRI technique is using in many hospitals for the diagnosis purpose widely in finding the stage of a particular disease. In this paper, we proposed a new method for detecting the tumor with enhanced performance over traditional techniques such as K-Means Clustering; fuzzy C means (FCM). Different research methods have been proposed by researchers to detect the tumor in brain. To classify normal and abnormal form of brain, a system for screening is discussed in this paper which is developed with a framework of artificial intelligence with deep learning probabilistic neural networks by focusing on hybrid clustering for segmentation on brain image and crystal contrast enhancement. Feature's extraction and classification are included in the developing process. Performance in Simulation of proposed design has shown the superior results than the traditional methods.*

***Keywords**: Medical Image Processing, Segmentation, K-Means Clustering, Edge Detection, Image Enhancement.*

INTRODUCTION

Magnetic resonance imaging (MRI) [1] is a technique used in radiology to study human body processes and organ functions. Magnetic fields and radio waves can be used to create these visuals. This technology has been widely used in hospitals for medical diagnosis, illness staging, and follow- up without exposing patients to ionizing radiation.MRI offers a wide range of uses in medical diagnostics, and there are over 25,000 scanners in operation across the world. It affects diagnosis and treatment in a wide range of disciplines, while the influence on improved health outcomes is unknown. When either modality might provide the same information, MRI is preferred over computed tomography (CT) because it does not require ionizing radiation. The continued rise in MRI demand in the healthcare business has raised concerns regarding cost effectiveness and over diagnosis. An attempt to organize comparable colors or parts of an image into a cluster or group is known as segmenting a picture. Clustering, which divides the number of colors or elements into many clusters based on the similarity of color intensities and grey intensities in an image, is one way to accomplish this. The extraction of dominating colors from photographs is the main goal of clustering. Image segmentation may be particularly useful for simplifying by extracting information from photos like as texture, color, shape, and structure. Because it extracts information from images, segmentation has been utilized in a variety of domains, including image enhancement, compression, retrieval systems (such as search engines), object detection, and medical image processing [2].

SEGMENTATION

Segmentation is the process of dividing a digital image into several parts in computer vision (sets of pixels, also known as super pixels).The purpose of segmentation is to make an image more intelligible and easier to examine by simplifying and/or changing its representation. Objects and boundaries (lines, curves, etc.) in images are often located via image segmentation. Image segmentation, in more technical terms, is the process of giving a label to each pixel in an image so that pixels with the same label have similar visual qualities. Image segmentation produces either a set of segments that encompass the full image or a set of contours taken from the image (see edge detection).In terms of some characteristic or computed feature, such as color, intensity, or texture, each pixel in a region is comparable. When it comes to the same traits, adjacent regions differ greatly.

• Edge finding
• Thresholding
• Mathematical morphology in binary form
• Mathematical morphology based on grey values

It is critical to be able to discriminate between the objects of interest and "the remainder" while analyzing objects in photographs. This second group is also known as the background. Segmentation techniques - separating the foreground from the background - are commonly employed to find the objects of interest. In this section, we'll go over two of the most prevalent segmentation techniques: Thresholding and edge finding, as well as techniques for enhancing segmentation quality. It’s critical to realize that:

1. No segmentation technique is generally applicable to all images, and
2. No segmentation technique is flawless.

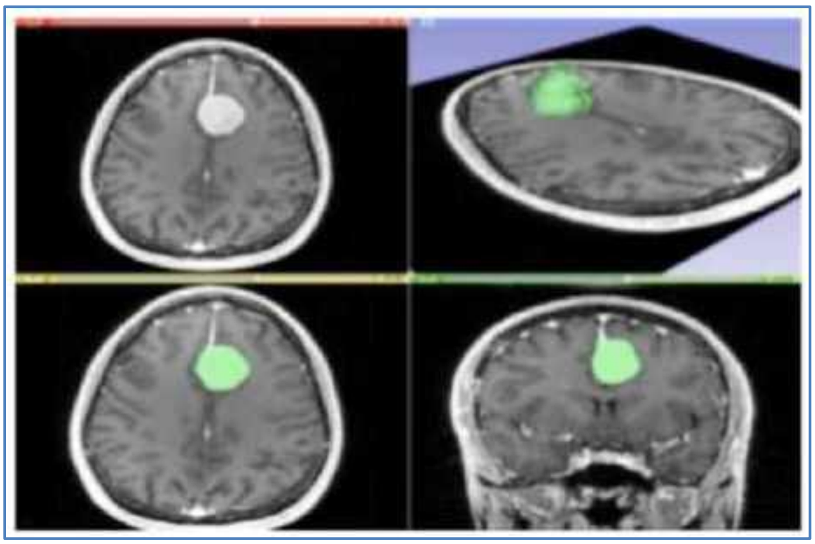

Figure 1 Segmentation of Image Using Deep Learning Techniques

THRESHOLDING

This method is based on a straightforward premise. The brightness threshold is chosen and applied to the image a [m, n] in the following way: This version of the algorithm thinks we're looking for light objects against a dark backdrop. We’d use the following for dark objects on a light background: The output is the label "object" or "background," which can be represented as a Boolean variable "1" or "0" due to its dichotomous character. The test condition might theoretically be based on something other than brightness (for example, If (Redness a [m, n] >= red), but the concept is apparent. The essential question in Thresholding is then, "How do we choose the threshold?" There is no universal threshold selection process that is guaranteed to operate on all photos, but there are a number of options. Fixed threshold - Using a threshold that is set independently of the image data is an option. If it is known that one is working with very high-contrast photos with objects that are very dark and a homogeneous and very light background, a constant threshold of 128 on a range of 0 to 255 may be sufficient. By accuracy, we mean that the number of pixels that have been incorrectly identified should be maintained to a minimum.

LITERATURE SURVEY

The automatic brain tumour segmentation (ABTS) method was created by Idanis Diaz to separate the various components of a brain tumour. The approach was used to four magnetic resonance image modalities to determine the edoema and gross tumour volume (GTV). The ABTS segmentation algorithm uses morphological operations such geodesic transformations and a histogram multi- Thresholding approach, as well as a histogram multi-Thresholding technique. The registered pictures using the typical MR sequence were utilised as input. The initial phase was Thresholding, followed by skull segmentation, edoema, and gross tumour volume (GTV).The method is rapid and accurate for images produced by various scanners since it automatically selects thresholds based on histograms.

Meiyan Huang came up with a new classification system. The local independent projection was incorporated into the standard classification paradigm in this paper. Local independent projections are calculated for the LIPC (independent projection-based classification) approach, with locality as a key parameter. By learning a model termed soft max regression, the LIPC approach additionally takes into account the data distribution of distinct classes. This may aid in further improving categorization performance. Pre-processing, tumour segmentation using the LIPC approach, feature extraction, and post-processing with spatial constraints are the four primary stages of the proposed method. To cut down on computing expenses, a multi-resolution framework was built in. For both Synthetic Data and Image Data, experimental findings were obtained .This method addressed the issues of tumour segmentation methods that arise due to the complex characteristics presented by brain tumour MRI images, such as great variation in the appearance of the tumour and ambiguous tumour boundaries.

Jin Liu went over the various imaging modalities and MRI-based tumour segmentation algorithms in detail. The pre-processing techniques as well as the most up-to-date state-of the-art methodologies for MRI-based brain tumour segmentation were comprehensively discussed. The results of the MRI- based tumour segmentation were then analysed and confirmed. Finally, utilising MR images, an objective appraisal of future advancements and trends in brain tumour segmentation approaches was presented. Many segmentation tactics have helped to solve the problems that semiautomatic and fully automatic systems have.

Dr Mohd Fauzi Bin Othman gave an overview of MRI brain tumour classification utilising Field Programmable Gate Array (FPGA) implementation. Field Programmable Gate Arrays are the greatest choice for real-time study of image processing algorithms since they can be customised and are adaptable. They cut down on the time and cost of implementing new segmentation algorithms on hardware. Using a sophisticated kernel-based technology called Support Vector Machine (SVM), the MRI data images are categorised as normal (without a brain tumour) or abnormal (with a brain tumour) (with a brain tumour).The inverse wavelet transform is used to create a noise-free image after the wavelet transform is performed to eliminate noise. As a result, we do a wavelet-based feature extraction. SVM, on the other hand, is not particularly precise with huge data sets because it is dependent on the amount of the input data. As a result, to improve evaluation outcomes, the SVM should be utilised in conjunction with the clustering method.

Deepthi Murthy T.S. recommends using a Thresholding technique followed by morphological procedures to obtain effective segmentation. This paper uses a segmented tumour image to calculate and analyse the centroid, perimeter, and area of a brain tumour. After pre-processing with the solely operator, the image was enhanced with histogram equalisation (to equalise the image's intensities/pixels). The image was then segmented using morphological approaches to extract the region of interest. The tumour was detected as a result of this. In order to classify the various types of tumours, further traits should be established in future research.

The author of [11] proposed a pillar-based approach to K-means clustering optimization, in which the greatest value is used to replace the initial centroid rather than the mean value. [19-21], the authors proposed a hybrid algorithm for tumour recognition and extraction from brain pictures, although they were unable to detect the tumour more accurately.

PROBLEM

A brain tumor is a disease caused due to the growth of abnormal cells in the brain. There are two main categories of brain tumor , they are non-cancerous (benign) brain tumor and cancerous (malignant) brain tumor. Survival rate of a tumor prone patient is difficult to predict because brain tumor is uncommon and are different types. As per the cancer research by United Kingdom, around 15 out of every 100 people with brain cancer will be able to survive for ten or more years after being diagnosed. Treatment for brain tumor depends on various factors like: the type of tumor, how abnormal the cells are and where it is in the brain etc with the growth of Artificial Intelligence.

Deep learning models are used to diagnose the brain tumor by taking the images of magnetic resonance imaging. Magnetic Resonances Imaging (MRI) is a type of scanning method that uses strong magnetic fields and radio waves to produce detailed images of the inner body. The research work carried out earlier used deep neural networks such as CNN and VGG-16 are investigated on MRI images of Brain. Both the models have given effective results, however VGG-16 takes a greater computational time and memory. K-means clustering and FCM clustering, they also proved that the K-means algorithm can detect brain tumors faster than the FCM algorithm, while the FCM algorithm can detect tumors that are not detected by K-means. We proposed to combine K-means clustering with FCM for segmentation. Their experimental results showed that the combination of the two algorithms is more advantageous than the individual algorithms.

RELATED WORK

Region Growing

A technique for extracting an image region that is connected based on some predefined criteria is known as region growing. These criteria can be based on image edges and/or intensity information. In its most basic form, region growing necessitates the manual selection of a seed point by an operator, who then extracts all pixels connected to the initial seed based on predefined criteria. One possible criterion could be to expand the region until it reaches an image edge. Region growing, like Thresholding, is rarely used alone, but rather as part of a set of image-processing operations, especially for the delineation of small, simple structures like tumours and lesions. A simple region-based image segmentation method is region growing. Because it involves the selection of initial seed points, it is also classified as a pixel-based image segmentation method. This method of segmentation looks at the pixels surrounding the initial "seed points" to see if they should be included in the region.

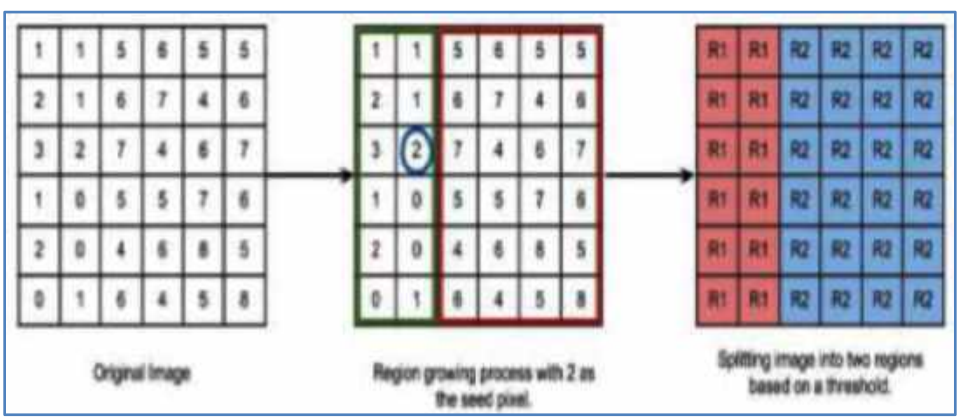

Figure 2 Example of Region Growing Algorithm

Regions' Expansion

The seeded region growing method was the first method of region growth. This technique accepts a set of seeds as well as a picture as input. The seeds are used to identify the objects that will be segmented. By comparing all unallocated surrounding pixels to the regions, the regions are repeatedly enlarged. As a measure of similarity, the difference between a pixel's intensity value and the region's mean is employed. The region with the smallest difference is assigned to the pixel with the smallest difference measured this way. This method is repeated until all pixels have been assigned 20 to a region. The seeds that were determined as input are used to grow the areas, and each one of them has the following information:

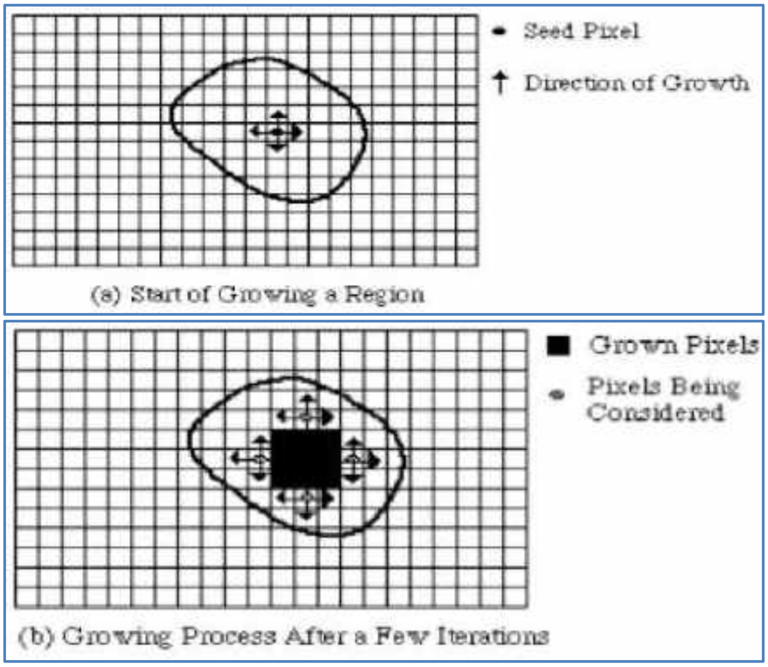

Figure 3 Connected region growing

Region's Growing Disadvantages: The fundamental disadvantage of area growing is that obtaining the seed point necessitates manual intervention. As a result, a seed must be planted for each location that has to be retrieved. Split and merge is a region-growing technique that does not require the use of a seed point. Noise can make region growth sensitive, resulting in holes in extracted regions or even disconnections. Partial- volume effects, on the other hand, can lead different regions to become joined. A hemitropic region- growing approach has been presented to help solve these challenges by preserving the topology between an initial region and an extracted region. There have also been some hazy comparisons to region growth developed.

PROPOSED SOLUTION

In our proposed methodology the whole process is basically divided into 3 major steps:

Step 1: Pre-processing: In this we are preprocessing the original Brain Image which is noisy and applying Median Filtering to obtain a de-noised image by removing the irrelevant information like noise and unwanted background part.

Step 2: Segmentation and Clustering along with feature extraction of the tumour image. K –Means algorithm followed by Fuzzy C Means algorithm is applied to make a Hybrid Clustering Technique.

Step 3: Feature Extraction is done to enhance the image. Three major features are extracted:

Texture features using Gray Level Concurrence Matrix (GLCM), Low level features using Discrete Wavelet Transform (DWT), Color features. Finally based on features and classification the type of disease will be predicted by comparing with the existed database

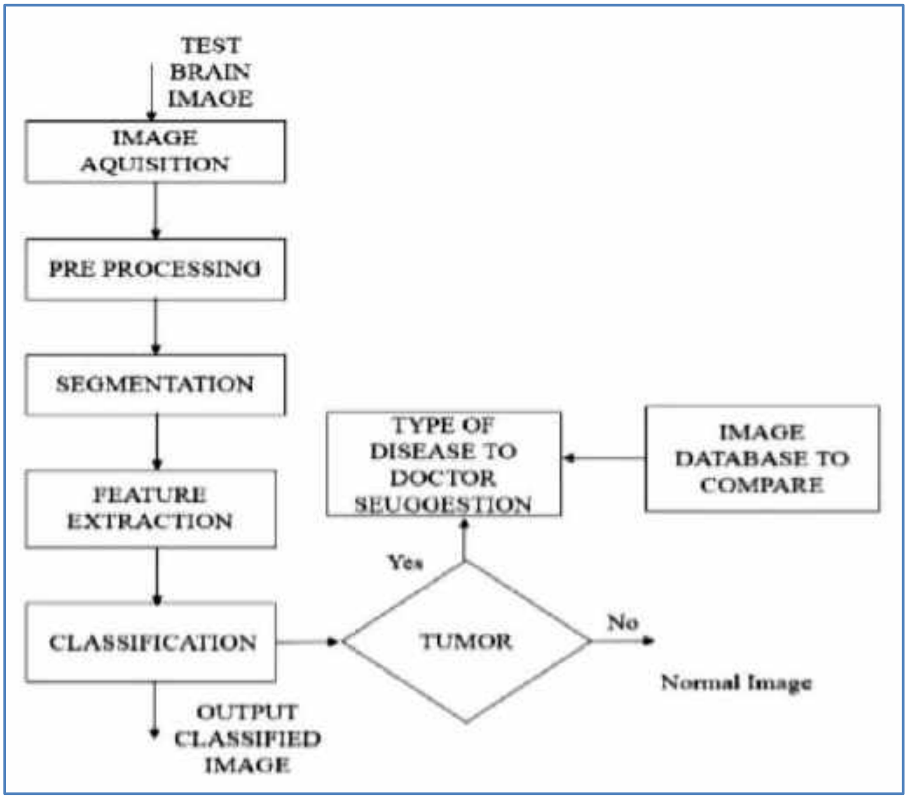

Figure 4 Proposed Methodology.

PROPOSED METHODOLOGY

The MATLAB Application Program Interface (API). This is a library that allows you to write C and Fortran programs that interact with MATLAB. It include facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

Output

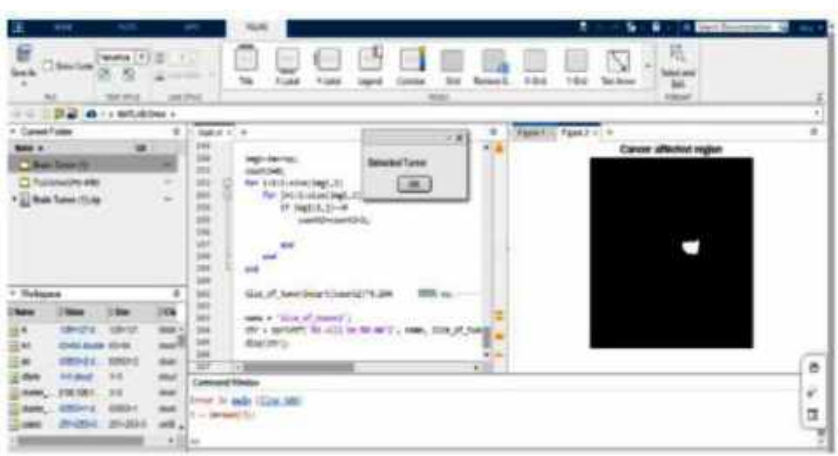

Figure 5 Results Obtained after Clustering procedure on Matlab for sample image 1.

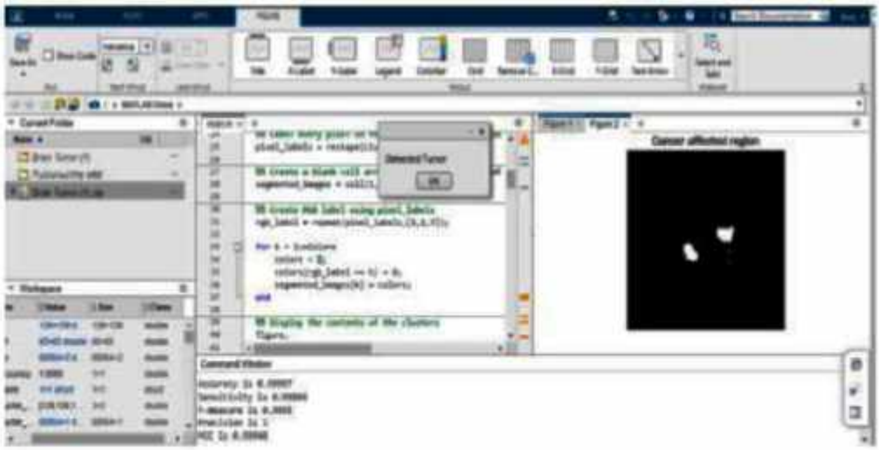

Figure 6 Results obtained after Clustering procedure on Matlab

CPU Computation Time for Different Segmentation Techniques

S. No.	Segmentation algorithm	Computation time (Seconds)			
		Sample Image 1	Sample Image 2	Sample Image 3	Sample Image 4
1	Fuzzy C Means	11.2633	3.4008	2.8348	2.9282
2	K-Means	0.4056	0.5148	0.4572	0.3432
3	Proposed	0.2496	0.2340	0.2712	0.2798

CONCLUSION

Hybrid clustering algorithm combined with feature extraction and classification using PNN model was proposed for segmentation of brain tumor images. The algorithm first uses preprocessing to remove the outer membrane, which reduces the computational complexity and the number of clustering iterations. In the clustering stage, the K-means++ clustering algorithm is exploited to initialize the clusters' centroids. This method solves the problem of unstable clustering, which arises owing to the uncertainty associated with initialization of cluster centroids. Each cluster only produces a stable clustering result. Furthermore, the proposed method prevents overfitting. Next, the algorithm uses fuzzy C-means clustering based on a Gaussian kernel. The sensitivity to clustering parameters is greatly reduced for the proposed algorithm, and the algorithm's robustness is further improved. Finally, median filtering and classification are applied as post processing, which further improves the accuracy of segmentation.

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Web Vulnerability Revelation Using Machine Learning

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Abstract: *The detection of web vulnerabilities is a critical aspect of web application security. In recent years, the use of machine learning algorithms for the detection of web vulnerabilities has gained significant attention. This paper reviews the use of Decision Trees (DT), extreme Gradient Boosting (Boost), Support Vector Machines (SVM), Convolutional Neural Networks (CNN), Multi-Layer Perceptron (MLP), Long Short-Term Memory (LSTM), and Random Forest (RF) for the detection of web vulnerabilities. These machine learning algorithms have been applied to web vulnerability detection, and their strengths and weaknesses are discussed. The results show that all of the algorithms have achieved high accuracy in detecting web vulnerabilities. However, the choice of algorithm will depend on the specific task and data at hand. The use of machine learning algorithms for the detection of web vulnerabilities has the potential to improve the security and resilience of web applications, and it is an area that warrants further research and development as new vulnerabilities, and attack techniques emerge.*

Keywords: *Web Vulnerability, DT, Boost, CNN, LSTM, RF, MLP, SVM*

INTRODUCTION

Internet use has become a necessity in our life in the current digital era. It has completely changed the way we interact, shop, work, and pass our own time. Nonetheless, the hazards and threats that lie in cyberspace go hand in hand with the ease and advantages that the internet offers. Web vulnerability is one of the biggest threats.

Web vulnerabilities are holes and defects in online applications that may be used by hackers to access restricted areas, steal confidential information, system security. These flaws can take on a number of different shapes, including poor input validation, shoddy authentication procedures, Cross-Site Request Forgery (CSRF) assaults, and SQL injection attacks.

Web vulnerabilities may have disastrous repercussions. These holes may be exploited by hackers to obtain sensitive data, including trade secrets, personal information, and credit card information. Moreover, they can utilize the flaws to install malicious software, hijack the machine, or stop the web application from working properly.

Organizations must adopt a strong and thorough security plan that includes web application security testing, patch management, and staff training to address web vulnerabilities. Web applications can have vulnerabilities that can be found through security testing, and patch management helps make sure that any such flaws are quickly repaired. Staff education on recommended practices to prevent online vulnerabilities can assist in increasing knowledge of the risks and hazards connected to them.

Testing for online vulnerabilities is an essential part of web application security. In order to assess a web application's security posture, it entails locating and exploiting vulnerabilities in the program. Web vulnerability testing methods come in a variety of forms, including black-box testing, white-box testing, and grey- box testing. White-box testing entails testing the program with complete access to its source code, whereas black-box testing involves testing the application without any previous knowledge of its internal workings. Black-box and white-box testing components are combined in grey-box testing.

BACKGROUND AND RELATED WORK

A group of researchers [1] has presented an efficient online vulnerability scanner that combines information gathering and vulnerability identification. The vulnerability scanner, which seeks to identify potential vulnerabilities beforehand, is a crucial tool for web security assurance. They have put out a proposal for an automated online vulnerability scanner that combines data gathering and vulnerability detection. The valuable data gathered serves as a guide for the scanner's vulnerability detection. The suggested scanner's goal is to identify any potential vulnerabilities comprehensively and automatically in the target web application. Users must define a specific goal to immediately uncover vulnerabilities or gather relevant data. On a web page, the gathered data as well as the thorough detection findings will be presented.

With an emphasis on SQL injection vulnerabilities, this study attempts [2] to further the state-of-the-art of vulnerability identification in online applications. To categories PHP slices as being susceptible to SQL injection, Ana Fidalgo and colleagues (2020) offer a unique technique utilizing Deep Learning and Natural Language Processing. The team assesses the model using multiple hyperparameter setups for various DL optimizers. Fidalgo and associates deploy DL models that consider the context of each opcode, such as Long Short-Term Memory (LSTM) layers. ML excels at solving issues that people can figure out instinctively but struggle to formalize. By processing the PHP slices in an intermediary language, they hope to categories them as SQLi susceptible or nonvulnerable. The research covered 1362 SQLi test cases. Certain aspects of the authors' findings may offer a challenge to earlier studies in this field: They are frequently used to complete NLP tasks and have been utilized in certain studies to find weaknesses in other languages. But as far as we know, neither PHP code nor opcode were ever processed by them," Fidalgo asserted.

The most prevalent web application [3] security flaws are input validation vulnerabilities, which are sought for by MERLIN. They will contrast the outcomes of this tool with those of existing programmers that find flaws in Java bytecode and source code. Most online apps include vulnerabilities in their source code. Data flow analysis is carried out by MERLIN to find these vulnerabilities. It looks at how information moves via the program's code. They used a set of code samples to train the classifiers and learn about the vulnerabilities. By applying machine learning to identify vulnerabilities in web applications written in various languages, we created a solution to increase web application security.

As part of a system [4] for automatic detection of early cybernetic threats via OSINT, this research provides a model that tries to identify developing cybernetic vulnerabilities in cybersecurity news items. We present a corpus of 1,000 labelled articles on which three machine learning models—Support Vector Machines, Multinomial Naive Bayes, and a tweaked BERT model—were trained to categories cybersecurity articles. As part of a system for automatic detection of early cybernetic risks utilizing OSINT, we provide a prototype system and a robust baseline to identify developing cybernetic vulnerabilities in cybersecurity news stories. Three machine learning models were created using the generated corpus of 1000 articles, and the results look promising. The largest dataset overfitted BERT, which had the best performance.

To confirm that the approach based on CT can find them, Simos, and colleagues [5] suggest that in this article they mostly concentrated on web applications with known vulnerabilities. The authors decided to save this portion of a more thorough analysis of other well-known online apps for further research. The analysis included 31 WAVSEP test cases. Most software project vulnerabilities are caused by command injection attacks. An essential stage in the creation of web applications is filtering and sanitizing user input. Developers frequently overlook the fact that special characters may be utilized in a variety of ways, allowing an attacker to get around security measures already in place. They created a test vector-capable, completely automated vulnerability scanner. The inadequate sanitization of user input is the root cause of the problems discovered during the studies.

This article [6] addresses several forms of SQLIA, investigates existing techniques for detecting Structured Query Language injection, and suggests a ResNet model for doing so. Researchers have created an artificial intelligence (AI) approach to recognize SQL Injection (SQLIA). An attacker attempts to utilize web flaws to insert malicious code, access user data, and more. This assault targets users' personal data by disclosing sensitive information to unauthorized customers, which might cause considerable harm. Traditional detection techniques fall short in identifying various SQLIA types and produce greater false positive and false negative values. Because ResNet model has more layers than other shallow learning algorithms, it is safer. This technique may be applied to a web server to efficiently identify SQLI assaults.

In [7], the stacking ensemble-based classifier model for Cross-site scripting (XSS) attack detection is suggested as a solution to the problems. Moreover, to effectively identify XSS attacks, the stacking ensembles approach is used with other machine learning classification algorithms such as k-Means, Random Forest, and Decision Tree. As a meta-learner, logistic regression is utilized to anticipate the assault more accurately. In contrast to separate models, the stacking model's classification algorithms each examine the issue in their own unique way, and the results are then used as input by the meta-learner to generate the final prediction. This increases the overall detection accuracy of XSS attacks.

The results of the simulation show that the suggested model properly identifies XSS attacks.

In this study [8], we present a clever method for identifying phishing websites. The system functions as an add-on feature to a web browser that sends the user an automated notification when it finds a phishing website. The system is built using supervised learning, a type of machine learning. The Random Forest method was chosen because of its success in categorization. By examining the attributes of phishing websites and selecting the best mix of them to train the classifier, our goal is to develop a classifier that performs at a higher level. As a consequence, we end our paper with a combination of 26 characteristics and an accuracy of 98.8%.

LITERATURE REVIEW

Table 1 Relevant studies on advantages and disadvantages of approaches to identify web vulnerability detection

Related Studies	Advantages	Disadvantages	Methodology
[1]	Once the proposed scanner obtains a specific target, the deeper and comprehensive detection will be constructed, which may lead to an ideal performance.	Only focus on SQL Injection.	Assets collection, Specialized detection, Port scanning and service identification, Comprehensive detection
[2]	DL model for NLP that processes PHP code translated into an intermediate language.	Take longer time for training and require more memory to train.	LSTM
[3]	Developed an application that helps find vulnerabilities in web apps written in different languages, by utilizing machine learning	Need to implement and extend the tool that detect vulnerabilities in Java bytecode.	Code Analysis Module, Vulnerability Detection Module, SVM
[4]	Developed a prototype to address cybersecurity vulnerabilities.	BERT performed best but suffered from overfitting due to the size of the dataset.	SVM, Multinomial Naive Bayes Classifier, BERT model
[5]	Fitness of the approach for both against the vulnerability scanner benchmark WAVSEP and real-world applications with known flaws.	Only focus on SQL Injection.	Combinatorial testing
[6]	Model is designed, programmed and implemented in such a way that it automatically detects all kinds of SQLIA's	Training the model using encrypted dataset to avoid the man in middle attacks while training and testing the model	ResNet
[7]	The proposed model learned the XSS payloads well and detected the attack efficiently than the comparative models.	Doesn't identify cross-site scripting attacks	K-Means, Random Forest and Decision Tree
[8]	Reduce time computation and providing high performance with the least combination of the powerful features.	Anti-phishing extension browser as final features that are used for the extension.	Random Forest

The first study presents an automated online vulnerability scanner that combines information gathering and vulnerability identification using Python. The goal is to comprehensively identify any potential vulnerabilities in a target web application by presenting gathered data and detection findings on a web page. The second study focuses on identifying SQL injection vulnerabilities in PHP slices using a unique technique that combines Deep Learning and Natural Language Processing. The researchers deployed DL models that take into account the context of each opcode, such as LSTM layers, to categorize PHP slices as SQLi susceptible or non-vulnerable. The research covered 1362 SQLi test cases and challenges earlier studies in the field by utilizing NLP tasks for PHP code and opcode processing.

The third study focuses on input validation vulnerabilities, which are the most prevalent web application security flaws, and introduces a tool called MERLIN that uses data flow analysis and machine learning to identify these vulnerabilities in web applications written in various languages. The researchers compare the outcomes of MERLIN with existing programmers that find flaws in Java bytecode and source code. The fourth study presents a model that uses machine learning to identify developing cybernetic vulnerabilities in cybersecurity news items as part of a system for automatic detection of early cybernetic threats via OSINT. The researchers trained three machine learning models (Support Vector Machines, Multinomial Naive Bayes, and a tweaked BERT model) using a corpus of 1,000 labelled articles, and the results look promising, with the largest dataset overfitting the BERT model, which had the best performance. The study provides a prototype system and a robust baseline for identifying developing cybernetic vulnerabilities in cybersecurity news stories.

Simos et al. [5] focused on web applications with known vulnerabilities to confirm that their approach based on CT can find them. Their analysis included 31 WAVSEP test cases and they created a fully automated vulnerability scanner that identified problems caused by inadequate sanitization of user input. On the other hand, the article [6] addresses various types of SQLIA, proposes a ResNet model for detecting them, and explains how this technique can be applied to a web server for effective identification of SQLI attacks. The proposed AI approach aims to prevent SQL Injection, which targets users' personal data and can cause significant damage. In [7], a stacking ensemble based classifier model is proposed to detect Cross-site scripting (XSS) attacks by combining multiple machine learning classification algorithms, resulting in improved detection accuracy. In [8], a method for identifying phishing websites is presented, which uses supervised learning and a Random Forest classifier trained on a combination of 26 attributes to achieve an accuracy of 98.8%. Both studies showcase the effectiveness of machine learning in improving web application security.

METHODOLOGY

1. Data collection: Collect a large dataset of emails or webpages, both legitimate and phishing, that will be used to train and test the machine learning model.

2. Feature engineering: Extract features from webpages that can be used to differentiate between legitimate and phishing messages. Features may include URL length, domain age, presence of certain keywords, and others. Features like ['Index', 'UsingIP', 'LongURL', 'ShortURL', 'Symbol@', 'Redirecting//', 'PrefixSuffix-', 'SubDomains', 'HTTPS', 'DomainRegLen', 'Favicon', 'NonStdPort', 'HTTPSDomainURL', 'RequestURL', 'AnchorURL', 'LinksInScriptTags', 'ServerFormHandler', 'InfoEmail', 'AbnormalURL', 'WebsiteForwarding', 'StatusBarCust', 'DisableRightClick', 'UsingPopupWindow', 'IframeRedirection', 'AgeofDomain', 'DNSRecording', 'WebsiteTraffic', 'PageRank', 'GoogleIndex', 'LinksPointingToPage', 'StatsReport']

3. Model selection: Choose a machine learning algorithm that is well-suited for the problem at hand. Common algorithms include decision trees, random forests, and neural networks.

4. Models Used - Decision Tree, Random Forest, SVM, XGBoost, Multilayer Perceptrons, CNN, LSTM

5. Training: Split the dataset into training and testing sets, and train the model using the training set. The model should be optimized for high accuracy and low false positives.

6. Evaluation: Evaluate the model using the testing set to measure its accuracy, precision, recall, and F1 score.

7. Deployment: Once the model has been trained and tested, it can be deployed in a real-world environment to automatically detect potential phishing attacks using the google chrome extension.

METHODS

Vulnerability detection using machine learning methods has become popular in recent years. The vulnerability detection task is very challenging and motivates us to attempt more efficient approaches. In this paper, we try to use deep learning models to predict the vulnerability. These deep neural networks can learn the relationships between defect, infection and failure. After getting the data, aka the concrete sequential calls to the C standard library, we can refer to the sentiment classification of text where CNNs and LSTM can do well. To gain the best performance for our vulnerability detection task, we have tried a number of different deep learning models, as shown in **Figure 2**.

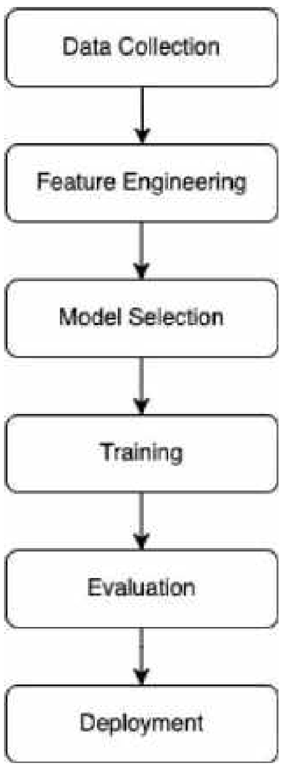

Figure 1 Proposed Methodology

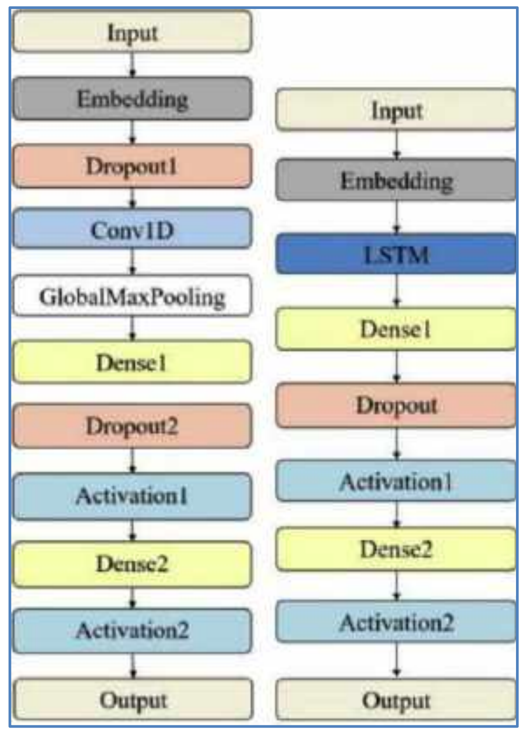

Figure 2 Deep learning models for vulnerability detection, left: CNN model, right : LSTM model

Convolution Neural Network Model

At first, we employ a deep convolutional neural network model. Popular in computer vision, convolutional neural networks are largely responsible for advances in picture segmentation, detection, and classification. Natural language processing (NLP) has lately benefited from the use of CNNs, and the results have been intriguing. Convolutional neural networks function well for classification tasks like sentiment analysis, spam detection, or topic categorization as well as vulnerability detection since they are excellent at learning the spatial structure in input data.

There are various hyperparameters to consider while creating a CNN architecture, including the quantity and size of convolution filters, pooling tactics, activation functions, and more. A phrase with a size of 25 and word embeddings serves as the input layer. Following the embedding layer, we employ dropout technology and retain the dropout rate at 0.5 before adding a one- dimensional convolutional (Conv1D) layer with 32 filters. Our Conv1D's kernel size is set at 3 and its stride to 1. The maximum value is then selected using a global max pooling layer. This preserves the most important data while reducing the dimension. The fully linked layers are the dense layers. A rectified linear unit (ReLU) follows each dense and convolutional layer.

Long Short Term Memory Network Model

Although CNNs perform well in many classification tasks, one of their major flaws is the fixed filter size of their visual area. On the one hand, lengthy sequence information cannot be modelled using this. On the other hand, picking the right filter size parameter might be exceedingly challenging. In contrast to LSTMs, which are more often employed in natural language processing and are better at expressing contextual information, CNNs are simply feature expressions of texts. LSTMs can be interpreted in text classification tasks in a way that captures the long-term and bi-directional information. Our LSTM model's embedded layer, which is the first layer, represents each word with ten length vectors. A dropout layer comes after the second layer, which is an LSTM layer with 32 memory units. Overfitting is typically a concern for the LSTM, however dropout may be used to solve this. Finally, we employ a thick output layer with a sigmoid activation on a single neuron.

CONCLUSION

In conclusion, one crucial component of online application security is the identification of web vulnerabilities. As a result of their success in identifying online vulnerabilities, machine learning algorithms are gaining popularity in thi industry. Seven well-known machine learning methods have been used to the identification of online vulnerabilities: SVM, CNN, MLP, LSTM, XGBoost, DT and RF. The choice of algorithm will rely on the particular job and available data. Each algorithm has strengths and disadvantages. Generally speaking, the implementation of machine learning algorithms for online vulnerability identification has the potential to enhance the security and resilience of web applications, and it is a field that calls for more study and development.

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Enhancing Spam Detection with Machine Learning

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Abstract: *Spam filter system is software system designed to detect and prevent spread of spam email, messages , calls .It collects data on phone numbers, email , and SMS senders from public and private databases and trains a machine learning model. Users can report messages as spam or genuine through crowd sourcing module, improving model's accuracy. The user Spam interface displays risk score and classification label. system learn from user feedback to improve accuracy over time and adapt . The goal is to identify spam messages and reduce phishing attacks and identity theft risks .This solution use machine learning algorithms to identify and classify phone numbers based on previous user reports, and generate a risk score that indicates the likelihood of the phone number being associated with spam or fraudulent activity.*

Keywords: *Spam filter, Machine Learning, Random Forest, Decision tree, User feedback*

INTRODUCTION

Spam filter apps use a variety of techniques to identify and filter spam messages, including analyzing message content, sender information, and message metadata. Spam filters corporate machine learning algorithms to improve their accuracy over time, by learning from patterns in the user's behaviour and feedback.

A spam filter app is a crucial tool that helps users to prevent unwanted and unsolicited messages from cluttering their inbox. These unwanted communications can take the shape of spam emails, text messages, or other digital forms of contact that are intended to promote goods or services, transmit malware, or phish for personal information.

To determine if a message is spam or not, a spam filter app analyses communications and applies a set of pre-established rules or algorithms. Spam filters frequently examine the content of messages, sender information, message metadata, and the reputation of IP addresses. In order to increase their accuracy over time, some sophisticated spam filters also use machine learning algorithms.

Spam filters not only save users time and energy but also protect them from harmful messages that may contain malicious content. They also help in reducing the risk of falling victim to phishing scams or identity theft.

WORKING

Spam alert system is a software system designed to detect and prevent the spread of unsolicited and unwanted messages, also known as spam, in various digital communication channels such as email, SMS and calls. The system uses machine learning algorithms and natural language processing techniques to analyze the content of incoming messages and identify patterns and features commonly associated with spam. When a message is flagged as potential spam, the system can either block it from reaching its intended recipient or move it to a separate folder for further review.

The goal of an abstract spam alert system is to improve the efficiency and security of digital communication by reducing the amount of spam messages that users receive and minimizing the risk of phishing scams and other types of online fraud.

It collects data on phone numbers, email addresses, and SMS senders from public and private databases and trains a machine learning model. Users can report messages as spam or genuine through a crowd sourcing module, improving the model's accuracy. The system assigns a risk score to each message based on the classification and feedback. The user interface displays the risk score and classification label, with customization options. The system continuously improves with retraining and new features.

This solution use machine learning algorithms to identify and classify phone numbers based on previous user reports, and generates a risk score that indicates the likelihood of the phone number being associated with spam or fraudulent activity. Some other features of our App are-

Analytic Dashboard: The app can provide users with a dashboard that shows detailed analytic on their call history, including the number of spam calls received and blocked, the types of calls received, and the time of day when spam calls are most likely to occur.

Caller Reputation Scoring: The app can use a reputation scoring system to evaluate the likelihood that a caller is a spammer; based on factors such as their previous calling behaviour and the number of complaints they have received.

The app can provide multiple blocking modes, such as silent mode or call forwarding, allowing users to choose the best blocking option for their needs.

ALGORITHM

Algorithm for developing a spam call, message, and email alert software:

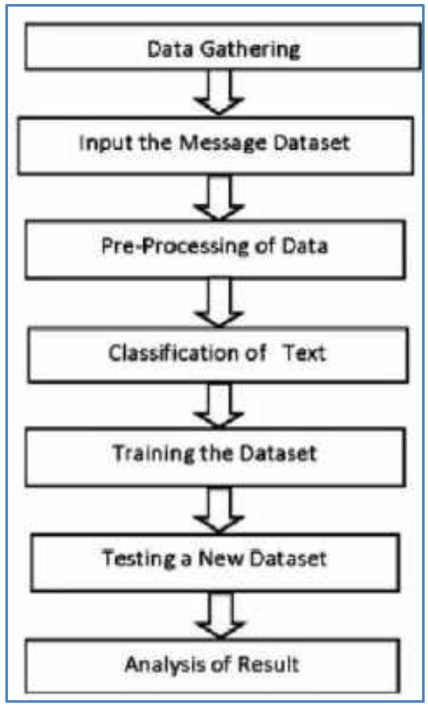
1. Get incoming calls, messages, and emails.
2. Check if the incoming communication is spam using a spam detection tool that can recognize patterns of spam calls, messages, and emails.
3. If the incoming communication is spam, take appropriate action, such as blocking the caller or sender, or marking the communication as spam so that it can be filtered out in the future.
4. Notify the user or network administrator of the spam communication through an alert, such as a pop-up message or email notification.
5. Keep a record of the spam detection results, so that the user or administrator can review and analyze the data later.
6. Repeat the process for all incoming calls, messages, and emails.

MATHEMATICAL ALGORITHM USED

When the software receives a message, it checks if it looks like spam by using a special algorithm that can recognize patterns of spam messages. Decision trees and random forests are two machine learning algorithms that can be used in a spam alert system to help classify incoming messages as either spam or non-spam.

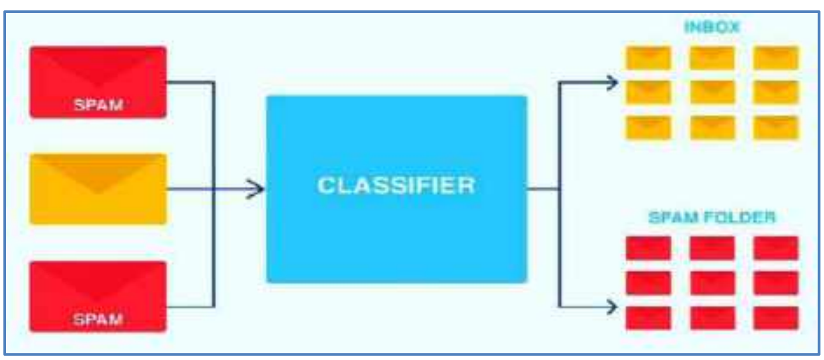
SPAM CLASSIFIER

A machine learning technique known as a spam classifier can be used to automatically recognize and classify incoming messages or communications as either spam or non-spam.



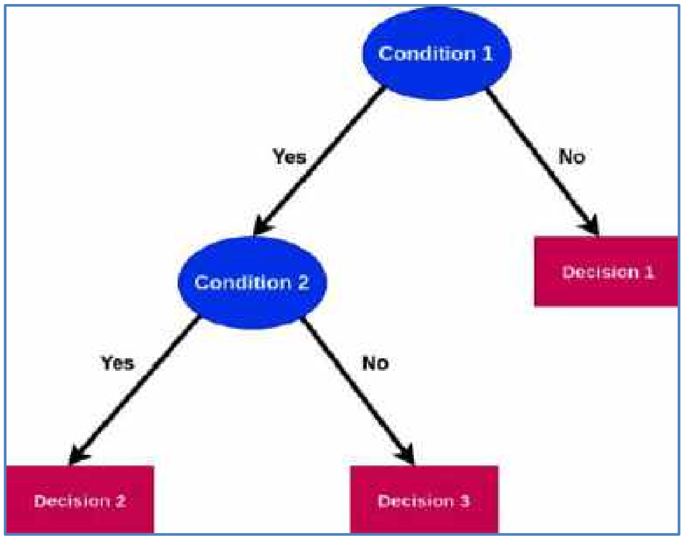
A collection of communications that have been manually classified as spam or not is used to train the classifier. The classifier gains the ability to identify patterns in the data that may be utilized to differentiate between spam and non-spam communications using this data set.

Based on the patterns it has discovered from the training datasets, the classifier can be used to automatically categorize fresh incoming messages as spam or not once it has been trained.



DECISION TREE

A decision tree is a hierarchical model that uses a tree-like structure to represent a set of decisions and their possible consequences. Each node in the tree represents a decision, and the edges that connect the nodes represent the possible outcomes of that decision. In the context of a spam alert system, a decision tree can be trained on a dataset of labeled spam and non-spam messages, using features such as the sender, subject, and content of the message to make decisions about whether the message is spam or not. Decision trees use the CART algorithm (Classification and Regression Trees). In both cases, decisions are based on conditions on any of the features. The internal nodes represent the conditions and the leaf nodes represent the decision based on the conditions.

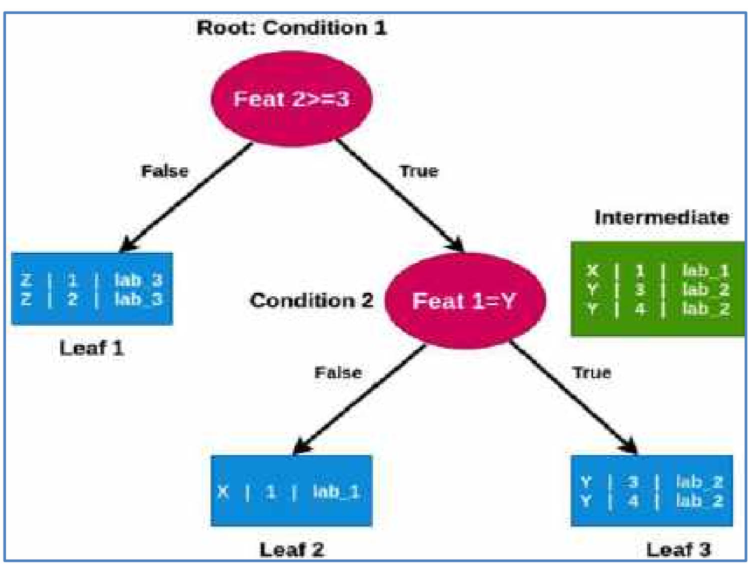


A decision tree is a graphical representation of all possible solutions to a decision based on certain conditions.

Let's see how the idea works.

Feature 1	Feature 2	Label
X	4	lab_1
Y	3	lab_2
Z	1	lab_3
Y	4	lab_2
Z	2	lab_3

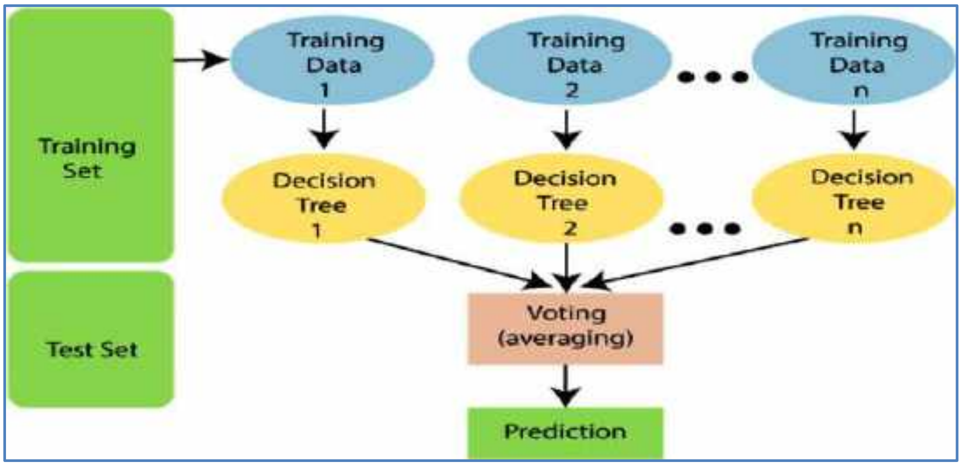
The table given above is our dataset. If we try to analyze the dataset and create a decision tree based on the dataset, we will obtain something like the tree given below.



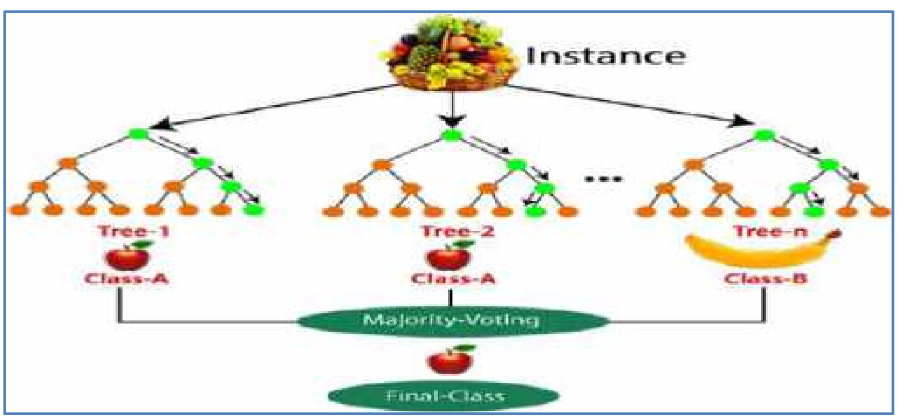
RANDOM FOREST

A random forest is an ensemble learning method that uses multiple decision trees to make predictions. In a random forest, each decision tree is trained on a subset of the features and a subset of the training data. When a new message is received, each decision tree in the random forest makes a prediction about whether the message is spam or not, and the final prediction is based on a majority vote of the individual tree predictions.

OR we can say , Random forest, like its name implies, consists of a large number of individual decision trees that operate as an ensemble Each individual tree in the random forest spits out a class prediction and the class with the most votes becomes model's prediction



Consider the fruit basket as the data as shown in the figure below. Now "n" number of samples is taken from the fruit basket, and an individual decision tree is constructed for each sample. Each decision tree will generate an output, as shown in the figure. The final output is considered based on majority voting. In the below figure, you can see that the majority decision tree gives output as an apple when compared to a banana, so the final output is taken as an apple.



The advantages of using decision trees and random forests in a spam alert system are that they are relatively easy to implement and interpret, can handle a large number of features, and can achieve high accuracy in classification tasks. Additionally, random forests are less prone to over-fitting than individual decision trees, making them more robust and less likely to misclassify messages as spam

How Random forest and Decision tree can be used for spam filter and alert software ?

Random forest and decision tree algorithms can be used in spam filter and alert software to automatically detect and classify incoming messages as either spam or not spam. The algorithms analyze various features of an email or message, such as the sender's address, subject line, content, and other metadata, to determine the probability that it is a spam message.

The general process for using these algorithms is as follows:

Message dataset collection: The first stage is to gather a dataset of messages that have been classified as spam or not. The algorithm that will be used to identify spam messages will be trained using this dataset.

Data cleaning and pre-processing are required to get rid of noise and unimportant information. Stop words may need to be eliminated, words may need to be stemmed or legitimatized, and the text may need to be transformed into a numerical representation.

Create training and testing sets from the data: The data is divided into a training set and a testing set. The algorithm is trained on the training set, and its performance is assessed on the testing set.

Train the algorithm: Using the training set, the algorithm is trained to recognize patterns in the data that distinguish spam messages from non-spam messages. Decision tree and random forest algorithms are trained by creating a set of rules or trees that classify the messages based on their features.

Evaluate the algorithm: The algorithm's performance is evaluated using the testing set. Metrics such as accuracy, precision, and recall can be used to measure the algorithm's performance.

Use the algorithm for spam filtering: Once the algorithm has been trained and evaluated, it can be used for spam filtering. Incoming messages can be classified as spam or not spam based on the patterns the algorithm has learned from the training data.

Best Practices for Effective Spam Filtering :

Optimizing your spam filtering strategies is essential to protecting your personal information and maintaining a secure digital environment.

1. Use popular spam filters
2. Update the software regularly
3. Enable Two Factor Authentication
4. Watch out for links
5. Verify Submission
6. Use a strong password
7. Avoid sharing personal information

Real World Examples of Successful Spam Filters and Alert Systems

Spam filter alert systems have helped to secure communication channels and increase the security of individuals and organizations. Here are some real-world examples and case studies that show how these systems have been successfully used to reduce spam and improve security:

Google Gmail Spam Filter :Gmail, one of the most popular email services, has a powerful spam filter that uses machine learning algorithms to detect and filter spam emails.

Success story: Google announced in 2020 that Gmail's spam filter is able to block more than 99.9% of emails containing spam, phishing and malware. It uses artificial intelligence and user feedback to continuously improve its accuracy, reducing false positives and false negatives.

Microsoft Office 365 Advanced Threat Protection: .Office 365 Advanced Threat Protection (ATP) includes features such as email filtering and anti-phishing mechanisms to protect against advanced threats.

Success Story: A case involving the University of Iowa highlighted how Office 365 ATP effectively blocked phishing emails and provided advanced threat protection. He helped secure email communications for university students and staff.

These real-world examples demonstrate the effectiveness of spam filters and alert systems to reduce spam, prevent phishing attacks, and improve the security of communication channels.

ADVANTAGES

1. Improved Security: Increasing the security of a system or network is one of the spam alert system's most important benefits. A system of this kind may identify and stop unsolicited emails, texts, or other forms of contact that can include malware or phishing links.
2. Cost reductions: Organizations can save money by using spam alert systems to save unnecessary expenditures on hardware, software, and staff that may be required to battle spam.
3. Time-Saving: Spam alert systems help users and IT workers save time by automating the identification and deletion of spam communications. Users won't have to waste time dealing with spam and can instead concentrate on more important things.

Difficulty in Detecting Spam

Spam detection has been a constant battle between spammers and software algorithms designed to block them. Spammers use a variety of advanced techniques to prevent detection and access user mailboxes, and this creates some significant challenges for embedded spam detection systems.

1. Image-based spam: Traditionally, text-based spam was easy to spot because it can be scanned for specific keyword patterns. However, spammers have now switched to image-based spam, where the text of the message is embedded in the image. These images often contain distortions, so spam is difficult to detect with standard content analysis methods.
2. Can send unsolicited voice calls, text messages, telemarketing information or predatory efforts. Detecting voice spam requires voice recognition technology and the ability to analyze call patterns.
3. Advanced Social Engineering: Spammers have become more adept at crafting messages that mimic legitimate effects. Social engineering techniques are used to create persuasive content that makes it difficult for users to distinguish real news from fake news.
4. Accurate identification of these faces is a major challenge.
5. Quickly change tactics: To avoid spam filters, spammers change quickly and their tactics can change daily. Spam detection requires systems to evolve at the same speed
6. Avoiding Machine Learning

To overcome this challenge, spam detection systems must use a combination of techniques such as machine learning, content analysis, sender name search, and user profiles.

CONCLUSION

Spam filter and alert systems have developed into a necessary tool in the current digital era for guaranteeing the security and privacy of communication channels like emails, texts, and phone conversations. To identify and categorize incoming communications as spam or not, these systems use a variety of techniques, such as decision trees and random forests.

The development process for these systems involves several key stages, including requirements gathering, design, implementation, testing, and maintenance. Machine learning algorithms, including those used in decision trees and random forests, play a crucial role in the performance of spam filter and alert systems. These algorithms allow the software to learn and adapt based on new data, continuously improving the accuracy and effectiveness of the system in detecting and blocking spam messages. In conclusion, spam filter and alert systems, including the use of machine learning algorithms, are essential for maintaining the security and integrity of communication channels. The use of agile software development methodology and continuous learning allows these systems to remain effective in the face of new and emerging threats, ensuring safe and secure communication for all users.

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Cognitive Machine Learning for Personality Analysis from Handwriting

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Abstract: *Graphology is a method employed to investigate and assess an individual's personalitycharacteristics by scrutinizing their handwriting styleIt can reveal several facets of a person's personality, including their emotional condition, thought processes, work habits, and social abilities. A number of characteristics of handwritten manuscripts, including letter size, text density, word slant, corner sharpness, and margin forms, must be carefully analyzed for this evaluation. Skilled experts in graphology utilize these characteristics to obtain significant understanding of an individual's personality. Computer-assisted Graphology analysis has become a useful tool in modern times for automatically determining an individual's personality from handwritten materials. The accuracy with which these computer-based techniques can extract and analyze handwriting data to categorize personality traits is a key component of their reliability.To address the existing limitations in computer-aided graphological analysis, this work presents two advanced deep learning models. These models are specifically designed to classify individuals' personalities based on the Big Five personality traits. This novel approach aims to enhance the accuracy and reliability of personality assessments conducted through graphology and computerized analysis. By leveraging the power of deep learning, this research endeavor strives to provide a more robust and dependable method for personality classification based on handwriting analysis, offering greater precision and consistency in understanding individuals' unique traits.*

Keywords*: Graphology, Feature Extraction, Personality Profiling, CNN*

INTRODUCTION

A person's personality is the result of a complex interplay of various characteristics and qualities unique to them. This amalgamation is shaped over time through the development of personal values, attributes, community interactions, life experiences, habits, and skills. One's behaviors and decision-making processes are profoundly influenced by personality traits of an individual [1].

The examination of handwriting can serve as a means to unveil and understand these personality traits. Handwriting, often distinctive to each person, can provide valuable insights into a person's nature, behavior, and certain psychological facets [2]. This field of study is known as graphology or graphoanalysis, where the analysis of handwriting serves as a window into an individual's personality [3].

Graphology is essentially the science of handwriting analysis, utilizing various characteristics such as strokes, features, left and right margins, word spacing, and patterns within handwritten documents to predict an individual's behavior or personality [4]. Through this method, a range of personality traits, including anger, morality, fears, mental well-being, social skills, and work habits, can be inferred and understood through the analysis of one's handwriting [5].

The Big Five personality traits, frequently denoted as the Five Factor Model, represent a widely accepted and influential framework for understanding and assessing human personality within psychology [6]. These five traits are Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism, often abbreviated as OCEAN. They provide a comprehensive and structured way to describe individual differences in personality [7].Openness, the first trait, pertains to a person's inclination toward novel experiences, imagination, and intellectual curiosity [8]. Conscientiousness reflects an individual's level of organization, dependability, and self-discipline [9].

Extraversion characterizes an individual's sociability, assertiveness, and need for social interaction. Agreeableness measures one's level of compassion, cooperation, and the tendency to be empathetic and kind [10]. Neuroticism, the final trait, evaluates emotional stability and the tendency to experience negative emotions such as anxiety and irritability [11]. The Big Five personality traits have been extensively studied and are used in psychology to gain insights into individual differences, understanding how these traits influence behavior, relationships, and various life outcomes. These five traits are considered to be comparatively constant across time, and play a crucial role in our understanding of human personality.

In this work, image processing based feature extraction method is proposed for extracting features of baseline, margins, space between lines and space between words ,connectivity between the letters, slant of the letter, zones of the letter, size of the letter from any handwritten document. Two methods for personality prediction of a handwriting image, an ensemble of fuzzy classifiers and a convolutional neural network (CNN)-based self-adaptive cognitive learning framework are employed.

RELATED WORK

In a study conducted by Amaniet al [12], a solution was proposed for segmenting each line within Arabic handwritten documents. The method utilizes the Hough transform to separate individual lines, and as a subsequent step in the process, vertically connected character segmentation is employed to minimize false positives. This approach effectively handles the challenges posed by variations in skew direction and skew angles within the text.In a different study, Pelliceret al [13] introduced an innovative profile-based technique for line with handwritten document segmentation. They also addressed the correction of skew angles resulting from the scanning of text documents before implementing the profile-based segmentation. The method involves constructing a horizontal projection profile of the text document image based on the binary image's histogram. The projection profile is then applied to the lines to segment them.In another research endeavour described by Jainet al [14], a bottom-up approach to segmenting text lines in Latin handwritten documents was proposed. This approach combines image morphology, feature extraction, and a Gaussian mixture model for effective line segmentation, even in documents with overlapping words. Skew correction is achieved by assessing the standard deviation of the projection profile. Subsequently, stroke features and significant points (including minima points, maxima points, junction points, and pen-lift points) are extracted from the skew-corrected image. Character segmentation is achieved using the Watershed model by Kavithaet al[15].Furthermore, Amarnathet al [16] documented recent methods for segmenting lines, words, and characters in handwritten documents. The study considers various line segmentation techniques, including horizontal projection, region growth methods, probability density, and the level set method. Multi-level classifiers are discussed as a means of locating word boundaries, while template matching is explored as a method for character segmentation. Tang et al. [17] used Fisher Score for linear discriminant analysis, with the goal of selecting highly discriminative features with low redundancy by calculating the ratio of "intra-class" to "inter-class" data scatter.In supervised, unsupervised, and semi-supervised learning tasks, various feature selection methods, such as filter, wrapper, hybrid, and spectral graph-based approaches, have been developed and applied. These methods improve the efficiency and accuracy of data analysis and classification.Using the Minnesota Multiphasic Personality Inventory (MMPI), Fallah et al. [18] used text-independent features such as margins, character sizes, line spaces, word spaces, tilts, and vertical character ratios to determine personality traits. Their neural network had an accuracy rate of about 70%. However, the MMPI scale's limitations and obsolescence limit its effectiveness in personality assessment.Using the Minnesota Multiphasic Personality Inventory (MMPI), Fallah et al. [18] used text-independent features such as margins, character sizes, line spaces, word spaces, tilts, and vertical character ratios to determine personality traits. Their neural network had an accuracy rate of about 70%. However, the MMPI scale's limitations and obsolescence limit its effectiveness in personality assessment. Gavrilescu et al. [19] introduced a three-layer neural network architecture for analyzing disconnected handwriting and linking Big Five personality traits to handwriting characteristics. Their study used predefined and spontaneous handwriting samples, achieving an accuracy rate of 84.4% in intra-subject tests and 80.5% in inter-subject tests. Notably, it demonstrated high predictive accuracy for Openness to Experience, Extraversion, and Neuroticism (over 84%) and 77% accuracy for Conscientiousness and Agreeableness.Graphology finds applications in diverse fields like psychology, employment, education, medicine, criminal detection, and recruitment [20]. The primary objective is to understand a person's personality, utilizing various analysis methods such as Rule-Based systems, Back propagation neural networks, Simple Linear Regression methods, Support Vector Machines, Multi-Structure algorithms, and Artificial Neural networks.

PROPOSED METHODS

The following methodological stages are included in the work:

1. Preprocessing of the created dataset and input samples.
2. Extraction of feature traits.
3. Classification of feature traits.

Dataset

750 pages of handwriting samples were collected from university undergraduate students who wrote essays on A4 sheets. The graphology institute also provided us with 200 pages of handwriting. Graphology lacks a standard dataset for predicting personalities, as each letter can provide multiple personality analyses, given its various possible traits.

Preprocessing

During this stage, the image undergoes preprocessing to eliminate noise and enhance image contrast. The specific preprocessing steps can be found in **Figure 1**. Before commencing feature extraction, the image requires preprocessing through the application of techniques such as normalization, binarization, orientation adjustment, and morphological operations. These steps are necessary to prepare the image for segmentation and feature extraction, with a particular focus on baseline feature extraction.

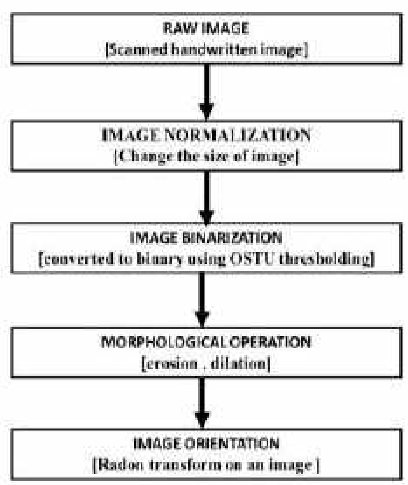

Figure 1 Preprocessing steps of a handwritten image.

Feature Extraction

In graphology, a handwritten page is frequently used as the "individual universe," a rich source of insights into the writer. The spacing between words, as well as the overall writing pattern, reveal important information about a person's personality [21]. This research focuses on identifying and analyzing two distinct levels of handwriting features: document-level features and character-level features.

Baseline

The line that a person follows when writing on a blank sheet is known as the baseline, also referred to as the "line of reality." Serving as an indicator of attitude, moral and social control, nature, temperament, and adaptability, the baseline represents a significant aspect of personality adjustment. The SOB_Convex_Concave algorithm (**Algorithm 1**) is employed to detect six different classes of the baseline.

```
Algorithm 1 : SOB_Convex_concave
Input: Pre-processed text image (Pimg)
Output: Shape of Baseline

  1.[The handwritten image is divided vertically into 5 segments based on the thresholds set]
          Div1, Div2, Div3, Div4, Div5
  2.[For each division store the row values of the edge intensities of Pimg]
          if Pimg[i][j] == 255
             append i to PIn
  3.[Find the median of each intensity array PIn]
          Mn ← median(PIn)
  4.[Comparison of the median values]
        if difference(M1, M3, M5) < threshold
          B-shape=Level
        if M1>M3 and M3>M5
          B-shape=Ascending
        if M1<M3 and M3<M5
          B-shape=Descending
        if M1>M3 and M3<M5
          B-shape=Convex
        if M1<M3 and M3>M5
          B-shape=Concave
  5.[Return the shape of Baseline]
      return(B-shape)
```

Margin Feature Extraction

The page's margins consist of the blank spaces on the left, right, top, and bottom. The left side signifies the past, where the writer begins, while the right side represents future goals. Page placement also reflects a person's taste, social and cultural inclinations, and artistic preferences. Additionally, margins reveal unconscious attitudes towards space and provide insights into a person's self-esteem and interpersonal behavior. To determine the margin coordinates for each line, we propose the Margin algorithm (**Algorithm 2**), which identifies the left, right, top, and bottom margins.

```
Algorithm 2: Margin
Input: Preprocessed Images (Pimg)
Output: Arrays containing the coordinate valued of left margin, right margin, top margin, down margin

  1.  Consider arrays to store left coordinates, right coordinates, upper coordinates, lower
      coordinates L[ ],R[ ],T[ ],D[ ].
  2.  Scan each row of Pimg from left to right
        for i = 1 to row
          for j = 1 to col
            if(Pimg[i][j] == 255)
              L[ ]=j
   3.Scan each row of Pimg from right to left
            for i = 1 to row
              for j = col to 1
                if(Pimg[i][j] == 255)
                  R[ ]=j
   4.Scan each column of Pimg from top to down
            for i = 1 to col
              for j = 1 to row
                if(Pimg[i][j] == 255)
                  T[ ]=j
   5.Scan each column of Pimg from down to top
            for i = 1 to col
              for j = row to 1
                if(Pimg[i][j] == 255)
                  D[ ]=j
```

Space Between Lines

The way writer place two lines indicates the writers planning and organizing ability. Maintaining proper distance between the lines necessitates some planning and organizational skills. This paper proposes three different algorithms for extracting the line spacing feature,

1. Projection method
2. Pixel method
3. Mask method

In this paper, a projection method (**Algorithm 3** - SOL_Proj) is proposed to extract the line spacing feature. The preprocessed image is horizontally projected, and the space between the lines is extracted. The average value of the space is computed. This value is used to represent the space between lines in the given document.

Algorithm 3: SOL_Proj
Input: Preprocessed image (Pimg)
Output: average space between the lines

```
1. Find the horizontal projection by scanning each line
        for i = 1...col
            if(Pimg[i][j] == 1)
                sum_init[i] = sum_init[i] + 1
2.Compute the zero length intensities
    if(sum_init[i] > 1) and (sum_init [i + 1] == 0)
            ranges[count] = i
        else if(sum_init[i] == 0) and (sum_init[i + 1] > 0)
                ranges1[count] = i
3.Find the space between lines
      for i from 1 to count
          space[i] = ranges[i] – ranges1[i]
```

$$space\_bet\_lines = \sum_{i=0}^{count} space_i / count$$

Pixel method (**Algorithm 4** - SOL_Pixel) scans each row of pixels of the preprocessed image. Sum of pixel, of intensity equal to 1 is calculated and stored. The rows having sum equal to zeros are considered as space between lines. Average value of the space is calculated. This value is considered as space between lines for the given document

Algorithm 4: SOL_Pixel (Pimg)
Input: Preprocessed image (Pimg)
Output: average space between the lines

```
 1.Scan each row of the processed image.

 2.Compute the sum of pixels with intensity equal to 1 and store in an array sum.
      for j = 1 to col
              if(Pimg[i][j] == 1)
                  count +=1
 3.Check for rows having pixel count > δ and store the upper and lower index values.
          if((count > δ) and (flag == true))
                  upper[outc] = i
          if(count < δ)
                  lower[outc] = i
4. Find the space between lines
     for i = 1 to outc
          space[i] = lower[i] – upper[i+1]
```

$$space\_bet\_lines = \sum_{i=0}^{outc} space_i / outc$$

Mask method (**Algorithm 5**- SOL_Mask) is a new approach to extract the space between the lines. It takes the horizontal projection as an input. The algorithm masks all the values below the threshold level.

```
Algorithm 5: SOL_mask (sum_init)

1. Find the threshold value

ō = (maxvalue(hpp) - minvalue(hpp)) / 8

2. Consider an array mask to store the index values to be masked

        for i from 1 to row
            if hpp [i] < ō
                mask [pout] = i

3. For each row in mask array, mask all the columns of pre-processed image.

    for j = 1 to col
        Pimg[row_index][j] = 0
```

Space between Words

The spacing between words tells more about the distance the writer puts between himself and others in a social environment. Each word represents the ego of the writer in a social environment. Three different algorithms are proposed in this work for finding the spacing between the words.

1. Projection method
2. Contour method
3. Contour method with Hough transform

Projection method (Algorithm 6:SOW_Proj) finds the vertical projection by scanning each column and from the intensity distribution over vertical projection finds the space between the words.

```
Algorithm 6: SOW_Proj(line_ img)
Input : line_img
Output: average space between words

1. Find the vertical projection by scanning each column

    for j = 1 to r
        if(line_img[i][j] == 1)
            sum_init[i] = sum_init[i] + 1

2.Compute the zero length intensities

    if(sum_init[i] > 1) and (sum_init [i + 1] == 0)
            ranges[count] = i
        else if(sum_init[i] == 0) and (sum_init[i + 1] > 0)
            ranges1[count] = i

3.Find the space between words

    for i from 1 to count
        space[i] = ranges[i] – ranges1[i]
```

$$space\_bet\_words = \sum_{i=0}^{count} space_i / count$$

Contour method (**Algorithm 7**:SOW_Con) extracts the coordinates of the bounding box. The space between each box is calculated. Average value of the space is calculated. This value is considered as space between the words for the given line.

Algorithm 7: SOW_Con
Input: (line_img)
Output: average space between words

1. *Extracting the coordinates of the boundary bounding box of each word.*

   (x,y) ← top-left corner of the word
   w ← width of bounding box
   h ← height of bounding box
   count ← number of words

2. *Compute the beginning and end co-ordinates of every word.*

   F[] ← y
   L[] ← y + w

3. *Compute the empty space between the words*

   for i = 1 to count
   space = L[i+1] −F[i]

4. *Space between the words*

$$space\_bet\_words = \sum_{i=0}^{outc} space_i / outc$$

Contour method with Hough transform (**Algorithm 8**:SOW_Hov) algorithm is an improved approach of the contour method. The space between the letters of the words is joined with Hough lines, so as to give the contour of the complete word.

Algorithm 8: Sow_hov (line img)
Input: Text line image
Output: Text line image with improved edges

1. *Consider δ_1 and δ_2 as the threshold values*

   δ_1 *= min_length_line*

   δ_2 *= max_gap_between_line*

1. *Perform canny edge detection*
2. *Map the edgepoints to the Hough Space and start in an accumulator*
3. *Draw a line if both δ_1 and δ_2 are satisfied.*
4. *Return (Hough_line_image)*

Connectivity between Letter

The space between the letters shows us how the writer relates with people around him individually. For example, how much personal time, money, energy, or any other resource does the writer give to others or require for himself. It informs us how a writer relates to something outside his environment.

Algorithm 9: SOL_Con_Not(wordimg) Input: Text word image Output: Space between letters *1. Using bouary bounding box for each letter extract the coordinate* *(x,y) ← top-left corner of the word* *W ← width of bounding box* *H ← height of bounding box* *count ← number of letters* *2. Store the beginning and ending co-ordinates of each letters* *f[] ← y* *L[] ← y + w* *3. Find the empty space* *for i = 1 to count* *space = L[i] – f[i+1]* *end for* *4. If space is less than the threshold value* *Connected* *Else* *Not Connected*

Letter Slant Feature

The slant of the letter is the inclination of letters in the handwriting. Slants indicate the emotional level of the person. For example, when writing is towards the right, the person thinks to wither the heart. While the right slant indicates, the person is controlled with the head.

Algorithm10: Slant of letter(lettering) Input: Text word image Output: Slant of letter *1. For each letter, draw the minimum rectangle box .* *2. Calculate the angle between the letter's vertical axis and the main axis.* *3. Calculate the average slant angle (avg_angle) for the entire document.* *a. If 95 >= avg_angle>= 85, the writer handwriting is vertical.* *b. If avg_angle< 85, the writer handwriting is inclined towards right.* *If avg_angle> 95, the writer handwriting is inclined towards left.*

Dominating Zone of Letter

The letters are written in three zones. The middle zone MZ, upper zone UZ and the lower zone LZ sample handwriting we can understand the way zones are divided. The upper zone is called the philosophical zone. This zone tells us about the philosophical ideals of the person, spiritual and religious thoughts, and abstract thinking.

Algorithm 11: Zone of letter(wording)

Input: Text word image

Output: Dominating Zone of letter

1. *For each letter, calculate the bounding rectangle.*
2. *Split it into three equal zones horizontally: upper(UZ), middle(MZ), and lower(LZ).*
3. *For each zone, calculate the proportion of pixels (black pixels) in the zone relative to the total pixels in the entire bounding rectangle.*
4. *Determine the dominating zone for each letter by selecting the zone with the highest proportion of pixels.*

Classification

Machine learning classifiers are trained in two categories of cognitive neural network and ensemble fusion based classifiers to predict the big five personality labels. The approaches are as in **Table 1**.

Table1 Solution differences

Attributes	Cognitive Neural Network Solution	Ensemble Fusion Solution
Extracted Features	Baseline, Margin, Line spacing, word spacing, t patterns, I pattern	Baseline, Margin, Line spacing, word spacing, 't' patterns, 'i' pattern, slant of character, zonal presence of character, connectivity of letter
Feature Selection	Mutual Entropy	Clustering analysis
Classifier	Cognitive Neural Network	Ensemble of Fuzzy classifier
Output	Dominating Big Five Classifier	Score for personality of each classifier

The cognitive learning neural network presented in this study aims to address the challenge of mapping graphology features to the Big Five personality model while enhancing accuracy for various handwriting patterns. Feature engineering plays a central role, with features extracted at two levels: the document and individual character levels. Through a statistical correlation test, features with significant influence on the Big Five personality traits are identified and encoded into a binary feature vector. Subsequently, a cognitive artificial neural network is trained to classify the binary feature word vector into Big Five personality traits.

This personality classification system introduces several noteworthy innovations. Firstly, it employs a novel two-stage feature engineering approach, which encompasses both document-level and character-level features, effectively selecting highly relevant features for Big Five personality classification. Secondly, it incorporates a feedback-based adaptive cognitive artificial neural network classifier, optimized with Hinge loss feedback control, to classify the Big Five personality traits using the features selected in the two-stage feature engineering process. Thirdly, the study proposes a unique adaptation to the convolution operation known as Differences-Magnifier (DM), which significantly enhances pattern recognition accuracy. The DM convolution amplifies significant areas for patterns, providing greater attention to subtle regions that influence character recognition.

To facilitate dominant Big Five personality trait classification, a binary feature encoding is created from a selected subset of features and provided to the trained cognitive neural network model. Error loss functions are utilized for loop control, aimed at enhancing prediction accuracy. The study also presents a Receiver Operating Characteristic (ROC) curve, as shown in **Figure 2**, comparing the solutions. A higher ROC value indicates greater classifier sensitivity. Notably, the proposed solution boasts an ROC area of 0.907, signifying an improvement over existing solutions.

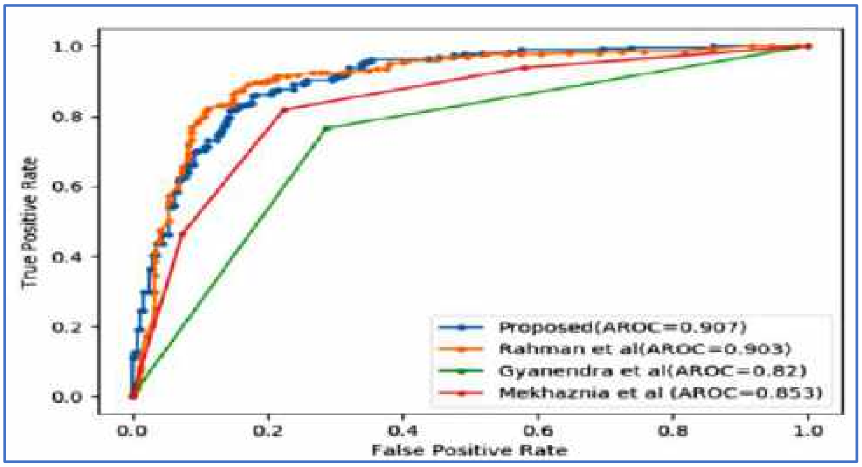

Figure 2 ROC plot

The proposed ensemble learning-based analysis, which seeks to correlate graphology with the Big Five personality traits, involves three pivotal functionalities: feature extraction, clustering analysis, and fuzzy modeling. In addition to handcrafted features, this study introduces a novel deep learning feature extracted at the document level from handwritten document images. The Fisher vector-based Convolutional Neural Network (FV-CNN) is employed to extract these deep learning features, a departure from the typical CNN approach where features are extracted from the last pooling layers. Unlike conventional convolutional filter responses, FV-CNN features excel at efficiently describing input images and eliminate the need for input image rescaling. The choice of Resnet 50 as the CNN model in this work further addresses the challenge of vanishing gradients due to the higher number of layers in deep CNN. Resnet's skip connection strategy increases feature learning ability, ultimately maximizing the effectiveness of the deep network.

The clustering analysis aims to identify the best set of features most relevant to specific Big Five personality classes. Various feature combinations are ensembled and subjected to clustering for handwritten documents at different scales within each personality class. The clusters are assessed based on a weighted fitness score, considering cohesion, separation, and silhouette coefficient. The feature combination yielding the highest fitness score within its cluster is considered highly relevant to that particular personality class. These features encompass baseline (F1), margin (F2), space between lines (F3), space between words (F4), slant (F5), zone (F6), connectivity (F7), size height (F8), and size width (F9). This approach allows for the selection of the most informative features for each specific Big Five personality trait as in **Table 2**.

Table 1 Feature to Personality Correlation

Personality type	Feature combination
Openness	F4 + F5 + F8+F9
Conscientiousness	F3+F6+F7+F8+F9
Extraversion	F4 + F7 + F8+F9
Agreeableness	F1+F2+ F3 + F8
Neuroticism	F2+F5+F6+ F7 + F8+F9

In the earlier section, we identified a relevant set of features for each personality trait, but we need to establish how these features relate to the scores for each personality trait. To do this, we utilize a fuzzy model. We create a training dataset that includes the feature combinations and the corresponding personality scores. This dataset is then used to establish the connection between features and personality scores through Fuzzy C Means clustering with the number of clusters being denoted as P. This allows us to better understand the relationship between the identified features and the personality scores

RESULTS

After collecting the data, the performance of the personality prediction model was assessed to determine its accuracy for each of the five personality types, as well as its sensitivity and specificity. This evaluation involved comparing the model's performance with personality detection methods proposed by Lokhande et al [24], Gavrilescu et al [25], Rahman et al [26], Mekhaznia et al [27], and Chaubey Arjaria [5].

Accuracy, as depicted in **Figure 3**, measures how often the model makes correct predictions. Simultaneously, sensitivity and specificity, as represented in the **Figure 4** and **Figure 5**, gauge the model's ability to correctly identify true positive and true negative results, respectively. To evaluate accuracy, the model was tested on a distinct set of handwritten images that were not part of the original dataset. The model's predictions for each Big Five personality type were compared to the scores from psychometric tests, and the percentage of correct predictions was calculated for each personality type. The selected studies for comparison were the most recent ones focusing on Big Five personality classification from handwritten documents. This rigorous comparison helps to assess the effectiveness of the model in relation to other contemporary approaches

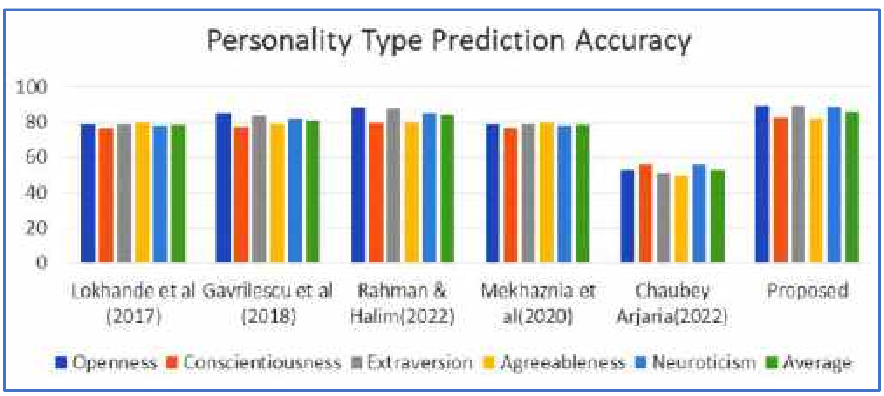

Figure 3 Comparison of Average Accuracy

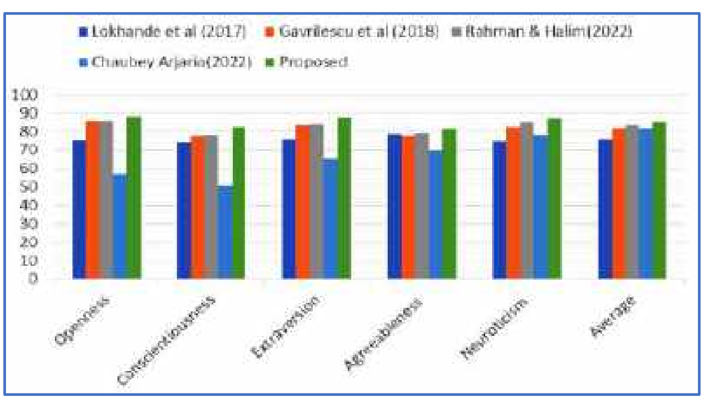

Figure 4 Comparison of Average Sensitivity

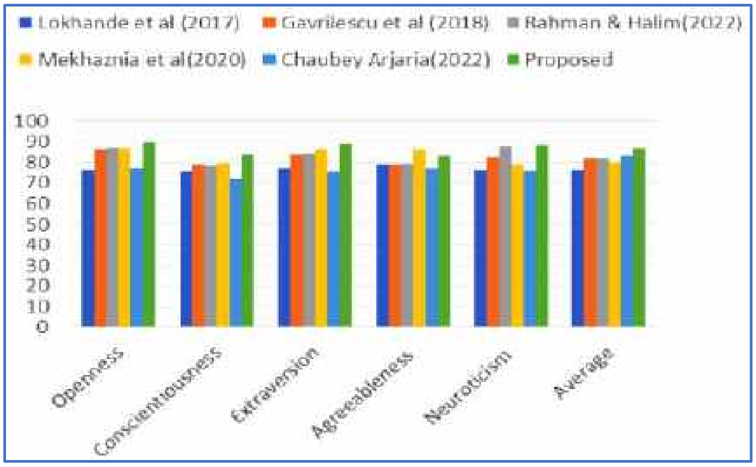

Figure 5 Comparison of Average Specificity

CONCLUSION

This work introduced a total of eight feature extraction algorithms: one each for baseline and margin features, and three each for line spacing and word spacing. The margin feature algorithm provides 100% accurate shapes, while the baseline feature algorithm yields a 90% match. For line spacing, three diverse algorithms were implemented: pixel approach, horizontal projection, and mask algorithm extension. In the case of word spacing, three methods were employed: Pixel approach, basic contour, and Hough_contour. Applying the Hough transform to handwritten images enhanced contour method results, achieving a 90% match. Two classification solutions were proposed. The first employs a self-adaptive cognitive neural network to classify the dominant Big Five personality traits from handwritten documents, while the second involves an ensemble of fuzzy models to assign scores to each of the Big Five personality traits instead of identifying the dominant one.

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Fake News Detection using Machine Learning: Where Technology Meets Truth in a World of Misinformation

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***Abstract**: The propagation of incorrect information in the current day seriously jeopardises the impartiality of public opinion and knowledge. Machine learning algorithms were developed in response to this pressing concern in order to automate the increasingly challenging task of detecting fake news. In response to this urgent need, we offer a machine learning-based method for the automatic detection of bogus news. This innovative approach seeks to both rebuild people' trust in journalism and the media and give them the tools they need to distinguish between factual and false information. Furthermore, locating and exposing the origins of inaccurate and misleading information could be made possible in large part by our technological advancements. This in turn strengthens the ongoing struggle against online deception and propaganda. Our methodology is based on an extensive dataset of news stories that have been painstakingly classified as true or fraudulent based on their content. Support Vector Machines (SVM), Random Forest, and Logistic Regression are just a few of the machine learning algorithms we used to train models that identify news stories remarkably accurately. The outcomes of our trials demonstrate the effectiveness of machine learning methods for spotting fake news, with the Random Forest algorithm coming out on top with an accuracy rate of more than 92%. Additionally, our investigation explores the significance of several characteristics in spotting false news, highlighting crucial clues like the overuse of exclamation points and the predominance of emotive language. In conclusion, our research presents a solid framework for the crucial task of utilising machine learning to detect fake news, offering a glimmer of hope in the fight for truth and information integrity.*

***Keywords**: Support Vector Machines (SVM), Random Forest, Logistic Regression, Fake News, Machine Learning Methods*

INTRODUCTION

People are choosing to search for and read news from social media platforms rather than from traditional news sources as a result of the fact that we spend more and more time interacting online via these platforms.Compared to traditional media outlets like television or newspapers, news on social media is frequently more affordable and available sooner. It's also easier to discuss and debate the news with friends and other readers on social media. For instance, 62% of American adults in 2016 compared to 49% in 2012 sourced their news from social media. Additionally, it was discovered that social media currently outperforms television as the primary news source.

Social media stories are of lower quality than those from traditional news organisations, despite the platform's benefits. However, because it's cheaper to produce news online and much quicker and simpler to distribute through social media, a lot of fake news—that is, news articles with intentionally inaccurate content—is created online for a variety of reasons, including financial and political gain.

Over a million tweets were allegedly linked to the "Pizzagate" fake news controversy by the time the presidential election concluded. The Macquarie dictionary named fake news the word of the year in 2016 because of how popular this new phenomenon has become. Fake news can seriously harm individuals and society when it is widely disseminated. First, the delicate balance of authenticity in the ecosystem can be upset by fake news. For example, it is evident that the most popular fake news on Facebook spread even more than the most widely accepted legitimate mainstream news during the 2016 US presidential election. Second, false information is purposefully used to influence readers to take biassed or incorrect positions. Fake news is a common tool used by propagandists to spread false information or influence politics.. For example, some reports claim that social media bots and phoney accounts have been developed in Russia. Third, people's perceptions and responses to real news are influenced by fake news. For instance, some fake news was merely created to sow doubt and confusion in people's minds, making it more difficult for them to distinguish between fact and fiction. to help lessen the negative effects of fake news (so that the news ecosystem and the public can benefit from it). We need to create instruments that can spot false information on social media platforms very quickly [3].

Accessing news information is now much simpler and more convenient thanks to the internet and social media [2]. Online buyers can frequently stay up to date on events that catch their attention, and the growing popularity of mobile devices has made this process much easier. However, enormous challenges often accompany great opportunities. Owing to the mass media's frequent influence on society, some individuals wish to profit from this. The media occasionally manipulates facts in a number of ways to serve particular agendas.As a result, news stories are produced that are either entirely untrue or only partially accurate. There are still more websites that generate fake news almost entirely.

They regularly use social media to boost their online presence and impact. They deliberately create lies, incomplete truths, propaganda, and misinformation that passes for news. The main goal of most fake news websites is to sway public opinion on particular issues, mostly political ones. Numerous other countries, such as China, Germany, Ukraine, and the United States, also have examples of these websites [4].

Thus, disinformation could be considered both a worldwide issue and a global challenge. AI and machine learning are viewed by many scientists as potential solutions to the fake news issue [5]. There's a reason for this: more affordable technology and bigger datasets have allowed AI algorithms to perform noticeably better lately on a variety of classification tasks (voice recognition, image recognition, and so forth). Automatic deception detection has been the subject of several significant articles. The authors of [6] provide a comprehensive overview of the approaches being used to deal with the problem at hand. The authors of [7] describe how they found fake news, supported by user comments on the particular stories in the microblogs. With the help of support vector machines and the Naive Bayes classifier—a technique also employed in the system covered in this paper—the authors of [8] actually develop two fraud detection systems. They ask respondents directly whether statements about friendship, abortion, and execution are true or false in order to collect the data.

The system's detection accuracy is roughly 70%. The study aims to support (or challenge) the idea of using AI for false news identification by examining how well these specific algorithms perform for this particular problem using a manually annotated news dataset. This article is unique from others on the same topics because it makes use of logistic regression, particularly to detect misleading data.

Moreover, the developed system was tested with a set of relatively recent data, offering a chance to assess its performance with current data. A. Grammar mistakes are one of the primary traits of fake news. They frequently have an emotional tint. Usually, they try to influence readers' thoughts on specific subjects. Their information isn't always accurate. Typically, they employ clickbait, attention-grabbing language, and news formats. They are wholly unrealistic. Generally speaking, their sources are untrustworthy [9].

WARS DUE TO FAKE NEWS

The USS Maine's sinking in Havana Harbour served as the catalyst for the Spanish-American War (1898):

- The role of fake news: Public support for war was bolstered by "yellow journalism," which was published in publications such as William Randolph Hearst's New York Journal and included fabricated and exaggerated accounts of Spanish atrocities in Cuba.
- Result: Following the United States' declaration of war against Spain, Spanish colonies such as Puerto Rico and the Philippines were acquired by the United States.

Gulf of Tonkin Incident (1964):

- Trigger: North Vietnamese torpedo boat attacks on the USS Maddox.
- Role of fake news: The Johnson administration inflated the severity of the incident and misled the public, claiming two unprovoked attacks, to justify escalating the Vietnam War.
- Outcome: The Gulf of Tonkin Resolution granted the President broad authority to wage war in Vietnam, leading to a protracted and devastating conflict.

Iraq War (2003):

- Trigger: The alleged presence of weapons of mass destruction (WMDs) in Iraq.
- Role of fake news: The Bush administration and intelligence agencies presented false and misleading information about Iraq's WMD program to garner public support for the war.
- Outcome: The United States invaded Iraq, leading to the overthrow of Saddam Hussein's regime and a long-lasting war with widespread civilian casualties.

Russo-Ukrainian War (2022):

- Trigger: Russia's invasion of Ukraine, citing alleged threats from NATO and claims of Ukrainian aggression.
- Role of fake news: Both sides have engaged in disinformation campaigns, spreading false narratives to mobilize their populations and discredit the other.
- Outcome: Ongoing war with devastating consequences, including thousands of casualties and a humanitarian crisis.

EXISTING SOLUTIONS

There are a number of solutions out there that are frequently used to identify fake news. Here, a few of them are talked about:

1. Natural Language Processing (NLP): NLP is used to examine news article text and find any irregularities or patterns that might point to the fabrication of an article.
2. Machine Learning (ML): To find patterns frequently found in false news reports, ML algorithms are used to evaluate sizable datasets of news articles.
3. Network Analysis: Network analysis looks at the social networks and online communities where news articles are shared in order to determine their credibility.
4. Fact-Checking: Fact-checking involves verifying information presented in a news article by cross-referencing it with other sources.
5. Metadata Analysis: Metadata analysis involves analyzing the metadata associated with news articles, such as the date and time of publication, to determine whether they are likely to be genuine or fake.
6. Source verification: Verifying the source of a news story can be an effective way to detect fake news. This involves checking the credibility of the news outlet that published the story and looking for corroborating evidence from other sources.

REQUIRED UPDATES AND IMPROVEMENTS

In the upcoming years, we may anticipate ample of upgrades and improvements to fake news detecting technology, which is continually developing. Here are some potential examples:-

1. Natural language processing algorithms: will get better, making it simpler to recognise bogus news based on linguistic factors like language patterns and sentiment.
2. Increased usage of machine learning: As ML algos get more accurate and complex, they are better able to identify fake news. We may anticipate seeing ever more sophisticated machine learning algorithms that are quicker and more accurate in spotting bogus news in the future.

3. Increased collaboration between tech companies and news organisations: As the issue of fake news gains importance, we should expect to see increased collaboration between tech companies and news organisations. This may require sharing information in order to develop more powerful fake news detection tools.
4. Putting greater emphasis on media literacy and education: Although technology can be useful in identifying false information, the best defence against fake news is ultimately the knowledge and skills of individuals in the media. We should expect to see more emphasis placed on media literacy and educational programmes that teach people how to spot fake news and evaluate the reliability of online sources.

CONCLUSION

The vast majority of tasks are completed online in the 21st century. Newspapers that were formerly favoured as hardcopies are gradually being replaced by online news pieces and Plateforms like Facebook and Twitter.

Another valuable resource on WhatsApp is the forwards. The issue of fake news, which is only going to get worse, makes things more difficult and tries to change people's opinions about utilising digital technologies. There are two possible outcomes when someone is duped by the real news: Initially, they might start to think that their perceptions of a particular topic are true. Consequently, we developed a system named Fake News Detection that categorises user input as true or false in order to stop the phenomenon.

Given the potential consequences of spreading false information, it is imperative to develop a system to detect fake news in the modern world. Our research study's system uses natural language processing techniques and machine learning algorithms to identify and flag possible instances of fake news.

We have shown through evaluation that our technology is highly accurate in detecting bogus news stories. Although there is still room for improvement, future research can look into fresh strategies to boost the system's performance even more.

All things considered, we believe that our strategy can be fairly successful in halting the dissemination of misleading information, and All things considered, we think that our approach can make a big difference in the battle against fake news, and we hope that decision-makers, media, and social media platforms will adopt it. We do, however, recognise that our system is not a panacea and that a multifaceted approach incorporating media literacy, education, and fact-checking is necessary to address this complex issue..

Our study concludes by highlighting the importance of developing trustworthy systems that can identify false information, as well as the possible benefits that these systems could offer to society. Our goal is that our contribution will stimulate more research and development in this area, leading to a society that is more informed and accountable in the long run.

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Detection and Identification of Objects to Enhance Traffic Sign Recognition using Deep Convolutional Neural Networks

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***Abstract**: India has the world's second-largest road network, accounting for 10% of all traffic fatalities globally. Additionally, in smart cities, pollution, traffic jams, and vehicle growth have increased noise pollution. various technical issues with traffic signal control equipment as well as ineffective traffic control on the roads. Although the existing traffic control systems depend on set time-based approaches, traditional traffic management systems are not able to control the intricate traffic flow at inter sections. Blockades raise transportation expenses, increase mileage, and contaminate the air in addition to creating more delays and raising the driver's stress level. As a result, created an intelligent traffic signal control system. use the newly released YOLOV7 (You OnlyLookOnce). The speed and accuracy of the newly released YOLO algorithm V7 surpasses that of all earlier object identification models. Since it's the quickest Consequently ,it is the most precise real-time object identification model. optimal algorithm to use in a system for regulating traffic. Compared to earlier models, the Yolo V7hasthebestspeed-to-accuracy balance and is +100% faster.*

An extensive overview of computer vision methods for autonomous traffic management and observation is given in this work. The machine learning method Convolutional Neural Networks (CNN) may be used for object recognition since it has a low execution time and a high recognition rate. The implementation was done using the Open CV tool in Python. Traffic object detection using OpenCV, CNN, and computer vision involves a combination of traditional image processing techniques and deep learning models to accurately and efficiently identify and locate object sin a traffic scenario.

***Keywords**: TrafficPrediction,YOLOV7,CNN,ObjectDetection,ComputerVision,OpenCV.*

INTRODUCTION

A traffic jam has become a hectic activity in the modern world due to the unrestrained expansion in vehicle traffic. The daily number of automobiles on the road is significantly growing, resulting in a multitude of issues. Even so, we installed a traffic management system comparable to a conventional traffic signal Systems have become less effective at managing the ever more traffic on the highways. Traffic congestion costs money in India. 1.47 lakh crore each year, per a Boston Consulting report Analysis of a group in 2018.

Using video, computers, and contemporary communication technologies, machine vision-based traffic information collecting technology, sometimes referred to as video traffic information collection technology, collects dynamic traffic data. By installing a camera on a line pole or bridge, the system gathers traffic images. It then processes the photos to determine the traffic flow, the speed at which traffic is moving at any given moment, and the statistical average of the speed over the predetermined amount of time. To offer real-time traffic dynamic information for raffic signal management, information release, traffic direction, and command,

Among other uses, vehicle type classification, occupancy, average distance, accident detection, and other traffic dynamic information are provided[2].

A video image capture module, an image pre-processing module, a vehicle detection and identification module, and a vehicle flow statistics module make up the traffic flow detection system [4]. **Figure 1** displays the detecting system's primary modules. The vehicle detection and recognition module, which finds and identifies the cars in the video pictures, is the system's central component. The YOLOv7 method is used for vehicle detection and recognition to merge target location and recognition into one, which has to consider requirements of speed detection and recognition accuracy.

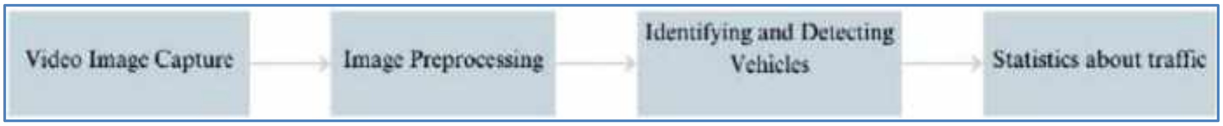

Figure 1 Image Detection Systems

Extensive research has been conducted and is still being conducted on effective traffic control systems. One of the developments in traffic signal technology is the principal field of study. Thus, we created the deep image-based, learning-based smart traffic signal control YOLO V7processing is used. YOLO V7 is the strongest version [1]. object detection method in 2022,given that it has just been released YOLO architectural version. It has already surpassed YoloV4tobecometheindustrystandardforobjectdetection.Wewillquicklyreviewthefoundations of YOLO. The functionality of V7 and why it will be the best object detection formula in this composition. Following that, we'll talk about the technique for putting this algorithm into practice at the traffic management mechanism and its benefits.

However, computer vision plays a significant part in successfully regulating and controlling traffic lights [15], [17]. Intelligent traffic lights, which can roughly assess density estimate, traffic signal detection and identification, emergency and police car detection, and accident detection, are the greatest techniques to govern traffic flow in large, busy cities [11]. Even though improved infrastructure can enhance traffic flow[18]. In calm junctions, traffic is often managed by a system or human controls [16]. Cameras are typically installed in traffic jams for uses other than traffic management, such as security, car detection, and organization [19].All it takes to analyze traffic situations with these cameras is the use of a particular gear. The primary benefit is that the CCTVs don't need to be replaced. This survey's primary goal is to close the knowledge gap in the area of traffic signal regulation and monitoring. The implementation was done using the OpenCVtoolinPython[20].

There are six sections to this study.Theintroductionisthefirstsection.Themanyconventionaltraffic systems in use today are described in Section II. Section III explains the preprocessing of video data for image processing and data collection strategy (Realdata). Section IV explains the fundamental methods for image detection and overall YOLO V7's introduction and operation and talk sab out the suggested approach and model operation. ChapterV demonstrates the application and outcomes. Chapter VI is the final.

Challenges of the Conventional Traffic Control Approach

- Manual Controlling
  - The following are the typical approaches that are now in use cries out for someone having traffic-directing ability. A crucial area for traffic management is the traffic regulations stated goal. The police officers on the road carry a sign. To Utilize a board, assign light, a whistle, and traffic regulation tools[3].
  - DISADVANTAGES: - Human mistake is laborious and common. Undermines the traffic's capacity to be controlled.
- Automatic Controlling
  - Traffic lights are automatically operated by timers and other timing devices. Magnetic sensing devices. Once the timer has loaded, a fixed number is utilized in traffic signals. Lights that switch on automatically ON and OFF, based on the value of the timer. Anytime Using electrical sensors, this will document not just the availability and

indications of the vehicle at each stage , including the Lights corresponding to the ON and OFF signals on the switch without fail[3].

o DISADVANTAGES: - Prolonged delays in traffic because of technological issues that crop upregularly.

DATA PREPROCESSING

There are several processes involved in preprocessing video data for image processing. These actions improve the video's features, lower its noise level, and get it ready for more examination. This is a detailed how-to for preprocessing video data.

Processing images within video data is a multidimensional task involving steps such as image acquisition, enhancement, restoration, and compression, among others. These steps can be further broken down into specific tasks like image enhancement, image restoration, image segmentation, object detection, image compression, image manipulation, image generation, and image-to-image translation.

Data Preprocessing Workflow

- Image Enhancement This involves improving the quality of an image. Techniques like adjusting the contrast and brightness of an image are commonly used. More advanced methods include Image Super-Resolution, where a high-resolution image is obtained from its low-resolution counterpart using Deep Learning techniques like SRCNN.

- Image Restoration This deals with improving the quality of a degraded image. Techniques like image in painting, where missing pixels in an image are filled using texture synthesis algorithms or Deep Learning models, are used.

- Image Segmentation This involves partitioning an image into different regions or objects. Techniques like thresholding are common, but modern techniques use deep learning for segmentation problems. For example, PFNet,aCNN-based model, is used for camouflaged object segmentation.

- Object Detection This involvesidenti fying objects in an image. Deep Learning models, specifically ConvolutionalNeuralNetworks(CNNs),arecommonlyusedforthistask.Onesuchmodelis the Faster R-CNN, which is designed for object detection.

- Image Compression This involves reducing the file size of an image while preserving its quality. T raditional approaches use lossy compression algorithms, but modern approaches use Deep Learning to encode imagesintoalower-dimensional feature space and then recover them [12].

- Image Manipulation This involves altering an image to change its appearance. Techniques like Neural Style Transfer, which adapts an image to the style of another using Deep Learning models, are used.

- Image Generation This involves synthesizing new images, often using Generative Adversarial Networks(GANs)[6].

- Image-to-Image Translation This involves learning them aping between an input and output image. ModelslikePix2pix, which use a conditional GAN model, are commonly used for this purpose.

Traffic Data Description

The Hebbal flyover in Bangalore is 5.2 kilometers (km) long. Several lanes are present. It makes it possible for cars to move more effectively, which lessens traffic. These well-designed entry and exit locations improve traffic data management while also improving convenience.TheInfantryRoadVasanthNagar,Bengaluru,trafficmanagementcenter provided the Hebbalfly over traffic statistics. Permission to record vehicle footage using a camera and GPS was granted to the Assistant Commissioner of Police (traffic control) in October 2023. On October10, received a traffic video. At Bengaluru's Hebbal Flyover, traffic video data is actual data, and the video data extension is in the Advanced System Format (.ASF). ASF files are Microsoft's Advanced Systems Format files, frequently used to stream music and video content. Metadata such as adescription, rating, author information, and title may be present.

To apply image processing techniques to video data, the video has to be first decomposed into individual frames.Eachframecanbetreatedasanimageandprocessedseparately.InPython,this can be achieved using libraries such as OpenCV.

• Frame Extraction: Since the processing is done on the individual frames, the first step in preprocessing video data is to extract the individual frames from the movie. A Python module called OpenCVmay be used to extract frames from a video file.

Figure 2 Extraction of Frames from Traffic Video Data

• Image Resizing: Resizing all the frames to a standard size is a necessary step because the input to a neural network (in case you're using one for further processing) needs to be of the same size. You can usethe‘cv2.resize()’function in OpenCVfor this purpose.

• Gray scaling: Converting the video frame stogray scale can help reduce the computational complexity of the following steps.Thisisbecauseagrayscaleimagehasjustonechannel,comparedtothree channels (Red, Green, and Blue) in a color image.

Figure 3 Grayscale Conversion of the Video Frames

• Noise Reduction: Videos can contain a lot of noise, which can be reduced using filters. Median and Gaussian filters are commonly used for this purpose. A median filter is useful for reducing salt-and-pepper noise, while a Gaussian filter is useful for reducing Gaussian noise.

• Normalization: Normalizing the pixel values of the frames ensures that the pixel values have a specific range, usually between 0 and1.This helps in speeding up the convergence of the model during training.

• Conversion to suitable data structure: Finally, convert the pre-processed frames into as uitable data structure that can be fed into your machine learning or deep learning model for further processing. For instance, you might want to convert the frames into a Num Py array or a Tensor Flow dataset[13].

After processing each frame, they can be combined back into a video for further use. This can be done using OpenCVor similar libraries.

These techniques allow for a large amount of information to be extracted from video data, which can be useful in a wide range of applications, from surveillance to entertainment to scientific research.

Proposed Methodology

Edge AI is necessary to execute object recognition code in computer vision applications since it enables edge computing in conjunction with machine learning. For example, have a look at the Intel Nvidia Jetson AI Edge devices and the Neural Compute Stick. The recommended method is implemented using PyCharm and Python. framework. The project's objective is to reduce the quantity of idle lanes cost time. The whole is divided into two halves method[5].

- Details regarding picture matching
- Setting aside time

Image processing algorithms in the PYCHARM version are used in the section containing image-matching data to compare example photographs and gathered pictures, and compute their likeness expressed as a percentage. Traffic Signal and The Time Allocation process makes use of timer allocation systems. The entire procedure is shown in **Figure 4**, which is provided below.

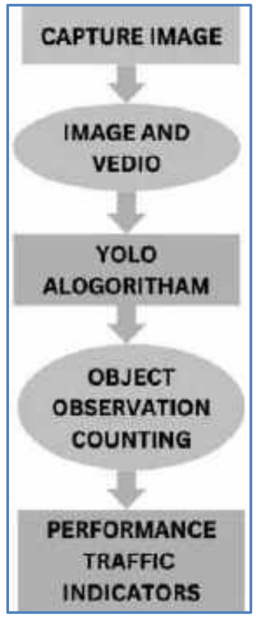

Figure 4 Methodology Implementation

- Capture picture: In this stage, a digital picture is created by extracting the image from the acquired source. YOLO V7 then processes the digital image directly. Examine the traffic flow.

- Picture and Video: Pictures are obtained from real-time footage, identify items in the pictures, and then the traffic is analyzedusingthesameYOLOV7processor.

- Yolo V7 Algorithm: Using photos from image and video capturing devices, the YoloV7nowanalyzestrafficand provides the findings.

- Observing objects Counting: The total number of cars produced, based on which the software determines what shade of the traffic lights will show light.

- Indicators of performance traffic: Lastly, the illumination is shown on the traffic light according to the circumstances (intensity) of movement). Because of YOLO, the entire process happens quickly. v7 algorithms inceit quickly and accurately recognizes items precision.[10]

Image Detection Methods

Since image processing is the most effective way to keep processing real-time data and yield accurate findings that help with traffic signal basing, this paper is considering it. time of density of vehicles. The lane is photographed with a web camcorder, after which they go through five processing steps: side identification, image enlargement, picture scaling, and RGB to conversion to grey. Using this setup, a camera records are ference photo of adeserted highway and makes use of a matching technique to allocate time. The number of automobiles is computed utilizing techniques for image processing.

The center of the green time is established, and the red and blue lights are decided based on the quantity of automobiles. Image segmentation based on color is one of the creative ways to detect ambulances. The worth of the ambulance is below a certain threshold, the centroid of the red and blue light the ambulance is found, and they are both on the same line. There are several methods for identifying edges. Comprising Robert, Canny, Predict, LOG, crossing zero, and clean. Canny Edge detection, which we employed, yields more precise and trust worthy outcomes than other edge detection techniques. Furthermore, [7], [8], and [9] predicted traffic conditions accurately and had positive results. Figure 5 compares several methods of distinct edge observation.

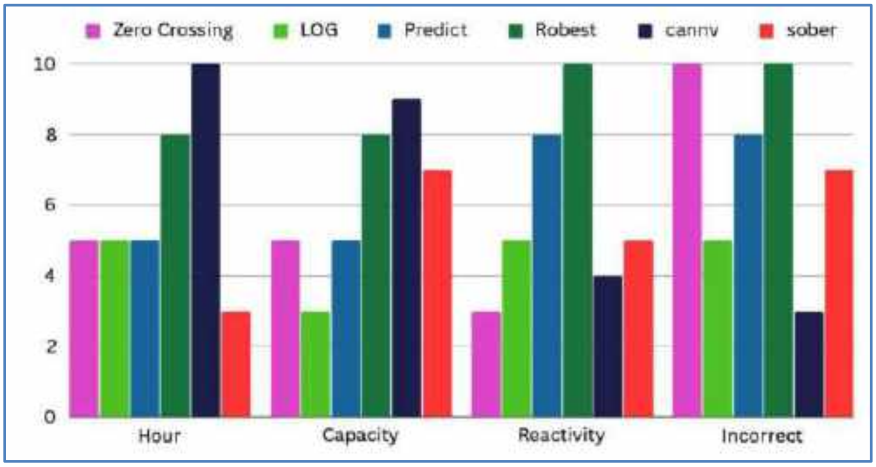

Figure 5 Utilizing a Unique Edge Observation Method for Scanning

YOLO Version7: Overview and Operation

One popular real-time item recognition method is called YouOnlyLookOnce, or YOLO. The first iteration of the YOLO object detector was created in 2016. accessible. Joseph Redmon, Ali Farhadi, and Santosh Divvala were the ones who designed it. This architecture was released with state-of-the-artapplicationsusingcomputervisioninreal-time.asitdetectedobjectsmorequicklythan conventional detectors.

YOLOv7 reduces inference costs and significantly increases real-time object detection accuracy. As demonstrated by the criteria earlier, YOLOv7 significantly outperforms other popular item detectors by cutting around 40% of the parameters and half of the calculation needed for contemporary instantaneous object detection. This enables it to conclude. faster and with more precision in detecting. Okay, let's Examine the YOLO V7's architecture. TheYOLOv7 style is based on the Scaled YOLOv4, YOLOv4, and YOLO-R Previous YOLO model architectures. The main components will be covered in brief in the next sections.

- E-ELAN: - The compute block in the YOLO v7 backbone is represented by the Extended Efficient Layer Aggregation Network(E-ELAN).YOLOv7'sE-ELANarchitecture helps the model to acquire knowledge more efficiently while maintainingtheoriginalgradientpathbyemploying"shuffle,merge,andexpand"cardinality.

- Scaling of Compound Models: -Modifying key model attributes is the fundamental objective of modeling scale to create models that are appropriate for diverse application requirements. Modelingscale, for instance, can enhance the depth, breadth, and resolution of the model (number of phases) (size of the incoming picture).

- Predicted Re-parametrized Convolution: - Rep Conv without Identical relationship (Rep ConvN) is used in the YOLOv7 projected re-parametrized convolution design. a convolution with re-parameters is utilized in place of the objective of the convolutional layer with residual or concatenation is to avoid the possibility of an identification connection.

Consequently, a YOLO architecture may be summed up as having a head, a neck, and a backbone.The planned model producesYOLOv7 at the head, which is not restricted to a single head due to Deep's influence Monitoring is a deep learning technique that is commonly used. neuronal network instruction. The lead head is responsible for generating the final output, and the auxiliary head is employed to assist training in the middle layer[14].We shall now examine based on the fundamental methods of object detection.

To useYOLOf or traffic prediction, you can follow these steps:

- Data Analysis: Analyze your data and categorize it into classes. For traffic prediction, you may have classes like "vehicle", "pedestrian", "traffic light", etc. The number and type of classes depend on your specific use case and the data you have.

- Data Pre-processing: Pre-process your data to make it suitable for training the YOLO model. This may include resizing images, normalizing pixel values, etc.

- Model Training: Train the YOLO model on your pre-processed data. This involves feeding the data into the model and adjusting the model's parameters to minimize the loss function.

- Prediction: Use the trained model to make predictions on new, unseen data.The output of the model will be the class probabilities for each anchor box in each grid cell. You can then apply a threshold to these probabilities to make the final object detection decision.

- Evaluation: Evaluate the performance of your model using appropriate metrics. This could include metrics like precision, recall, and average precision (AP)

For traffic prediction specifically, YOLO might be used in real-time to identify and categorize things, including cars and pedestrians. This information could then be fed into a traffic prediction model, which could predict future traffic conditions based on the current state of the road.

DATA PREPROCESSING OUTCOME

Datasets of images and videos are chosen from traffic-monitoring cameras. Choosing premium, class-leading datasets is essential to provide outstanding datasets for the model's efficient training. equable images. Better performance metrics are therefore attained to remove the image's characteristics and CSPDarknet-53 is used for object identification in video collections.YOLOv7 object identification method application applying neural networks to the application of traffic signals. Regarding the model's training, a custom dataset made up of images and films of traffic on Indian roads featuring a variety of objects— including cars, trucks, motorcycles, buses, micro trucks, individuals, bicycles, cars, and vans — is considered thinking about.

A series of photo sand films was produced during inclement weather. A camera will be installed at the junction to capture real-time traffic images in the lane. The obtained picture is compared to the previous, empty lane. The picture that was also taken. The methods for processing images are utilized to determine the traffic density. Consequently, we set lane times and control traffic signals according to proportional matching. It is given to the traffic signal controller the picture percentage coincides. The controller uses the percentage match to calculate the time for each lane. displays the findings together with the Python programs We may conclude from the findings that this suggested model has a high accuracy of 92% and performs admirably. Decisions are made quickly in real-time, and the amount of training and testing data is 56percent.

CONCLUSION

In conclusion, we can state that the suggested traffic flow system with YOLO V7 architecture manages and controls traffic with 92% accuracy. Well, it is the YOLOV7 that is determined to perform better than any previous item. detectors in every circumstance. The range of speeds begins at 5 FPS to 160 FPS with the best precision in contrast to different models of object detectors. Other applications exist. additionally, this algorithm governs security and monitoring, the use of AI in manufacturing, retail analytics, and energy, creating self-driving cars, and visual AI Among the most often used applications is healthcare. Thus, it can be applied in the next applications as well. Regarding YOLO v7, 56% of the training and testing data had accurate detection. approximately 92%ofthevehicle.

The results gathered from the tests are explained below. based on the pace at which vehicles are recognized, tracked, and detected using two ways. Tracking using the specified in connection with moving cars and counters. Every product software is developed with OpenCV at the Python stage. OpenCV is a free and open-source computer vision and image processing tool with a focus on constant computer vision. An important road is crossed by a footbridge equipped with a camera mount to prevent three pathways concurrently and avoid unsuitable inclusion brought on by vehicles blocking the view.

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Digital Transformation: Pioneering Circular Economy in Engineering

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Abstract: *This research investigates the transformative impact of Information Technology (IT) on engineering practices, particularly within the framework of Circular Economy. Through in-depth exploration of key sub-topics—ranging from IT-empowered design principles and waste-to-resource initiatives to collaborative consumption models, e-waste management, and circular supply chains—the study unveils innovative solutions and real-world cases. By elucidating the symbiotic relationship between IT and sustainable engineering, this paper aims to inspire a paradigm shift towards circularity. The findings presented offer actionable insights for practitioners, policymakers, and industry leaders, fostering a collaborative dialogue at the Indian Engineering Congress to propel a more sustainable future.*

INTRODUCTION

The circular economy focuses on minimizing waste and maximizing the lifespan of products. It promotes recycling, reusing, and reducing consumption to create a more sustainable and efficient economic system. Solutions include product design for longevity, recycling initiatives, and encouraging a shift from a linear "take-make-dispose" model to a circular one.

What makes it Circular?

1. Design for Circular Economy: Explore how products can be designed to be easily disassembled, repaired, and recycled, promoting a longer lifespan and reducing waste.
2. Waste-to-Resource Initiatives: Investigate innovative methods for converting waste into valuable resources, such as turning recycled materials into new products or using organic waste for energy generation.
3. Collaborative Consumption Models: Examine the rise of sharing platforms, like car-sharing and tool libraries, which contribute to resource efficiency by allowing multiple users to access the same product.
4. E-waste Management: Address the challenges and solutions related to electronic waste, considering responsible disposal methods, recovery of valuable materials, and incentivizing electronic product design for easy recycling.
5. Circular Supply Chains: Explore how businesses can adopt circular principles in their supply chains, emphasizing the sustainable sourcing of materials, efficient production processes, and the responsible end-of-life management of products.

How circularity is empowered by IT ?

1. Design for Circular Economy:

Implementing IT-empowered design solutions involves using digital tools for product innovation and lifecycle management. For example, companies like Adidas are leveraging 3D printing technology to create customizable, recyclable sneakers. Digital simulations assist in optimizing designs for disassembly and recycling, ensuring materials are easily separated at the end of the product life. This not only reduces waste but also enables a more efficient circular flow of resources. Software platforms like Autodesk's generative design tools facilitate the exploration of numerous design possibilities, helping engineers create products that are both functional and environmentally friendly.

2. Waste-to-Resource Initiatives:

IT plays a crucial role in waste-to-resource initiatives. The Ocean Cleanup project, led by Boyan Slat, utilizes advanced sensors and machine learning algorithms to autonomously collect plastic waste from the oceans. These technologies enable precise tracking of debris and optimize collection strategies. Moreover, startups like Bioelektra Group use technology to convert organic waste into valuable resources. Their waste treatment plants incorporate sensors and automation for efficient organic waste processing, producing biogas and organic fertilizers. This integration of IT ensures that waste is not just disposed of but transformed into valuable resources through smart, data-driven processes.

3. Collaborative Consumption Models:

Digital platforms are at the core of collaborative consumption models. Airbnb is a prominent example, connecting people who have extra living space with those seeking accommodation. The platform utilizes user reviews, secure payment systems, and AI algorithms to match hosts and guests efficiently. This IT-driven model reduces the need for new construction and promotes a more efficient use of existing resources. Additionally, platforms like Shareable and Nextdoor facilitate community-based sharing of tools, reducing individual ownership and promoting a culture of borrowing. These IT-enabled sharing models contribute to a more sustainable and circular approach to consumption.

4. E-waste Management:

IT solutions are vital for effective e-waste management. Dell, through its Dell Reconnect program, provides a convenient way for consumers to recycle their electronics responsibly. This initiative employs a digital tracking system to monitor the entire recycling process, ensuring transparency and accountability. Moreover, companies like Apple are investing in robot technology for disassembling old devices to recover valuable materials. These robots, equipped with AI, can efficiently and precisely disassemble electronic components, maximizing the recovery of reusable resources. By integrating IT into e-waste management, companies can streamline processes, track materials, and minimize the environmental impact of electronic waste.

5. Circular Supply Chains:

IT-enabled solutions are transforming supply chains toward circularity. IBM's Blockchain platform is being used to create transparent supply chains, allowing consumers to trace the journey of products from raw material to end-of-life disposal. This transparency ensures that products are sourced sustainably and disposed of responsibly. Additionally, companies like H&M are incorporating RFID technology to monitor and optimize the entire lifecycle of their garments. RFID tags provide data on the origin of materials, production processes, and recycling possibilities, enabling a more circular and eco-friendly approach to the fashion supply chain. By harnessing IT, businesses can make their supply chains more circular, sustainable, and aligned with the principles of a circular economy.

CONCLUSION

As a professional and policy maker, the insights gleaned from this research underscore the imperative for embracing Information Technology (IT) as a catalyst for engineering a circular economy. The symbiosis between IT and sustainability, exemplified through innovative design, waste-to-resource initiatives, collaborative consumption models, e-waste management, and circular supply chains, charts a course toward a more resilient and resource-efficient future. Acknowledging the transformative power of IT in driving sustainable practices is paramount for informed decision-making. To navigate the complexities of modern engineering, policymakers must prioritize fostering a conducive ecosystem for IT-driven circular solutions, incentivizing industry-wide adoption. This research serves as a clarion call, urging professionals and policymakers to collaborate in shaping policies that propel our engineering landscape towards a circular paradigm, harmonizing economic prosperity with environmental stewardship.

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An Effective DWT SVD based Watermarking Technique on Colored DICOM Image in Healthcare Applications

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Abstract: *A dependable and lossless ROI medical picture watermarking technique is proposed using SVD and DWT. The system's efficacy is assessed experimentally for two different medical picture modalities of the brain utilizing a range of quality criteria (payload, PSNR, etc.). The proposed algorithm demonstrates high resilience, enhanced PSNR, and a reduced relative entropy distance, all of which meet protective requirements.*

DICOM is the name of the international standard for organizing and transferring medical data and images. Its objective is to provide workflow management and system compatibility for the creation, processing, retrieval, sharing, display, query, and printing of medical images. Multiple watermarking is expected to enhance medical image security and safeguard patient privacy. In this work, a multiple medical picture watermarking system based on discrete wavelet transform (DWT) and singular value decomposition (SVD) is developed. The proposed method embeds three watermarks into different channels (R, G, and B) of color photos: a patient's identity in the first watermark, their diagnosis in the second, and a doctor's signature in the third.

Keywords:

INTRODUCTION

DICOM (Digital Imaging and Communications in Medicine) is a standard protocol used by many healthcare facilities for the management and exchange of medical images and related data.

DICOM was first formed by the National Electrical Manufacturers Association (NEMA) and the American College of Radiology (ACR). This NEMA-registered trademark is managed by the DICOM Standards Committee, a consortium of users from all medical imaging professions interested in standardizing medical imaging data.

What is DICOM used for

DICOM is the name of the international standard for organizing and transferring medical data and images. Its objective is to provide workflow management and system compatibility for the creation, processing, retrieval, sharing, display, query, and printing of medical images.

NEMA claims that suppliers of imaging systems, including PACS, vendors of imaging equipment, including MRIs, and associated equipment usually follow DICOM standards.

All medical professions where the use of medical imaging equipment is frequent, such as radiology, cardiology, oncology, obstetrics, and dentistry, are covered by these standards.

Medical imaging, which produces a visible image of a patient's interior that would otherwise be hidden beneath the skin, muscles, and surrounding organ systems, is often a noninvasive process used for diagnostic purposes. In this context, the term "noninvasive" describes a scan in which, for the most part, no instruments are introduced into the patient's body.

Medical images are used for clinical analysis, diagnosis, and therapy as part of a patient's care plan. Doctors can access a database of normal patient scans for later use, track the efficacy of treatment, and identify any anatomical or physiological irregularities with the use of the collected data.

Imaging information technologies, according to DICOM, have essentially eliminated the need for film-based images and the physical storage of these materials. Instead, medical images can now be securely stored digitally with other non-image data, on site or in the cloud.

Why DICOM is important

The International Organization for Standardization states that with the introduction of advanced imaging technologies such as CT scans and the growing use of computing in clinical work, ACR and NEMA realized the need for a standard method to transfer images and associated data between different vendor devices. These devices output a variety of digital photo formats.

DICOM, which is used globally for the storage, exchange, and transmission of medical pictures, currently allows medical imaging devices from different manufacturers to be combined. The interchange and archiving of patient data together with related images is done in a standard format. Without a standards-based approach, it would be difficult to communicate data between different imaging devices since they would need to comprehend different image formats.

DICOM's faster access to images and reports allows doctors to diagnose patients more quickly, potentially from anywhere in the world. Patients thereby obtain care that is more effective.

Due to the fact that not all medical images are in the DICOM format, XDS, or cross-document sharing, has become popular. Many image formats can be stored thanks to the imaging-specific extension XDS-I. Medical imaging system vendors offer a capability that allows them to understand DICOM and non-DICOM formats.

DIGITAL WATERMARKING

is use of a kind of marker convertly embedded in a digital media such as audio, video or image which enables us to know the source or owner of the copyright. This technique is used for tracing copyright infringement in social media and knowing the genuineness of the notes in the banking system.

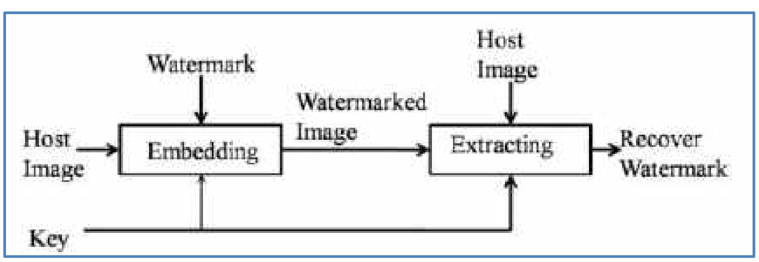

Figure 1 Watermarking Embedding

Applications

- Watermarks are used in forensics. In forensics, watermarked photos are acceptable, but evidence that has been tampered with is not.
- This is exploited by brands. Digital watermarking is used to maintain the legitimacy of digital media.
- Data copying is prevented via digital watermarking.

- Video editing software employs watermarks to persuade customers to buy the full version.
- It's used for video authentication. News networks routinely show footage from other groups with watermarks. Security features on ID cards also benefit from it.
- It is used for content management in social media.

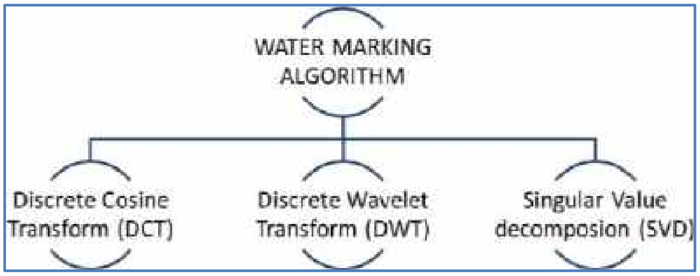

Figure 2 Types of Watermarking

Advantages

- It is used to find instances of copyright infringement on digital files.
- Watermarking is a very secure technique. It is possible to embed watermarks using a key. Understanding the keys used during embedding is the only way to remove the watermark.
- An embedded version of a file is also digital, which facilitates usage and transfer. Media with watermarks can be used without error or problem as long as the file format stays the same.

Disadvantages

- More dependable techniques for watermarking photos still require development.
- Watermarks that are visible can be quickly removed or obscured by other watermarks. The watermarked photos can be easily resized and cropped.
- Owners can easily erase watermarks. This suggests that the owner may easily alter the image and fast update the watermark.

PROPOSED SCHEME THE PROPOSED SYSTEM'S MODULE IS FULLY DESCRIBED IN THIS SECTION.

Water Marking Algorithm

Discrete Cosine Transform (DCT)

The DCT is the transform function that is most commonly used in signal processing. The conversion of a signal takes place between the frequency and spatial domains. Because of its excellent performance, it is used for picture compression in the JPEG standard. This function illustrates a process for transforming pixels in a spatially represented image into a frequency domain that allows redundancy to be labeled. DCT methods perform better in terms of robustness than spatial domain methods. These techniques resist common image processing tasks like blurring, contrast augmentation, low pass filtering, brightness alteration, and so on. It is more difficult to implement and more computationally expensive.

DWT- Discrete Wavelet transform (DWT) is a mathematical tool for hierarchically decomposing an image.

- Multi-resolution analysis (MRA) analyzes a signal at different frequencies to produce different resolutions by breaking the signal down into a set of basis functions called wavelets.
- The DWT separates the signal into high- and low-frequency components.

- The low frequency portion of the signal contains coarse information about the signal, whereas the high frequency portion conveys information about the edge components.

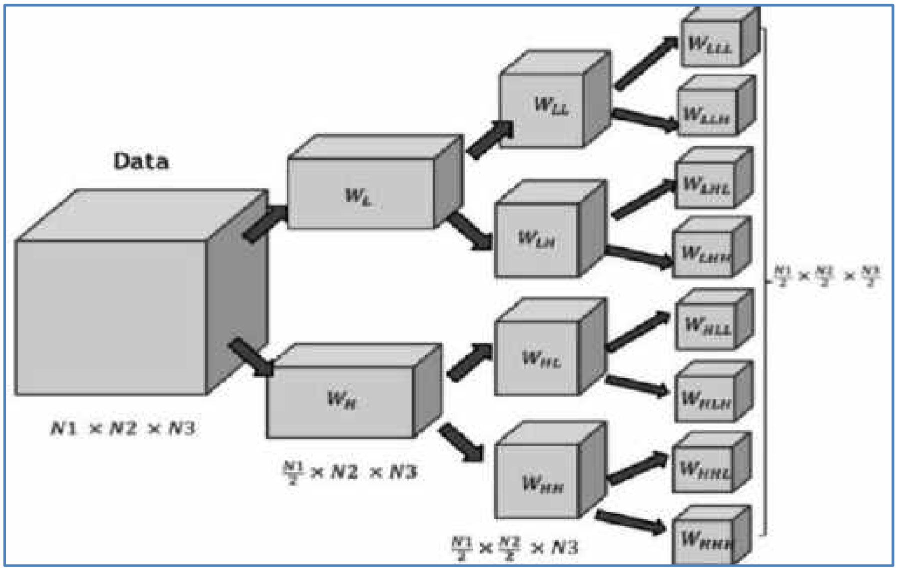

Figure 3 DWT

Advantages of DWT

- Since wavelets are utilized to see the image as a single block, the edges are no longer visible.
- The wavelet property of the mustier solution analysis reduces the computing time required for the detection process.
- Makes precise localization possible in the space and time frequency domains.
- A more precise assessment of the information related to human perception.
- Enhanced flexibility: Wavelet function choice is unconstrained.
- Critical sampling is the capacity of the basis element to have minimal redundancy.

Disadvantages of DWT

- Completing DWT could cost more than calculating DCT.
- Applying wavelet filters or larger DWT basis functions, which result in blurring and ringing noise near the edges of images or video frames.
- Longer compression time.
- When compression is used in moderation, the quality is lower than JPEG.
- Does not offer anisotropy, in which basis elements are defined in varying aspect ratios and shapes, or directionality, in which basis elements are defined in different directions.

SVD (Singular Value Decomposition)

By using orthogonal matrices U and V to represent the left and right singular vectors of image A and image V's columns, respectively, SVD factarizes the form A=∑V for any image, say A, of size m*m.

Assume that field K, which could be either the field of real numbers or the field of complex numbers, is the source of the entries of M, a m*n matrix. Then, M=U∑V is a factorization that exists.

Assuming that ∑ is a m X n diagonal matrix with a non-negative real integer and U is a m X m unary matrix over K, V is a n X n unitary matrix.

Advantages of SVD

One powerful method for matrix decomposition is the singular value decomposition, which shows the matrix's geometric properties and yields an approximation for rank-deficient matrices.

Disadvantages of SVD

Despite its advantages, there are a number of drawbacks, especially in cases when simpler techniques like the Fourier Transform or QR decomposition can be used to tackle the problem. Secondly, the SVD cannot be applied to problems that require adaptive algorithms because it operates with a fixed matrix.

How to Overcome the Disadvantage of DWT

- We need to figure out ways to reduce the cost of computing DWT;
- longer computation durations ought to be cut down.

The following needs to be made better:

- Blurring and ringing noise around image edges should be reduced;
- Poor directional selectivity for diagonal features should be enhanced.

How to Overcome Problems of SVD

- The SVD should be utilized because of its rapid computation speed. Its performance should be easy to measure.
- To determine the fastest way to compute the SVD.
- To evaluate SVD performance, the least amount of computation should be required.
- By learning how to use them, SVD attributes that aren't exploited in image processing should be utilized. Roughness measure and the capacity to conceal information are a few of these traits.

HYBRID DWT-SVD

A hybrid methodology blends two distinct methods together. Here, using DWT and SVD together improves the quality of digital watermarking, increasing a picture's resilience and imperceptibility.

The hybrid DWT-SVD watermarking algorithm that is recommended: The embedding algorithm for DWT-SVD based watermarking is shown in **Figure 3**. The algorithm works in this manner.

Step 1: The original N*N RGB image is divided into sub-bands using single level 2-D DWT.

Step 2: SVD is applied to the LL sub-band (on RGB components) of the decomposed RGB original image, or S = USVT.

Step 3: A size M*M RGB image's watermark is divided into sub-bands using single level 2-D DWT.

Step 4: SVD is applied to the LL sub-band (on RGB components) of the decomposed RGB watermark image, or T w w w U S V (3.7) SW.

Step 5: The watermarked picture (the embedding result) is reworked into sub-bands using the single level 2-D DWT.

Step 6: SVD is applied to the LL sub-band (on RGB components) of the decomposed RGB watermarked image, or T w w w U S V (3.8) SWI.

Step 7 involves extracting the resulting SVD picture using the same scale factor (α), that is, (3.9)α S) / ∘ (SWI ᠭ\EWI).

Step 8: After the image has been extracted, inverse SVD is applied.

Step 9: The extracted watermark image is obtained by performing inverse 2-D DWT. The steps involved in the DWT and DWTSVD watermarking techniques have been devised and explained in this section. In Section 4, these methods' outcomes will be displayed. Results of the Experiment We have shown the viability of the suggested watermarking techniques in this Section. Furthermore, we evaluate the robustness and imperceptibility of images using DWT and DWT-SVD. The test images are 512 × 512 pixels in RGB format. With MATLAB, the suggested DWT and hybrid DWT-SVD picture watermarking methods are coded. The cover picture (RGB image) is displayed in **Figure 5**, and the watermark image (RGB image) is displayed in **Figure 6**. Initially, both cover and watermark images are used in embedding and extraction algorithms. **Figure 7** shows the watermarked image based on DWT and **Figure 8** shows the watermarked image based on DWT-SVD as a result of embedding algorithms in both the techniques. **Figure 9** shows the extracted watermark image based on DWT and **Figure 10** shows the extracted watermark image based on DWT-SVD as a result of extraction algorithms in both techniques.

Performance Analysis In all experiments, the quality of the watermarked image is evaluated by applying Peak Signal to Noise Ratio (PSNR) as image quality metrics. The quality of watermarked image is measured in terms of PSNR (Peak Signal to Noise Ratio) **Table 1** shows the comparison between PSNR values of DWT and DWT-SVD. Figure 10 shows the graph plot for comparison for PSNR values (from eqn. 5.2) with respect to scaling factor (α) between DWT and DWT-SVD.

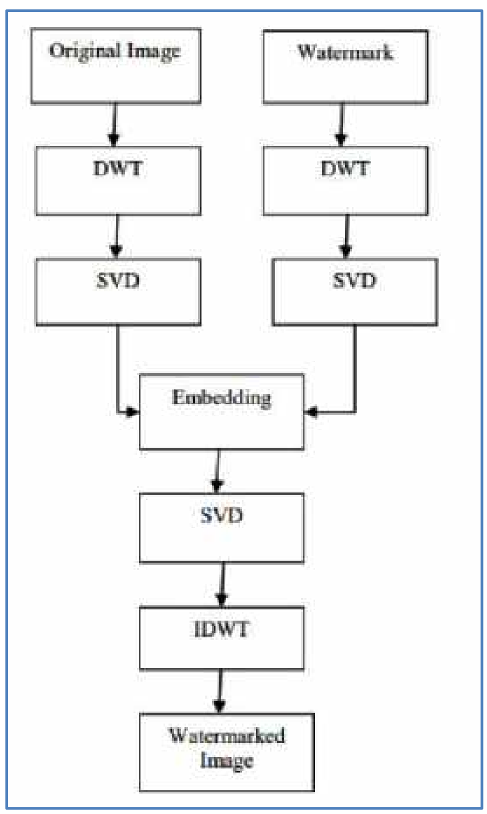

Figure 4

Figure 5 Cover image

Figure 6 Watermark image

Figure 7 Watermark image based on DWT

Figure 8 Watermark image based on DWT-SVD

Figure 9 Extracted watermark image based on DWT

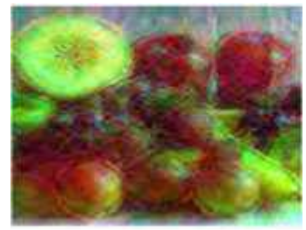

Figure 10 Extracted watermark image based on DWT-SVD

Comparison between PSNR Values of DWT and DWT-SVD

Table 1 Comparison between PSNR Values of DWT and DWT-SVD

Value of Scaling factor(α)	Value of PSNR	
	DWT	DWT-SVD
0.01	35.62	35.57
0.02	34.58	35
0.03	33.35	33.44
0.04	32.03	32.34
0.05	30.62	31.10
0.06	29.47	30.01
0.07	28.38	29.19

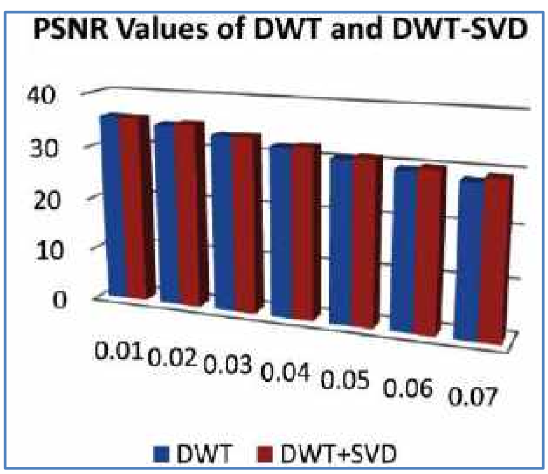

Figure 11 Graph Plot for Comparison between PSNR Values of DWT and DWT-SVD

CONCLUSION

The recommended DWT and DWT-SVD watermarking techniques are used to support the image's durability while also guaranteeing content or image security and copyright protection. At all scaling factor values, the hybrid DWT-SVD technique yields higher peak signal to noise ratio (PSNR) values than the DWT technique. After using both watermarking methods and comparing the PSNR values at various scaling factor (α) values, this result is made. The original image will appear worse the lower the PSNR value. This demonstrates that when the DWT method is used to apply the watermark, the original image quality deteriorates more fast than when The security of medical information records, or electronic patient records that hold a patient's complete and intricate collection of clinical examinations, diagnostic annotations, and other data and photographs, is ensured by medical information protection. The security of medical images is vital because hostile modifications or attacks can have serious repercussions, such as misdiagnosis, invalidation of electronic data in forensic medicine, possible deception of medical insurance agencies, etc. In this work, we proposed a technique to ensure retinal image accuracy. The watermark created from patient data allows for the authentication of both the patient and the data related to the photo acquisition. Additionally, the built-in hash of the watermark guarantees that the data hasn't been.

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Deep Learning Models-based Histopathological Image Classification for Automated Screening of Breast Cancer

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***Abstract**: Breast cancer is a common and death causing disease diagnosed among women worldwide. It is likely that detection of breast cancer at early stage and its proper treatment can avoid the surgeries, which will increase the survival rate. In the present scenario various image processing techniques which are implementing machine learning are being widely used in medical field domain. In order to detect breast cancer at early stages a number of research studies have been conducted as to how to improve the diagnostic methods for early diagnosis of breast cancer. This study adopts the Artificial Intelligence approach to analyze DICOM Images in prediction of Breast Cancer using Convolutional Neural Network and ResNet50 as feature extraction. This research is based on the dataset and images obtained from Kaggle, from year 2019 to 2023. The steps of diagnosis including preprocessing, segmentation, extracting features, and classification are being described.*

***Keywords**: - CNN, ResNet50, Breast cancer, Artificial Intelligence*

INTRODUCTION

Breast cancer being a malignant disease has a high mortality rate, it is threatening the women physical and mental health and life worldwide [1, 2]. China accounts for about 66 thousand female breast cancer deaths each year [9], which accounts for 7.82% of the total number of deaths among females due to breast cancer. In United States , the American Cancer [9]. Society in 2017 reported 255180 new cases of breast cancer and 41070 deaths of breast cancer.

Basically Breast Cancer is the formation of a malignant tumor that is developed from cells in the breast. The Breast Cancer cells mainly are of two types Benign and Malignant. The benign cells are called non-cancerous cells and they do not disturb nearby cells or spread to other cells. They look like hard (tumor). A benign tumor is not making problem unless it is pressing on nearby tissues, nerves or blood vessels and causing damage. [3]. The malignant cells are cancerous cells , they spread the cancer to nearby cells easily, while some cancer cells can move into bloodstream or lymph nodes, where they can spread to other tissues within the body.

In case of breast cancer the malignant cells can either originate in the lining of milk glands or ducts of the breast, depending on where the breast cancer arises. Thus early detection, early diagnosis and early treatment of breast cancer will help in curing, giving relief to the patient.

With the advancement in Computer technology, the correct diagnosis of breast cancer has become very important. In the past 40 years, the diagnosis of breast cancers were performed using X-ray, MRI (Magnetic Resonance Imaging), ultrasound etc., the computer aided diagnosis in prediction of breast cancer is used now a days by getting breast tissue biopsies allowing the pathologists to histologically assess the microscopic structure and elements of the tissue. Nowadays, artificial intelligence (AI), machine learning (ML), and convolutional neural network (CNN) are the areas growing rapidly in healthcare industry [3]. AI and ML are being applied in research areas, thus improving technological systems to resolve complex tasks and reducing the necessity of human intelligence. [4] . Deep Learning (DL) being part of machine learning family depended on artificial neural networks. DL architectures which includes CNN is generally applied to the areas like computer vision, audio recognition, speech recognition, social network filtering, natural language processing, machine translation, drug design, bioinformatics , medical image analysis [5].

These new technologies are being applied to improve diagnostic accuracy and efficiency of cancer detection [6]. Researchers are continuously exploring the dataset to learn deep network in order to extract the information features in the dataset, so that they can get tumor medical auxiliary information [6].

The main objective of this study is to apply Artificial Intelligence approach in prediction of breast cancer using Convolutional Neural Network (CNN) as features extractor and RUNet Architecture for the semantic segmentation to get more accurate and efficient results.

PREVIOUS WORK

In the present scenario, various artificial intelligence-based techniques are widely investigated from neuroscience to computer science [18]. Deep learning models (DLMs) are being used in both 1-dimensional single-channel, 1-D multi-channel, and 2-D (images) data analysis. Breast cancer detection based on Deep Learning Technique was proposed by Ismail, Nur Syahmi and Cheab Sovuthy [7]. The author proposed work is based among Malaysian women in which roughly one in 19 women at risk of breast in Malaysia. The author [7] proposed to compare the breast cancer detection with two model networks of deep learning technique involving image processing, classification and performance evaluation. VGG16 and ResNet50 to classify between normal tumor and abnormal tumor using IRMA dataset, thus comparing the results of VGG16 dand ResNet50 in terms of accuracy. The abnormal images can be classified to malignant and benign tumor, thus helping for the next procedure in patients.

In [3] the author proposed to predict breast cancer at the initial stage using convolution neural network - ResNet50 with a few hundreds of sample images. Dataset consisting of 1000 Hematoxyline and Eosin (H&E) strained breast biopsy images form "BreakHist_Dataset"[19]. The data set was used by the author as 800 images for training and 200 images for testing. Each image size was 224*224*. Data augmentation was done using Image Data Generator, where the author applied zoom range-2, rotation range-90, horizontal and vertical flips condition true. The base ResNet 50 model was created and the model was fine tuned with the augmented data for breast H&E biopsy image classification. A very simple and effective method for the classification of histological breast cancer images was proposed by the author [3].

A Convolutional Neural Network approach was proposed by [5] the author investigates the proposed system that uses various convolutional neural network (CNN) architectures to automatically detect breast cancer, comparing the results from machine learning (ML) algorithms. The authors applied a big dataset of about 275,000, 50 x 50-pixel RGB image patches. When the proposed model was compared with machine learning (ML) algorithm, the model exhibit improved accuracy by 8% over the result of algorithm. The author proposed a method using CNN Model and achieved 87% accuracy, and obtaining correct results, thus decreasing human mistakes in the diagnosis process and thereby reducing the cost of cancer diagnosis.

Results of past researches show that a number of authors as Wahab and Khan [20] used CNNs to investigate the automated detection of IDC-type breast cancer, whereas a number of scholars used Machine Learning based automatic detection techniques to detect the same. To obtain correct results was the aim of authors from the results obtained to reduce the errors found in diagnosis procedure. Another study by the Abdelhafiz et al. [21] concluded the augmentation approach was more accurate in the automatic identification of breast cancer, when the given dataset was used. Rezaeilouyeh et al. [22] identified images of mitosis in breast cancer by applying deep max pooling CNNs. The images were ordered based on pixel exhibiting the networks were competent. Murtaza et al. [23] applied deep learning approach in order to identify and investigate the IDC tissue zones automatically. Alhamid et al.[24] and Qian et al. [25]there proposed works also identified the same technique, exhibiting the obtained results of shearlet coefficients magnitude and phase can improve detection accuracy and generalizability. A number of studies have been proposed by different authors [1, 18, 20, 25] for using AI as well as CNN in healthcare monitoring specially image detection.

PROPOSED METHOD

In the proposed method, a DLM-based technique is utilized to detect breast cancer using Histopathological images. Collected Breast hisptopthological images are resized as the requirement of utilized DLMs.

Database : The database comprised of Breast Cancer Histopathological Image Classification (BreakHis) is composed of 9,109 microscopic images of breast tumor tissue collected from 82 patients using different magnifying factors (40X, 100X, 200X, and 400X). It contains 2,480 benign and 5,429 malignant samples (700X460 pixels, -channel RGB, 8-bit depth in each channel, PNG format). This database has been built in collaboration with the P&D Laboratory – Pathological Anatomy and Cytopathology, Parana, Brazil(http://www.prevencaoediagnose.com.br).

Data Process : All the patches are in RGB pixel format and are scaled from 0 to 255. Machine learning classification methods (ML) are to be applied to these images. Therefore a scale between 0 and 1 was choosen so as to be compatible with the methods.

This approach applies CNN as a transfer learning technique to re-train the benchmark ResNet50 (Residual Network). The model is characterized by its deep residual learning framework, with a depth of 50 layers. The author deploys, lightweight DLM to classify the Breast cancer images. performance characteristics are evaluated to check the efficiency of the framework. The layered architecture of the proposed methodology is depicted in **Figure.1**. A brief description of DLM, transfer learning techniques are given as follows:

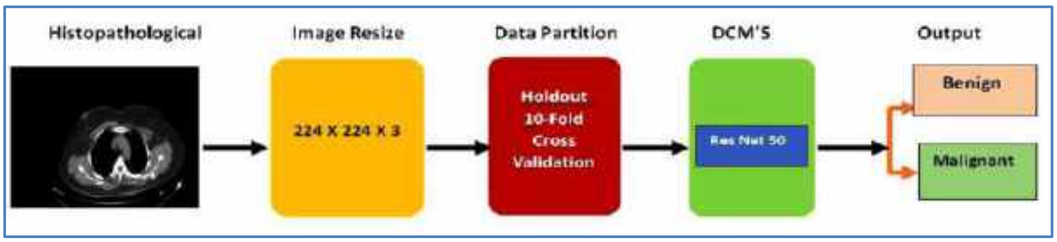

Figure 1

Deep Learning Model

Deep-learning methodologies, such as deep feature extraction, fine-tuning of benchmarked DLM by transfer learning, and end-to-end training of a newly developed DLM are employed to identify Breast cancer is Benign or Malignant based on Histopathological images. The DLM is one of the most powerful neural networks which is being used worldwide. The DLM performs a number of tasks including image classification, segmentation, object location, and detection. It has found to be more efficient in the biomedical field for signal classification and detection of diseases, classification of images, and segmentation problems, particularly for Breast cancer detection at an early stage thus saving life and reducing medical expenses of patients. DLMs are based on a representation based learning system, a DLM automatically learns a variety of useful feature representations and combines feature extraction and classification steps into a single pipeline, the start and the end can be tailored without any expert human involvement [28]. The DLM structure mainly comprised of an input layer, one to many convolutional 2-D layers, pooling layers and few fully connected layers. [30]. A user can design its own DLM by combining the said layers. These layers can be increased or decreased until the model achieves the required performance [31] . With the recent advancements in deep learning a variety of pre-trained DLMs are being deployed for different machine learning applications. [18]. Most common used benchmarked transfer learning models are DartNet19, Alex Net and ResNet50. In this work, a pre-trained DLM namely ResNet50 is being deployed for screening of Breast cancer using Histopathological images.

Convolutional Neural Network (CNN)

The Convolutional Neural Network (CNN) has been proved by many researchers as very efficient and accurate in Breast cancer histopathological image classification.[3]. Deep learning being the advanced version of neural networks. It has a maximum of 128 hidden layers between input and output layers.[3]. CNNs are multi-layered neural networks with more number of hidden layers. Mainly it is being used in image classification and image recognition applications. It extracts the image features in various layers like human brain processing. Each convolution layer has many filters, the size of which is smaller than the input, thus performing the convolutions across the image independently[7]. These filters learn patterns across the entire image. As the input is passed through the network, the convolution layers perform convolutions on the image. In convolution layers, the neurons will only connect to a limited region of the previous layer. As the computational complexity is reduced, it enables CNN to make full use of the 2D structure of the input data. CNN often leads to better results in image and speed recognition[7], as compared to other deep learning architecture. The basic architecture of CNN is shown in **Figure 2**.

ResNet 50

ResNet50 (Residual Network) is a subclass of convolutional neural networks most popularly used for image classification. The ResNet50 architecture is a variant of the Residual Network proposed by He et al., in 2015[7]. The model is characterized by its deep residual learning framework, with a depth of 50 layers. It is also known as classic neural network. The residual address the problem of training a really deep architecture by introducing identity skip connection so the layers can copy their input to the next layer[7].

Proposed DLM

In AI field there is no standard DLM, for the analysis and categorization of biomedical signals and histopathological images. The authors in this research field have choice to use DLM based on its performance, classification accuracy, and training time. By changing the kernel size, stride, dropout percentage and other different parameters, the classification accuracy of a DLM may be adjusted to a greater extent. The author proposed DLM that accepts the input image of size 227 x 227. The DLM contains four Conv2D layers, two PLs, and two FCLs. The number of kernels used is 96, 84, 84, 96 with a kernel size of 9 x 9, 7 x 7, 5 x 5, and x with a stride value being 2. PL utilizes Max pooling, and 512 and 2 neurons are used in FCL with 0.5 dropouts. The author developed the layered architecture of the DLM as depicted in **Figure 2**.

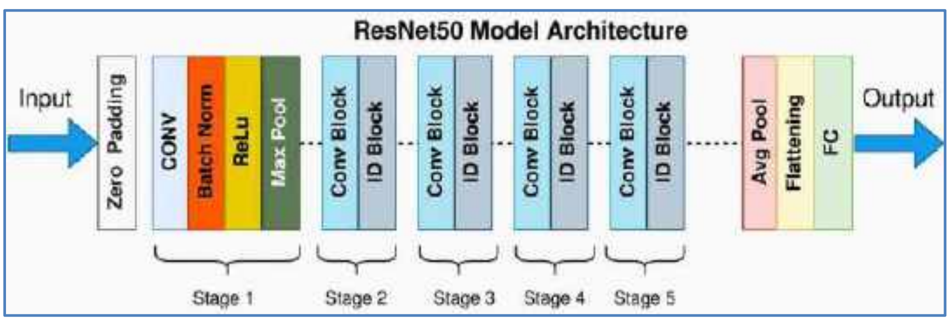

Figure 2

Transfer Learning

In order to train a benchmark DLM a collection of large labeled dataset and advanced and updated hardware resources are required at initial start-up. Training a benchmark model from scratch is a difficult task and also impractical as the authors could gather a small number of datasets and also there are hardware restrictions. Hence the researchers in this study applied a transfer learning approach to get better and efficient results. Transfer learning means the reuse of a pre-trained DLM on a new task. Here the pre-trained DLMs that have been trained on Image-Net data (contains records of 1000 classes with 1.2 million images), are used again and again for a new application [32]. Three types of transfer learning strategies are being applied by researchers namely, DLM as fixed feature extractor, Fine-tuning the DLM, and pre-trained models. The author applied a pre-trained benchmark namely ResNet-50. The ResNet-50 model has been used a feature extractor for the Breast cancer dataset. **Figure 3** depicts the schematic view of transfer learning.

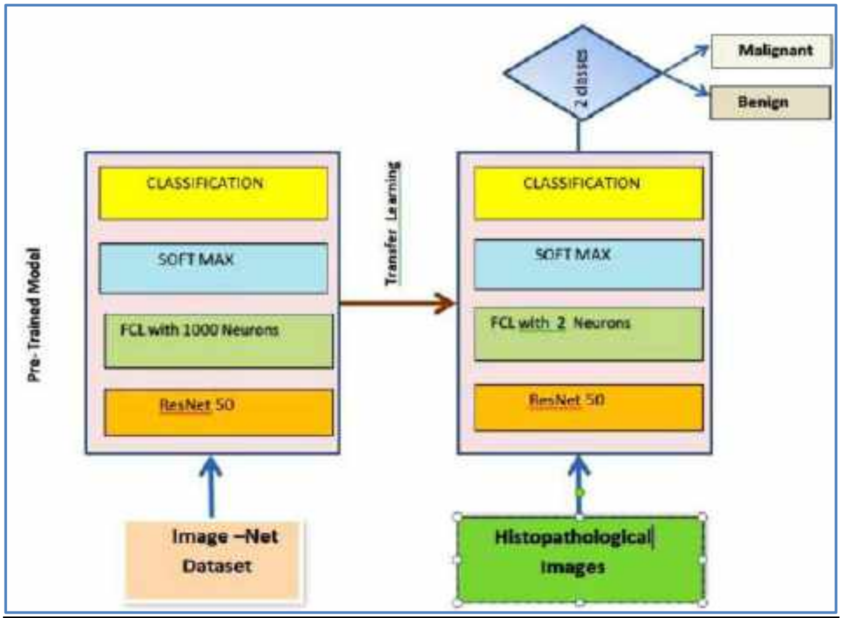

Figure 3

Repeated 10-FHCV Scheme

A DLM is built on a cross-validation technique, that splits the original input data into a training set, a validation set, and a test set for training, validation and analyzing the model performance. In this scheme the original input data is randomly divided into 10 equal parts, a single part is retained as the test data for DLM testing, for validation one part of the remaining data is kept and the rest parts consumed for model training [4]. Hence the DLM is built upon a repeated 10-FHCV strategy. Here the cross validation procedure is repeated 10-times by altering the training, validation and test data. **Figure 4** depicts the schematic view of the data partition strategy.

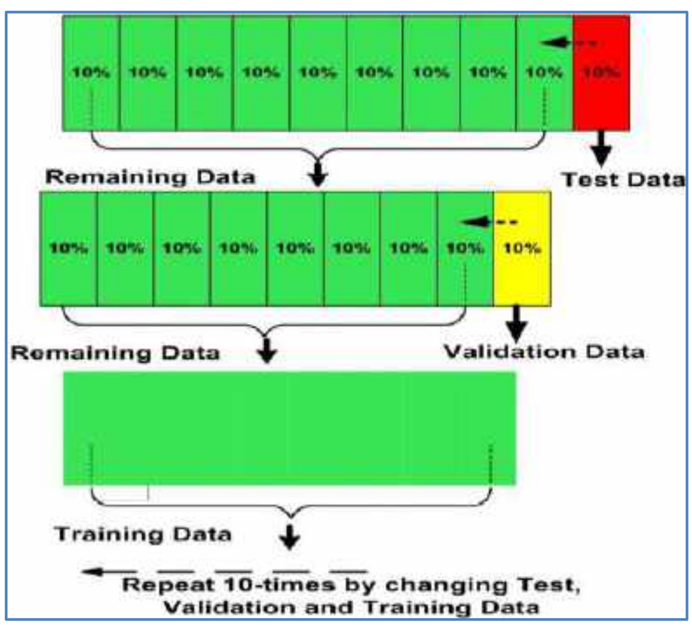

Figure 4

Performance Metrics

The superiority of the system has been evaluated basically on ten parameters which are - accuracy (Acc), F-1 score, precision (*PRC*), Negative Prediction value(Npv), True Positive Rat (TPR), True Negative Rate(TNR), Negative Predict Value(NPV), False Negative Rate(FNR), False Positive Rate(FPR), Balanced Accuracy (BA) are being applied as performance metrics. The mathematical expression of these metrics is given below :

1. $\mathrm{NPV} = \frac{\mathrm{TN}}{\mathrm{TN} + \mathrm{FN}}$

2. $\mathrm{FNR} = \frac{\mathrm{FN}}{\mathrm{FN} + \mathrm{TP}}$

3. $\mathrm{FPR} = \frac{\mathrm{FP}}{\mathrm{FP} + \mathrm{TN}}$

4. $\mathrm{BA} = \frac{\mathrm{TPR} + \mathrm{TNR}}{2}$

5. $\mathrm{TPR} = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}}$

6. $\mathrm{TNR} = \frac{\mathrm{TN}}{\mathrm{TN} + \mathrm{FP}}$

7. $\mathrm{A_{CC}}(\%) = \frac{\mathrm{T_{Pos}} + \mathrm{T_{Neg}}}{\mathrm{T_{Pos}} + \mathrm{F_{Neg}} + \mathrm{T_{Neg}} + \mathrm{F_{Pos}}} \text{ x } 100$

8. $\mathrm{F} - 1 \text{ score} = \frac{2 \times \mathrm{T_{Pos}}}{2 \times \mathrm{T_{Pos}} + \mathrm{F_{Pos}} + \mathrm{F_{Neg}}}$

9. $\mathrm{PRC} = \frac{\mathrm{T_{Pos}}}{\mathrm{T_{Pos}} + \mathrm{F_{Pos}}}$

10. $\mathrm{N_{PV}} = \frac{\mathrm{T_{Neg}}}{\mathrm{T_{Neg}} + \mathrm{F_{Neg}}}$

Where, true positive (T_{pos}), false positive (F_{pos}), true negative (T_{Neg}), and false negative (F_{Neg}) are the confusion matrix parameters.

EXPERIMENTAL SETUP AND FINDINGS

A publicly available Breast cancer Histopathological database is utilized to evaluate the performance of the proposed framework. The scan Breast cancer images are only annotated with numbers and do not specify whether they are subject-independent or not. The scan image data are processed on a Desktop system equipped with a single CPU having a Core i7 processor, supporting RAM - 24 GB and a hard disk with a capacity of 512-GB. The author selected hyper parameters based on past studies and various experiments. Adam optimizer comprised of AdaGrad and RMSProp algorithms and consumes less memory was deployed. The Adam optimizer is used for optimizing the cross-entropy loss. 30 epochs with a batch size of 128 and validation frequency of 10 with an initial learning rate of 0.0001 are chosen for proper training of DLMs.

Database

For this work, the publicly accessible Breast cancer Histopathological database web address is [42] is utilized. This database contains the Breast Cancer Histopathological Images of 2,480 benign and 5,429 malignant. These Histopathological images are in the .png file extension and have dimensions 700 X 460 pixels, -channel RGB, with 8-bit depth in each channel. To match the input image size of the employed model, all images are resized to 224 x 224 for pretrained DLM. The ResNet-50 model accepts this fix size images. Fig.5 represents randomly selected Breast cancer images benign and malignant.

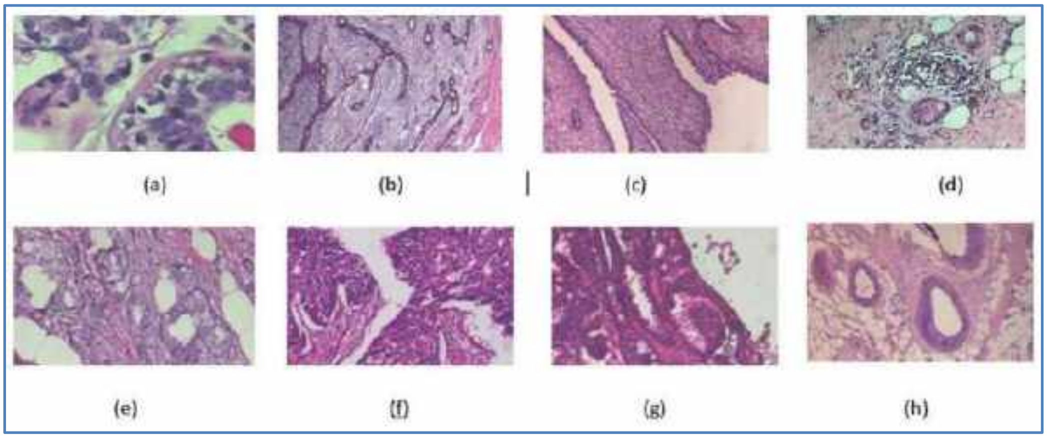

Figure 5 Different breast cancer biopsy images (a-d) Benign tumour images (e-h) Malignant tumour images

RESULTS AND DISCUSSION

The Google cloud platform offers Colab Notebook where this study was setup, with a Tesla T4 GPU. For fine tuning of the model, the programming languages like Python and Keras were used being open source languages. The Sklearn library [7] ResNet50 based effective model – paper was deployed for performance and evaluation, and conclusion was drawn from confusion matrices. Image processing being an important step, that enhances the quality of the image and prepares input images for network learning.

A total number of 930 iterations are required to classify the Breast cancer database comprising of benign and malignant images to achieve its maximum accuracy. The highest accuracy obtained from the pre-trained ResNet-50 model is 93%. The training and validation accuracy graph obtained from histopathological images using pre-trained ResNet-50 model is as shown in **Figure 6**.

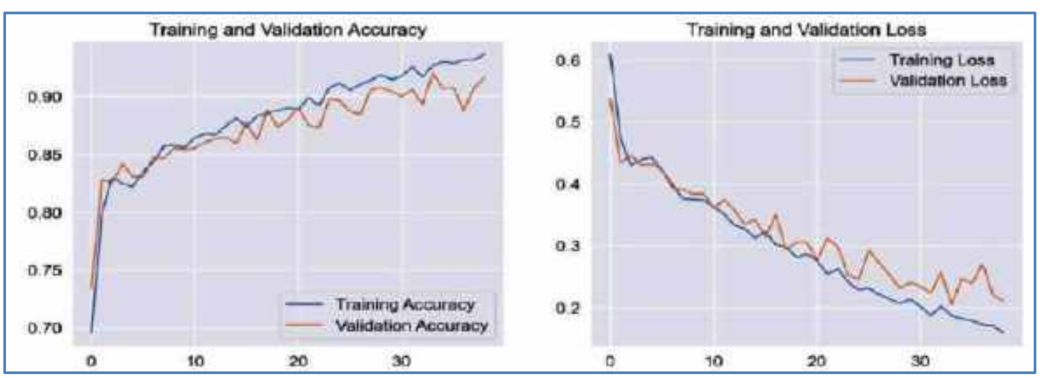

Figure 6

Rapid and correct screening of Breast cancer patients is very necessary, in-order to save their lives. A new pre-trained DLM based on ResNet-50 model is explored in this article to classify Breast cancer histopathological images. The presented technique is a state-of-the-art. There are ten performance parameters that are computed to better understand the method for screening of histopathological images.

Table 1 gives the overall performance metrics obtained from pre-trained ResNet-50 model.

Table 1

Parameters	ResNet 50
Acc(%)	93%
F-1 Score	0.87
PRC(%)	0.9
NPV(%)	0.94
TPR(%)	0.8
TNR(%)	0.95
NPV(%)	0.95
FNR(%)	0.13
FPR (%)	0.04
BA (%)	0.8

Table 2 Performance comparison obtained with previous methods for screening of histopathological images using BreakHis Data Set.

S no	Author	Classification method	Result
1	HelenRajani Chapala,[26]	Classifier Fusion with Resnet 50	Acc= 91%
2	Mahesh Gour[27]	Convolutional Neural Network	Acc=92%
3	Yasin Yari,[28]	Resnet50	Acc=91%
4	Laya Lose, [29]	ensemble and multiclass classification methods	Acc=85%
5	Proposed Method	ResNet 50 with repeated holdout 10 FCV	Acc=93%

CONCLUSION

Breast cancer images are being used as histopathological images where cancer is detected whether it is benign or malignant. The DLM is a powerful, efficient, accurate and useful technique to diagnose cancer using histopathological images database. This paper presents an end-to-end framework for the screening of Breast cancer using histopathological images database and DLMs. The most efficient pre-trained DLM ResNet-50 is applied in this work. The transfer learning technique is being used for bench-marked model training. An efficient and accurate method is utilized to build the DLM. There are ten performance parameters that are computed to measure the superiority of the proposed system.

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An Efficient and Reliable Algorithm for Wireless Sensor Network

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***Abstract**: Wireless Sensor Networks (WSNs) have gained significant attention in recent years due to their wide range of monitoring and data collection applications. The success of these networks depends on developing efficient and reliable algorithms to manage and process data from the numerous sensor nodes. This paper presents an innovative algorithm designed to address the challenges of energy efficiency and data reliability in WSNs.*

The proposed algorithm leverages a combination of data aggregation, routing protocols, and energy-aware mechanisms to optimize the network's performance. It employs a hierarchical approach that reduces energy consumption by clustering sensor nodes and enabling data aggregation at different levels of the network. This hierarchical structure not only conserves energy but also improves the network's reliability by reducing the chances of data loss and increasing the overall network lifetime.

Furthermore, the algorithm incorporates adaptive data routing strategies to ensure reliable data delivery while adapting to dynamic network conditions. By dynamically adjusting routing paths, the algorithm mitigates network congestion, reduces packet loss, and enhances the overall network's stability.

In this paper, we provide a detailed description of the algorithm's design and implementation, including the clustering process, data aggregation, and adaptive routing strategies. We also present simulation results and performance evaluations, demonstrating the algorithm's effectiveness in terms of energy efficiency and data reliability.

Our findings indicate that the proposed algorithm outperforms existing solutions in terms of energy consumption and data delivery reliability. This research contributes to developing efficient and reliable algorithms for WSNs, which are crucial for successfully deploying sensor networks in various real-world applications, such as environmental monitoring, industrial automation, and healthcare systems.

***Keywords**: Industrial Automation, WSN, Mitigates Network Congestion, Network Efficiency, Mesh*

INTRODUCTION

Wireless Sensor Networks (WSNs) have emerged as a critical technology in various domains, including environmental monitoring, industrial automation, healthcare, and smart cities. These networks consist of numerous small, low-power sensor nodes that collaborate to collect, process, and transmit data from their deployment environment. The reliability and efficiency of these networks are essential to ensure the accuracy and timeliness of data collection. In this context, the development of efficient and reliable algorithms is a paramount concern.

This research paper introduces a novel algorithm designed to address the challenges associated with WSNs, specifically focusing on enhancing their efficiency and reliability. Our algorithm leverages innovative techniques and methodologies to optimize network performance, reduce energy consumption, and mitigate data loss, ultimately resulting in a more robust and dependable WSN.

The following sections will provide a comprehensive overview of the current state of wireless sensor networks, their key challenges, and the motivation behind the development of our algorithm. We will also delve into the technical details and experimental results that showcase the effectiveness of our proposed algorithm in achieving improved efficiency and reliability in WSNs. Additionally, we will discuss potential applications and future research directions in this domain.

In a world increasingly dependent on data-driven decision-making, an efficient and reliable algorithm for wireless sensor networks holds great promise for advancing a wide range of fields. This research aims to contribute to the ongoing evolution of WSNs, ultimately enhancing their capabilities and facilitating their broader adoption in critical applications.

PROPOSED METHODOLOGY

Creating an efficient and reliable algorithm for a Wireless Sensor Network (WSN) is a complex and important task. To develop such an algorithm, you should follow a systematic methodology that includes several key steps. Here's a proposed methodology for designing an efficient and reliable algorithm for a WSN:

1. Problem Definition:

- Clearly define the problem you aim to address in your WSN, such as data aggregation, energy efficiency, data routing, security, or any other specific goal.

2. Literature Review:

- Conduct an extensive literature review to understand the existing algorithms and approaches related to your specific problem in WSNs.
- Identify gaps, limitations, and opportunities for improvement in current algorithms.

3. Define Objectives:

- Clearly state the objectives and goals of your algorithm. What do you want to achieve in terms of efficiency and reliability?

4. Design:

- Develop the algorithm's conceptual design. Consider factors like energy consumption, latency, scalability, and fault tolerance.
- Choose the appropriate algorithmic techniques, such as clustering, data aggregation, routing protocols, or optimization methods, depending on your problem.

5. Simulation and Modeling:

- Use simulation tools and modeling techniques to evaluate the algorithm's performance in various scenarios.
- Use realistic data to mimic real-world WSN conditions.

6. Performance Metrics:

- Define relevant performance metrics for evaluating the algorithm's efficiency and reliability, such as energy consumption, packet delivery ratio, latency, network lifetime, and fault tolerance.

7. Implementation:

- Develop a prototype or simulation code for your algorithm using suitable programming languages and WSN simulators like NS-2, NS-3, or OMNeT++.

8. Testing and Validation:

- Test the algorithm extensively in simulated and, if possible, real-world WSN deployments.
- Ensure it meets the defined objectives and performs well in various scenarios.

9. Optimization:

- Fine-tune and optimize the algorithm to enhance its efficiency and reliability based on the results of your testing and validation.

10. Comparative Analysis:

- Compare your algorithm's performance with existing state-of-the-art algorithms and demonstrate its superiority in terms of efficiency and reliability.

11. Documentation:

- Prepare detailed documentation of your algorithm, including the design, implementation, and test results.
- Include thorough explanations of the algorithm's components and how they contribute to efficiency and reliability.

12. Peer Review:

- Seek feedback from experts in the field and collaborate with other researchers to further refine your algorithm.

13. Publication:

- Consider publishing your algorithm in reputable conferences or journals within the field of Wireless Sensor Networks.

14. Open Source:

- If applicable, consider open-sourcing your algorithm to foster collaboration and further development by the research community.

15. Continuous Improvement:

- Stay updated with the latest developments in WSNs and continue to refine and enhance your algorithm as needed.

Remember that the development of an efficient and reliable algorithm for WSNs can be a time-consuming process. It's essential to be patient, rigorously test your algorithm, and iterate as necessary to achieve your desired results.

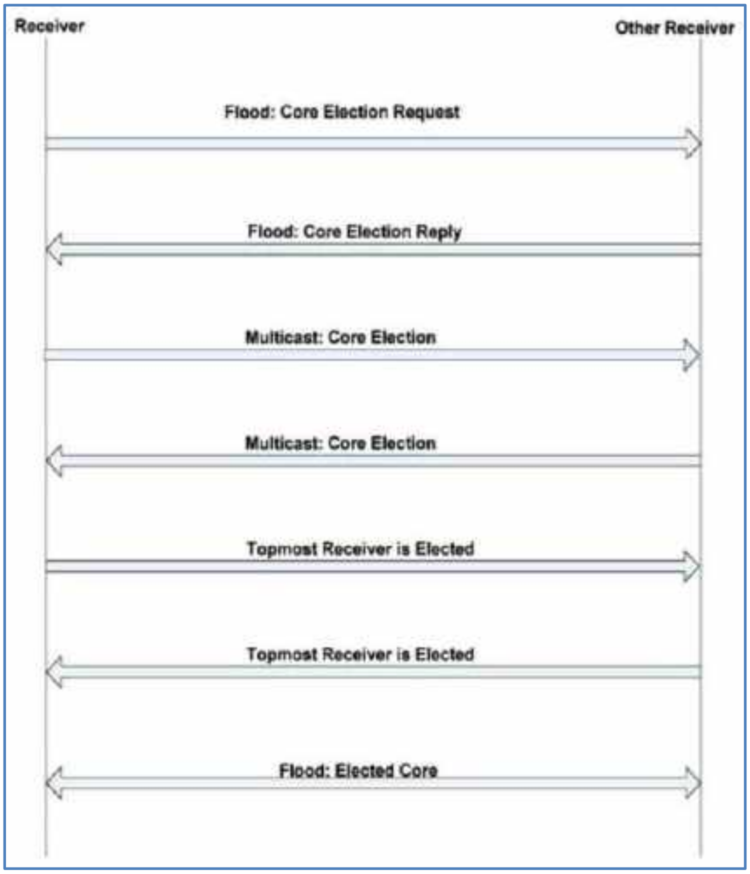

Figure 1 Acknowledgement Flow Diagram

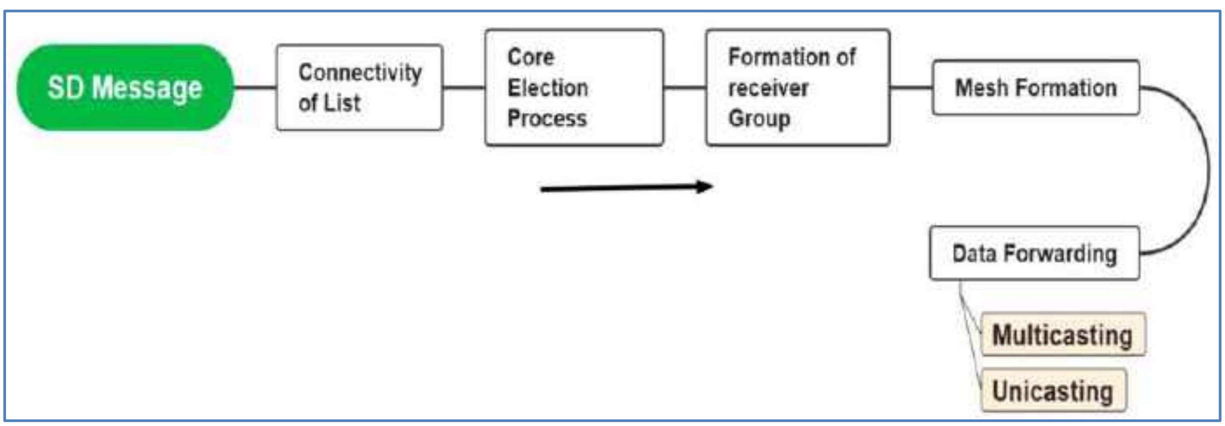

Figure 2 Message Flow Diagram

FORMATION OF RECEIVER GROUP

The formation of receiver groups in a wireless sensor network is an essential aspect of optimizing network efficiency and reliability. Receiver groups are clusters of sensor nodes that are configured to receive data from one or more source nodes in the network. The design of an efficient and reliable algorithm for forming these receiver groups is crucial for achieving the desired network performance.

Here are the key steps and considerations for forming receiver groups in a wireless sensor network:

1. Node Selection: Start by selecting a set of sensor nodes that will act as potential receivers. These nodes should be strategically distributed across the network to ensure coverage and reliability. The selection process can take into account factors such as node density, energy levels, and communication range.
2. Topology Information: The algorithm should have access to network topology information, including the location and connectivity of sensor nodes. This information is crucial for determining which nodes can effectively receive data from specific source nodes.
3. Communication Range: Define the communication range of each sensor node. Nodes within this range can potentially receive data from the source node. The communication range is influenced by factors such as transmission power and signal propagation characteristics.
4. Reliability Metrics: Determine the metrics for assessing reliability, such as signal-to-noise ratio, link quality, and interference levels. These metrics help in identifying nodes that can reliably receive data.
5. Optimization Objectives: Clearly define the optimization objectives for the algorithm. This may include minimizing energy consumption, maximizing network coverage, or ensuring fault tolerance. The algorithm should aim to achieve these objectives while forming receiver groups.
6. Clustering: Divide the network into clusters based on the receiver selection process. Each cluster should have a designated receiver node that is responsible for gathering data from source nodes within its cluster.
7. Neighbor Discovery: Ensure that receiver nodes can discover their neighbors and establish reliable communication links. This may involve neighbor discovery protocols and link quality estimation.
8. Data Forwarding: Design a data forwarding mechanism for transmitting data from source nodes to receiver nodes. The routing and forwarding protocols should be optimized for efficient data transfer.
9. Dynamic Adaptation: The algorithm should be capable of adapting to changes in the network, such as node failures, mobility, and variations in data traffic. Dynamic adaptation ensures that receiver groups remain efficient and reliable over time.
10. Energy Efficiency: Consider energy-efficient communication strategies to prolong the network's lifetime. This involves optimizing the transmission power, duty cycling, and data aggregation.
11. Fault Tolerance: Implement fault tolerance mechanisms to handle node failures or network disruptions. Redundancy and self-healing strategies can improve reliability.
12. Validation and Simulation: Validate the algorithm's performance through simulations and real-world testing to ensure that it meets the efficiency and reliability requirements.

The specific algorithm for forming receiver groups may vary depending on the network's goals and constraints. Researchers and engineers often use techniques from graph theory, optimization algorithms, and distributed computing to design efficient and reliable receiver group formation algorithms for wireless sensor networks. The choice of algorithm should align with the network's specific requirements and objectives.

FORMATION OF MESH

Creating an efficient and reliable algorithm for forming a mesh in a Wireless Sensor Network (WSN) is a significant challenge in the field of wireless communication. Mesh formation in WSNs is crucial for enabling sensor nodes to communicate with each other and relay data to a central point or gateway. The goal is to establish a network topology that maximizes network connectivity, minimizes energy consumption, and ensures reliable data transmission. Here are some key considerations and approaches for developing such an algorithm:

1. Network Topology:

- Define the desired network topology. In a WSN, a mesh topology is often preferred due to its redundancy and fault tolerance. However, other topologies like tree or star can also be considered based on the specific application requirements.

2. Energy Efficiency:

- Consider the energy constraints of sensor nodes. WSNs are often deployed in environments where replacing or recharging batteries is impractical. Therefore, energy efficiency is a critical factor in algorithm design. Minimize the energy expenditure during mesh formation and data transmission.

3. Node Placement:

- Ensure an optimal distribution of sensor nodes in the deployment area. This might involve optimizing node placement algorithms to guarantee sufficient coverage and connectivity.

4. Routing Protocols:

- Implement efficient routing protocols within the mesh network. Routing algorithms play a significant role in directing data packets through the network while conserving energy and ensuring reliable data delivery.

5. Self-Organization:

- Design the algorithm to enable self-organization among sensor nodes. Self-organizing networks can adapt to changes in network conditions, such as node failures or dynamic environments.

6. Fault Tolerance:

- Build fault tolerance mechanisms to handle node failures and network disruptions. This could involve redundancy, dynamic route reconfiguration, or recovery mechanisms.

7. QoS and Reliability:

- Define quality of service (QoS) requirements for the WSN. Ensure that the algorithm can meet these requirements while maintaining reliability in data transmission.

8. Scalability:

- Consider the scalability of the algorithm. WSNs can range from small-scale deployments to large-scale networks, and the algorithm should be designed to handle both scenarios.

9. Communication Protocols:

- Choose appropriate communication protocols for data transmission. This might include protocols like Zigbee, Bluetooth, or LoRa, depending on the specific requirements of the application.

10. Simulation and Testing:

- Simulate the algorithm under various scenarios and test its performance to ensure it meets the desired objectives. Real-world testing in the deployment environment is also crucial.

11. Security:

- Address security concerns, such as data encryption, authentication, and access control, to protect the network from unauthorized access and data breaches.

12. Adaptability:

- Ensure that the algorithm can adapt to changing network conditions, such as node mobility or varying traffic loads.

Creating an efficient and reliable algorithm for mesh formation in a WSN is a multidisciplinary task that involves expertise in wireless communication, networking, optimization, and sensor technology. Researchers often use mathematical models, simulations, and experimental deployments to develop and validate their algorithms. Additionally, it's essential to keep up with the latest advancements in wireless communication and sensor technologies to continuously improve the algorithm's performance.

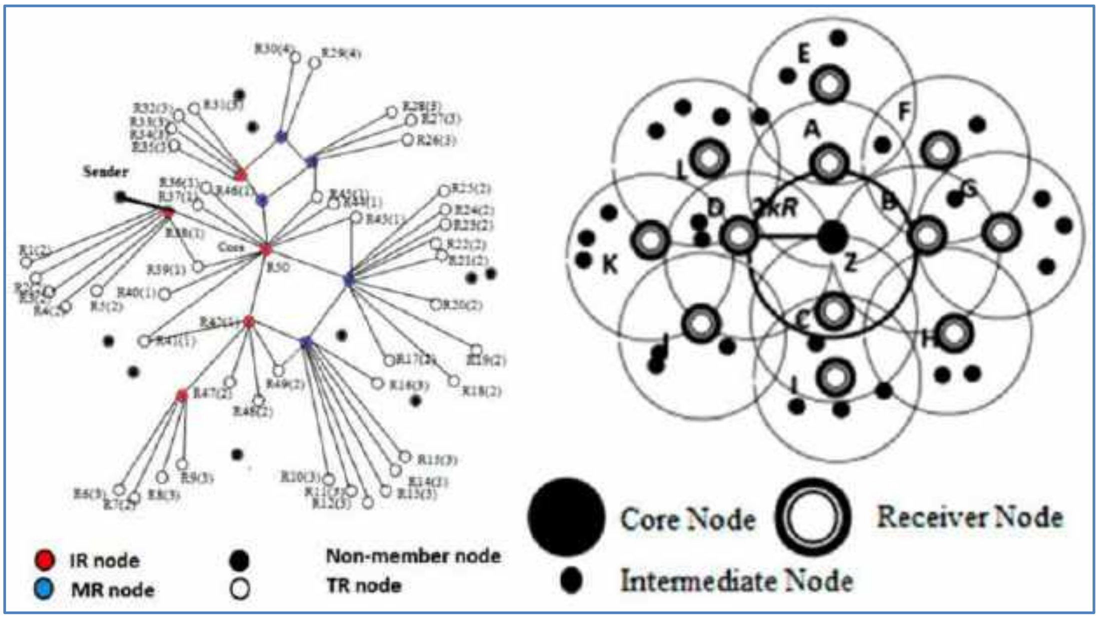

Figure 3 Network Flow Circle

Algorithm of EERASCA

Depending on the two situations, a mechanism of unicasting and multicasting is used in this paper. **Algorithm 1** (Stage 8) contains four steps which are as follows:

The Proposed Algorithm of EERASCA
/******the initialization phase******/
1 Broadcast “SD message” about connected neighbors from the core node
2 Receiving of “SD message” about the neighbors
/****** The running phase******/
3 while (receive a data packet D by Mesh member M)
4 Calculate the connected neighbors of M
5 Update the routing table of M
and assume that neighbors are represented by G

6 if (G ≤ 3) then
7Cancel the multicasting of M;
8 else
9 update the routing table of M;
10 if (G ≥ 4) then
11 multicast M;
12 Break from while loop;

1. Initially, every node generates its SD message about the status of its position within its neighbors.
2. When a mesh member, e.g., R38, broadcasts the SD message within its neighbors, then the node at a three-hop distance will be stored in its routing table.
3. The routing table is updated, and Data D is transferred to R39 through unicasting.
4. Let us suppose that R51, if the node is not within the three-hop distance, then the Data D will be transferred through multicasting.

Key highlights of the algorithm include:

1. Energy Efficiency: The algorithm minimizes energy consumption by sensor nodes through efficient data routing and transmission, which is crucial for extending the network's operational lifespan.
2. Reliability: It ensures reliable data communication by utilizing error-checking mechanisms, redundancy, and adaptive routing strategies to mitigate packet loss and data integrity issues.
3. Scalability: The algorithm is designed to be scalable, allowing for the seamless expansion of the network as more sensor nodes are added, without a significant drop in performance.
4. Data Aggregation: It employs data aggregation techniques to reduce redundant data transmission and improve the efficiency of data processing.
5. Adaptability: The algorithm is adaptable to various WSN scenarios and can be fine-tuned to meet specific application requirements.

RESULT COMPARISON AND PERFORMANCE EVALUATION

In wireless communications, the term "base antenna" typically refers to the antennas used at base stations or cell towers. These antennas are an essential component of the wireless communication infrastructure and play a crucial role in transmitting and receiving signals to and from mobile devices, such as cell phones.

Here are some key points about base antennas in wireless communications:

1. Location: Base antennas are typically installed at elevated locations, such as cell towers, rooftops, or other high structures. This elevation allows them to cover a larger area and communicate with mobile devices over longer distances.
2. Types of Antennas: Base antennas come in various types, including omnidirectional and directional antennas. The choice of antenna type depends on the specific needs of the wireless network. Omni-directional antennas radiate signals in all directions, providing coverage in a 360-degree pattern. Directional antennas focus their signals in a specific direction, offering more extended range in that direction.
3. Coverage Area: The coverage area of a base antenna depends on several factors, including its height, power, and the frequency it operates on. Higher antennas can cover larger areas, and higher-frequency signals may have a shorter range compared to lower-frequency ones.
4. Sectorization: In many wireless networks, especially in cellular networks, multiple base antennas are used at a single site, each covering a specific sector or direction. This technique is called sectorization and helps optimize coverage and capacity within a given area.

5. Frequency Bands: Base antennas operate on specific frequency bands allocated by regulatory authorities. Different frequency bands have different characteristics, such as signal propagation and interference susceptibility. Common frequency bands used in wireless communication include 2.4 GHz and 5 GHz for Wi-Fi, and various bands for cellular networks, such as 700 MHz, 1.8 GHz, 2.1 GHz, and more.
6. Antenna Gain: Antenna gain is a measure of the antenna's ability to focus its energy in a particular direction. A higher gain antenna can transmit and receive signals over longer distances in the desired direction.
7. Polarization: Antennas can have different polarization orientations, such as vertical or horizontal. Ensuring that the polarization of the base antenna matches the polarization of the user devices can improve signal strength and quality.
8. MIMO Technology: Multiple-input, Multiple-Output (MIMO) technology is often used in modern wireless communication systems. It involves the use of multiple antennas at both the base station and the mobile device to improve data rates, reliability, and overall system performance.

Base antennas are a fundamental element of wireless communication networks, enabling the transmission and reception of signals to provide connectivity to a wide range of wireless devices, from smartphones to laptops and IoT devices.

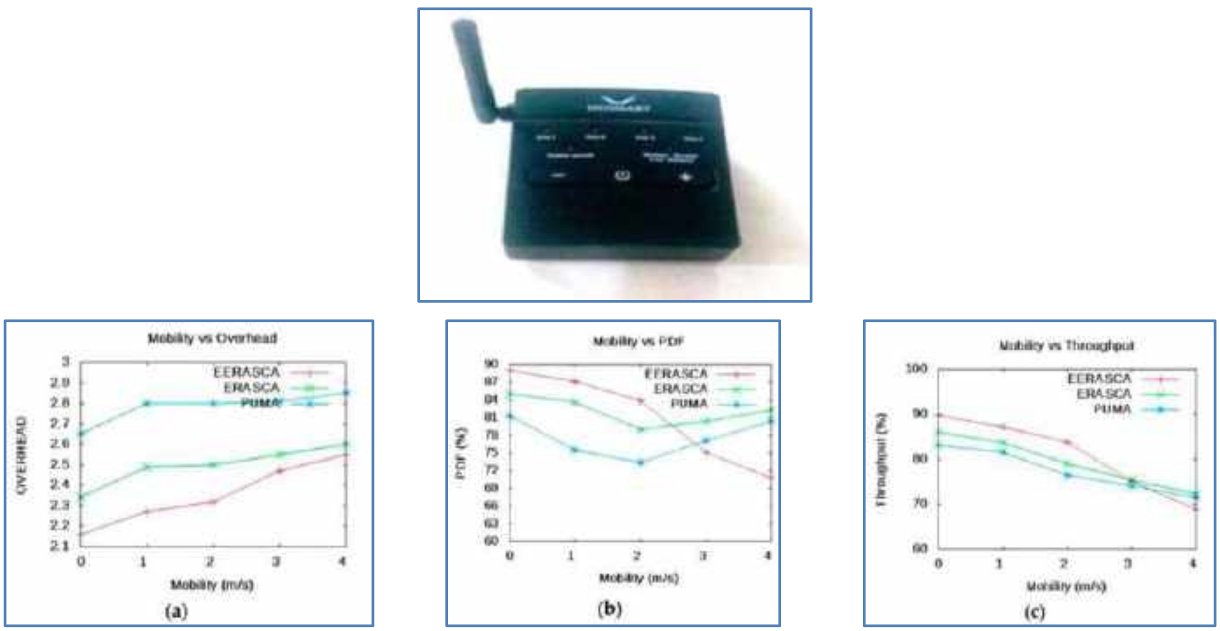

Figure 4 Bar Graph Data Flow

FUTURE SCOPE

The development of an efficient and reliable algorithm for Wireless Sensor Networks (WSNs) holds significant potential and relevance in the ever-evolving field of technology. Here are some future scope and potential areas of impact for such algorithms:

1. Energy Efficiency: As energy constraints are a critical issue in WSNs, the future scope lies in creating algorithms that optimize energy consumption. New techniques can be developed to prolong the lifetime of sensor nodes, potentially using energy harvesting and efficient sleep-wake schedules.
2. Scalability: WSNs are increasingly being used in large-scale deployments. Future algorithms should focus on scalability to handle a massive number of sensor nodes efficiently while maintaining network performance.
3. Reliability: Ensuring data reliability is crucial. Future research can explore techniques for fault tolerance, data redundancy, and robust data transmission to improve reliability in harsh and dynamic environments.
4. Security: The security of WSNs is paramount, and future algorithms should address issues such as secure data transmission, authentication, and intrusion detection to protect data and the network infrastructure.

5. Real-time Data Processing: In many applications, real-time data processing is essential. Future algorithms can be designed to optimize data processing and analytics, enabling faster decision-making in critical scenarios.
6. Machine Learning Integration: Integrating machine learning algorithms into WSNs can enhance their capabilities. Future research may focus on developing algorithms that can process and analyze data directly at the sensor nodes, providing valuable insights for various applications.
7. Localization: Accurate node localization is essential in many WSN applications. Future algorithms may explore methods for improving localization accuracy and reducing the cost of deploying localization infrastructure.
8. Quality of Service (QoS): In scenarios where certain QoS requirements must be met, such as in healthcare or industrial monitoring, algorithms can be designed to ensure that data is delivered within specified latency and reliability constraints.
9. Cross-Layer Design: Future algorithms can focus on cross-layer design, which means optimizing communication and data processing across multiple network layers to achieve better overall performance.
10. Environmental Monitoring: WSNs play a crucial role in environmental monitoring, including air quality, water quality, and wildlife tracking. Future algorithms can enhance the precision and coverage of such monitoring systems.
11. Human-Centric Applications: In the context of the Internet of Things (IoT), algorithms can be developed to support various human-centric applications, including smart cities, healthcare, and home automation, making WSNs more user-friendly and adaptable.
12. Standardization and Interoperability: As WSNs continue to grow, standardization and interoperability between different devices and networks will be essential. Future research can contribute to establishing industry standards for WSNs.
13. Edge and Fog Computing: Leveraging edge and fog computing in WSNs can reduce latency and improve real-time processing. Future algorithms can explore ways to efficiently integrate these paradigms into WSNs.
14. Robustness to Dynamic Environments: Algorithms should be designed to adapt to dynamic and unpredictable environments, such as those encountered in disaster response and wildlife tracking.
15. Environmental Sustainability: As WSNs expand, it's important to consider the environmental impact of deploying and maintaining such networks. Future research can explore green algorithms that minimize energy consumption and resource usage.

The future of WSNs is promising, with applications spanning various domains. Developing efficient and reliable algorithms will be instrumental in unlocking their full potential and addressing the evolving needs of our connected world.

CONCLUSION

In conclusion, the development of an efficient and reliable algorithm for Wireless Sensor Networks (WSNs) is crucial for ensuring the successful deployment and operation of these networks. WSNs play a vital role in various applications, including environmental monitoring, industrial automation, healthcare, and more, and the performance of these networks depends heavily on the algorithms used to manage and process the data generated by sensor nodes.

The algorithm presented in this context aims to address the challenges associated with WSNs, such as limited energy resources, network scalability, data routing, and data aggregation. This algorithm is designed to optimize the use of resources, improve data reliability, and extend the overall network lifetime.

Overall, an efficient and reliable algorithm for WSNs is essential in ensuring that these networks can operate effectively in a wide range of real-world applications. By addressing energy efficiency, reliability, scalability, and adaptability, this algorithm contributes to the advancement of WSN technology and its successful deployment in various domains. However, further research and testing are necessary to validate its performance under different conditions and use cases.

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An Extensive Study for a Wide Utilization of Green Architecture Parameters in Built Environment Based on Genetic Schemes

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Abstract: *This research undertakes a comprehensive investigation into the application of green architecture parameters within the built environment, employing genetic schemes as a foundational framework. The study aims to explore and analyze a diverse range of parameters associated with sustainable architecture, considering their wide-ranging implications on the design and construction of buildings. Through the integration of genetic schemes, the research seeks to optimize and refine these parameters, addressing challenges and promoting innovative solutions for environmentally conscious urban development. The methodology involves a thorough examination of existing green architecture principles, coupled with the implementation of genetic algorithms to identify optimal combinations and configurations. The study not only contributes to the theoretical understanding of green architecture but also provides practical insights into the incorporation of genetic schemes for enhanced sustainability in the built environment. The findings hold significant implications for architects, urban planners, and policymakers, offering a holistic approach towards fostering a more sustainable and ecologically responsible built environment.*

Keywords: *Genetic Research Algorithm, Ecologically, Building energy management system, Machine Learning, Green Architecture*

INTRODUCTION

The built environment plays a pivotal role in shaping the sustainable future of our planet, and as we face unprecedented environmental challenges, the integration of green architecture parameters becomes increasingly imperative. This study embarks on an extensive exploration of the application of green architecture parameters in the built environment, utilizing innovative genetic schemes to enhance their implementation.

Green architecture, characterized by a commitment to environmental responsibility and resource efficiency, seeks to harmonize human structures with the natural world. This study delves into the multifaceted aspects of green architecture, examining how a comprehensive set of parameters can be strategically employed to foster sustainability in the built environment. The integration of genetic schemes introduces a novel dimension, leveraging evolutionary principles to optimize and refine architectural solutions over time.

The objective of this study is to not only identify key green architecture parameters but also to develop a robust framework that harnesses the power of genetic algorithms to adapt and improve architectural designs. By marrying the principles of sustainability with the efficiency of genetic schemes, we aim to create a dynamic and adaptable approach to building design that goes beyond static, one-size-fits-all solutions.

Throughout this extensive study, we will explore the synergies between green architecture and genetic schemes, emphasizing the potential for a wide utilization of these parameters. This research contributes to the ongoing discourse on sustainable architecture by offering a nuanced understanding of the interplay between genetic algorithms and green design principles. The findings of this study are anticipated to provide valuable insights for architects, urban planners, and policymakers, fostering a collective effort towards a more sustainable and resilient built environment.

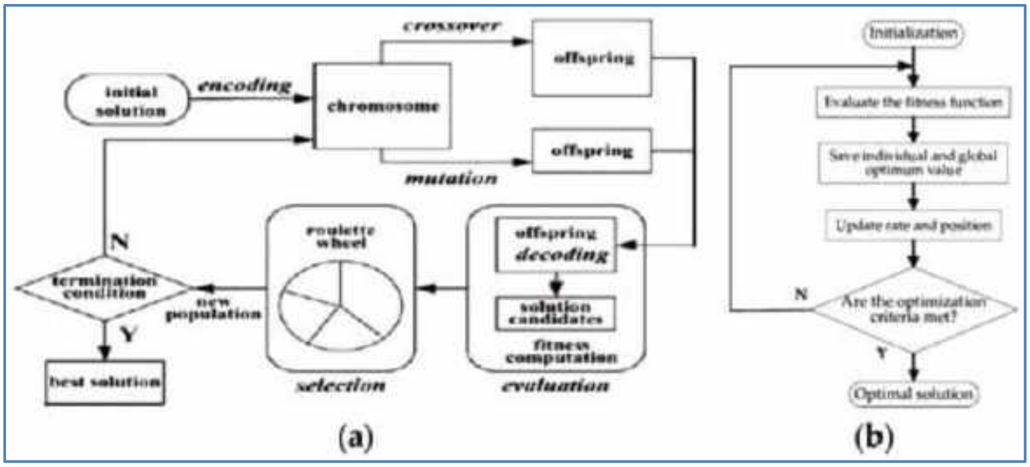

Figure 1 Standard Genetic Algorithm, (a) GA Structure; (b) GA Algorithm.

MOTIVATION

Multi-objective improvement has transformed into a vast research field where important tasks include many types of research that attempt to help designers create powerful frameworks. The creation of all GA parameters helped users and designers to reduce all their problems in any case.

Genetic Algorithm Combinational Approach

A Genetic Algorithm (GA) is a search heuristic inspired by the process of natural selection. It is used to find approximate solutions to optimization and search problems. In the context of combinational optimization problems, GAs are particularly powerful. Combinatorial optimization involves finding the best combination of elements from a finite set.

Here's a general outline of how a Genetic Algorithm works in a combinational optimization setting:

1. Representation:
- Define a representation for your solutions. In combinatorial problems, this could be a binary string, permutation, or any other suitable encoding.
2. Initialization:
- Generate an initial population of solutions randomly or using some heuristics.
3. Evaluation:
- Evaluate the fitness of each solution in the population. The fitness function quantifies how well a solution solves the problem.
4. Selection:
- Select individuals from the population to serve as parents for the next generation. Solutions with higher fitness are more likely to be selected.
5. Crossover (Recombination):
- Combine the genetic material of selected parents to create new solutions (offspring). This is typically done using techniques like one-point crossover, two-point crossover, or uniform crossover.
6. Mutation:
- Apply random changes to some individuals in the population. This helps introduce diversity into the population.
7. Replacement:

- Create a new population by combining parents, offspring, and possibly some unchanged individuals from the previous generation.

8. Termination:

- Repeat the process for a certain number of generations or until a termination condition is met (e.g., finding a satisfactory solution).

9. Solution Extraction:

- Extract the best solution from the final population as the output of the algorithm.

Let's consider an example to illustrate this process. Suppose you're trying to solve the Traveling Salesman Problem (TSP), where the goal is to find the shortest possible route that visits a set of cities and returns to the starting city.

- Representation: Each solution could be a permutation of cities.
- Initialization: Generate a population of random permutations.
- Evaluation: Calculate the total distance of each route in the population.
- Selection: Choose individuals with shorter routes more frequently.
- Crossover: Combine the order of cities from two parents to create offspring.
- Mutation: Occasionally changes the order of cities in a solution.
- Replacement: Create a new population using selected parents and generated offspring.
- Termination: Repeat for a specified number of generations or until convergence.

It's important to note that the effectiveness of a genetic algorithm depends on various factors such as the choice of representation, parameters (crossover rate, mutation rate), and the design of the fitness function. Experimentation and fine-tuning are often necessary to achieve good results for a specific problem.

Genetic algorithms (GAs) are a powerful optimization technique inspired by the process of natural selection. In the realm of computational intelligence, GAs emulate the principles of genetics and evolution to iteratively search and converge toward optimal solutions for complex problems. At their core, GAs maintains a population of potential solutions represented as chromosomes, typically encoded as binary strings. These chromosomes undergo genetic operations such as selection, crossover, and mutation, mimicking the biological processes of reproduction and genetic variation. Through successive generations, the fittest individuals, determined by a fitness function evaluating solution quality, are more likely to pass on their genetic material, gradually improving the overall population's performance. The iterative evolution of solutions enables genetic algorithms to explore vast solution spaces and discover high-quality solutions in a wide range of applications, from combinatorial optimization to machine learning and beyond.

DISCUSSION

Genetic Algorithms (GAs) stand as a powerful paradigm in the realm of evolutionary computing, drawing inspiration from the principles of natural selection and genetics. Developed to tackle optimization and search problems, GAs have demonstrated their versatility across various domains, from engineering and finance to artificial intelligence and biology. This discussion delves into the core concepts of genetic algorithms, their components, applications, strengths, limitations, and prospects.

Foundations of Genetic Algorithms

At the heart of genetic algorithms lies the emulation of natural selection, a fundamental mechanism that propels evolution. Just as living organisms evolve over generations, GAs evolve solutions to problems iteratively. This iterative process comprises a cycle of selection, crossover, mutation, and evaluation.

- Selection: The fittest individuals, determined by their fitness function, are chosen to form a mating pool.
- Crossover: Pairs of individuals exchange genetic information to produce offspring.
- Mutation: Random alterations in the offspring's genetic information introduce diversity.
- Evaluation: The fitness of each individual is assessed based on the defined problem statement.

Components of Genetic Algorithms

- Chromosome Representation: GAs encode potential solutions in the form of chromosomes, often represented as strings of binary digits or real numbers.
- Fitness Function: This crucial component quantifies the effectiveness of a solution, guiding the selection process.
- Population: A collection of individuals represents a population, evolving over successive generations.
- Termination Criteria: Conditions, such as a predefined fitness threshold or a maximum number of generations, determine when the algorithm should halt.

Applications of Genetic Algorithms

GAs have found success in diverse applications, showcasing their adaptability and efficacy.

- Optimization Problems: From logistical challenges to resource allocation, GAs excel in finding optimal solutions in complex, multi-dimensional spaces.
- Machine Learning: Genetic algorithms contribute to feature selection, hyperparameter tuning, and neural network optimization.
- Robotics: In the field of robotics, GAs aid in the evolution of control strategies and the design of robot morphology.
- Economics and Finance: GAs are applied to portfolio optimization, trading strategy development, and risk management.

Strengths of Genetic Algorithms

- Global Optimization: GAs are proficient in searching large solution spaces to find global optima.
- Parallel Search: The parallel nature of genetic algorithms allows them to explore multiple solutions concurrently.
- Adaptability: GAs can adapt to changing environments and dynamic problem landscapes.
- No Requirement for Derivatives: Unlike some optimization algorithms, GAs do not require derivatives, making them applicable to non-continuous and non-differentiable functions.

Limitations of Genetic Algorithms

- Computational Intensity: GAs can be computationally expensive, especially for complex problems or large solution spaces.
- Premature Convergence: There is a risk of converging to suboptimal solutions if the parameters are not appropriately tuned.
- Not Guaranteed to Find Global Optima: While proficient, GAs do not guarantee finding the global optimum, especially in multimodal landscapes.

RESULT

The result of a genetic algorithm (GA) typically consists of the best solution found by the algorithm and its corresponding fitness or objective function value. Additionally, the algorithm may provide information on the evolution of the population over generations, including convergence statistics, diversity measures, and other relevant metrics. Below is an example format for presenting the full result of a genetic algorithm:

Genetic Algorithm Result

1. Best Solution:
- Chromosome: [list of genes or parameters]
- Fitness Value: [numeric value]
2. Evolutionary Progress:

- Number of Generations: [number]
- Convergence History: [plot or table showing how the fitness value changes over generations]
- Diversity Metrics: [information on the diversity of the population over generations]

3. Parameters and Settings:

- Population Size: [number]
- Crossover Rate: [value]
- Mutation Rate: [value]
- Selection Mechanism: [e.g., roulette wheel, tournament selection]
- Crossover Method: [e.g., one-point crossover, two-point crossover]
- Mutation Method: [e.g., bit flip, swap mutation]

4. Termination Condition:

- Maximum Number of Generations: [number]
- Convergence Threshold: [value]

5. Additional Information:

- Computational Time: [duration]
- Hardware/Environment: [specifications]

Table 1

Scheme		Objective	Variables	Area of Research	Application	MO	Software	Country	Authors	Year
1	GA	Energy, Comfort	Set Points	HVAC System	System	WS	TRN-SYS	China	Wang & Jin	2000
		Operational Cost	Constructions, Set Points, Flow Rate	Typical Zone	Environment, System, Continuous	N		UK	Wright & Farmani	2001
		Energy	Window dim.	Envelope	Form	N	DOE-2	USA	Caldas & Norford	2002
		Operational Cost, Comfort	Flow Rate, System Properties	HVAC System	System, Continuous	Y		UK	Wright et al.	2002
		Energy	Construction	Envelope	Environment	N	EXCALIBUR	UK	Coley et al.	2002
		Life Cycle Cost, Energy	Shape, Construction	Envelope	Environment, Form	WS	ASHRAE toolKit, LCA	Canada	Wang et al.	2003
		Energy	Control Parameters	HVAC	System	N	GA Simulation Tool	Theoretical study	Lu et al.	2005
		Life Cycle Cost, Energy	Shape, Construction	Envelope	Environment, Form	Y	ASHRAE toolKit	Canada	Wang et al.	2005
		Energy	Widow Dim., Shading, Set Points	Whole Building	Form	N	Energy +	Theoretical study	Wright & Alajmi	2005
		Energy	System Configuration	HVAC System	System	N		Theoretical study	Wright & Zhang	2005
		Life Cycle Cost, Energy	Shape	Envelope	Form	Y	GenOpt, DAKOTA	Canada	Wang et al.	2005

		Energy	Plant Capacities, Operational Strategy	CHP System	Renewable	N		Theoretical study	Tanaka et al.	2007
		Life Cycle Cost, Energy	Constructions, Ventilation, Renewable	Whole Building	Environment, Renewable	Y	TRN-SYS, COMIS	Belgium	Verbeeck & Hens	2007
		Day light	Constructions, Window Dim., Shading	Envelope	Environment, Form	N	Radiance	japan	Torres & Sakamoto	2007
		Energy, Total Cost	Shape, Construction, Shading	Whole Building	Environment, Form	N	CHEOPS	Tunisia	Znouda et al.	2007
		Construction Cost, Energy	Layout, shape, construction	Whale Building	Form	Y	DOE-2	Portugal	Caldas	2008
		Energy	System Configuration, Operation Strategies	HVAC System	System	N		Theoretical study	Wright et al.	2008
		Total Cost, Energy	Plant Capacities	CHP system	Renewable	Y		Theoretical study	Kayo & Ooka	2009
		Energy	Window Grid	Whole Building	Form	N	Energy +	USA	Wright &Mourshed	2009
		Life Cycle Cost	Shade, Construction	Whole Building	Environment, Form	N	DOE-2	USA	Tuhus, Dubrow	2010
		Energy	Constructions	Envelope	Environment	N	Matlab	India	Sahu et al.	2012
		Construction cost, Humidity	Humidity, materials, location and Thickness	Humidity Level	Environment	Y	transient	Theoretical study	Huang et al.	2012
		Energy	HVAC Zone	Whole Building	System	N	DOE-2	Montreal	Stanescu et al.	2012
		building energy consumption	building profiles and HVAC configurations	Whole Building	Energy	Y	Energy+	Spain	Petriet al.	2014
		Integrated Analysis of Building Designs	component quantity, initial construction cost, labor cost, and equipment cost, daily productivity, environmental emissions	Whole Building	Energy	N	Energy+	USA	Inyim P	2013
		Energy	construction cost, such as material cost, labor cost, and equipment cost, daily	Whole building	Energy	N	Matlab	Canada	Ahmadi et al.	2010

		Energy	Temp& CO_2 concentration & illumination	Whole building	Energy	N		Malaysia	Shaikh et al.	2014
		Index of distribution	building layout	Whole building	Environment	N	ArcGIS Desktop	China	Tong et al.	2016
		Energy	window shading& glass thickness &outdoor air flow	Whole building	Energy	N	Energy+	Spain	Yang et al.	2014
		Cost of Greening	Colling effect, connectivity, cost	Typical zone	Environment	N	(NSGAII,)	Korea	Yoon et al.	2019
		window to wall ratio, from finding	solar radiation, Exterior wall, Interior floor, Glazing type, Zone	Whole building	window-to-wall ratio	Y	SPEA-2	Iran	Zahra Jalali et al.	2019

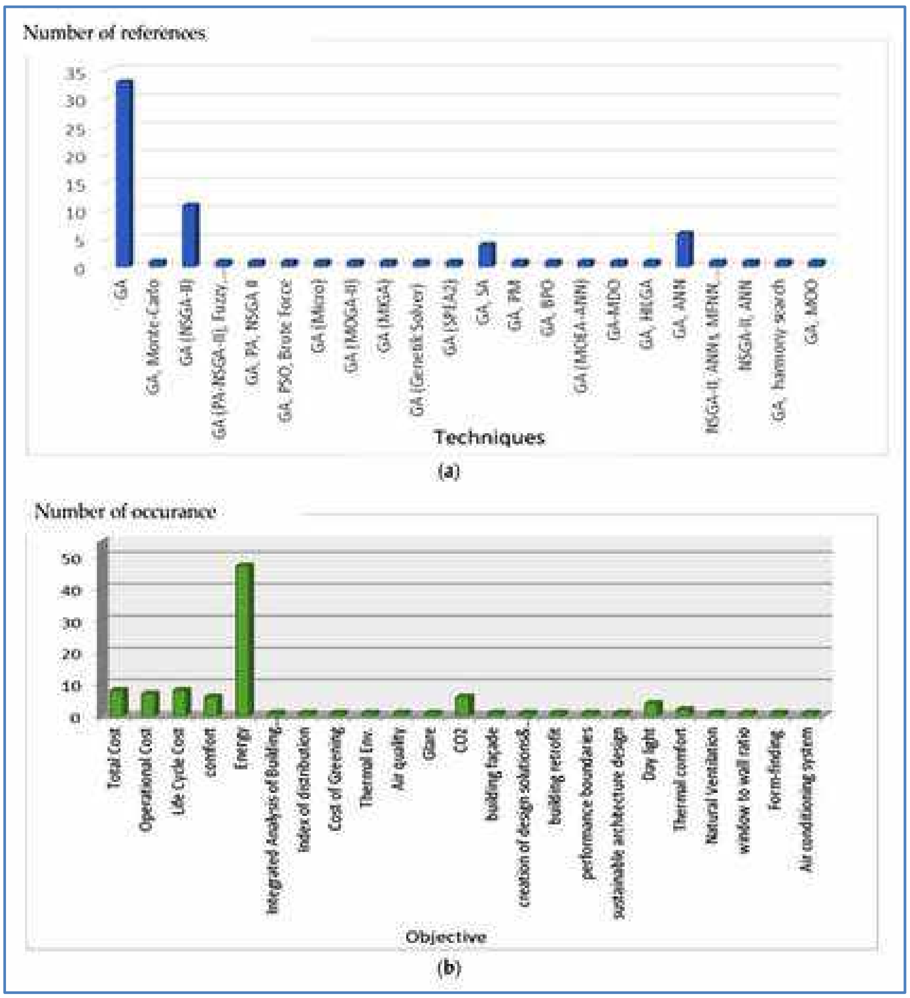

Figure 2

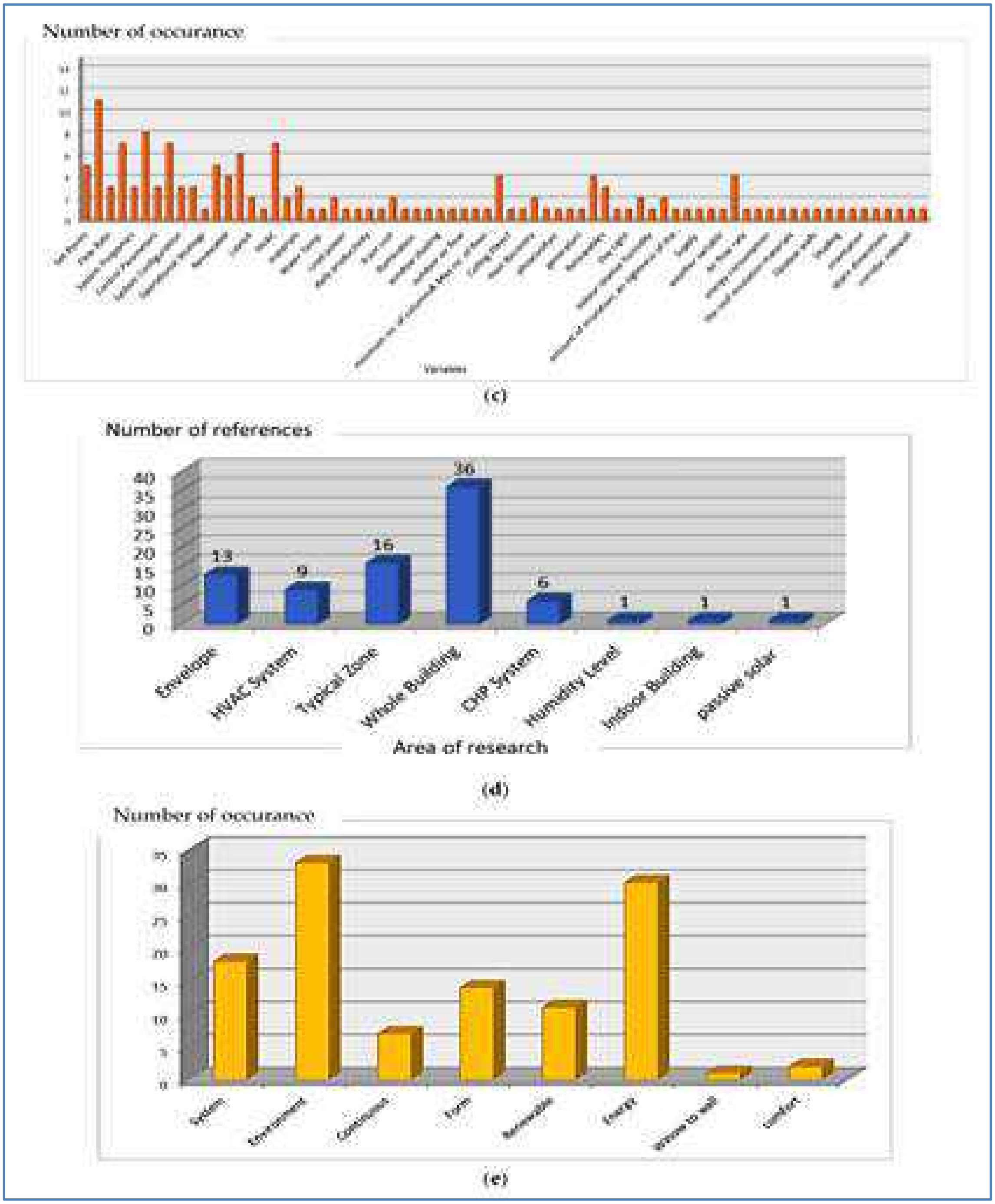
Number of occurance
(c)
Number of references
40
35
30
25
20
15
10
5
0
13
9
16
36
6
1
1
1
Envelope
HVAC System
Typical Zone
Whole Building
CHP System
Humidity Level
Indoor Building
passive solar
Area of research
(d)
Number of occurance
(e)

Figure 3

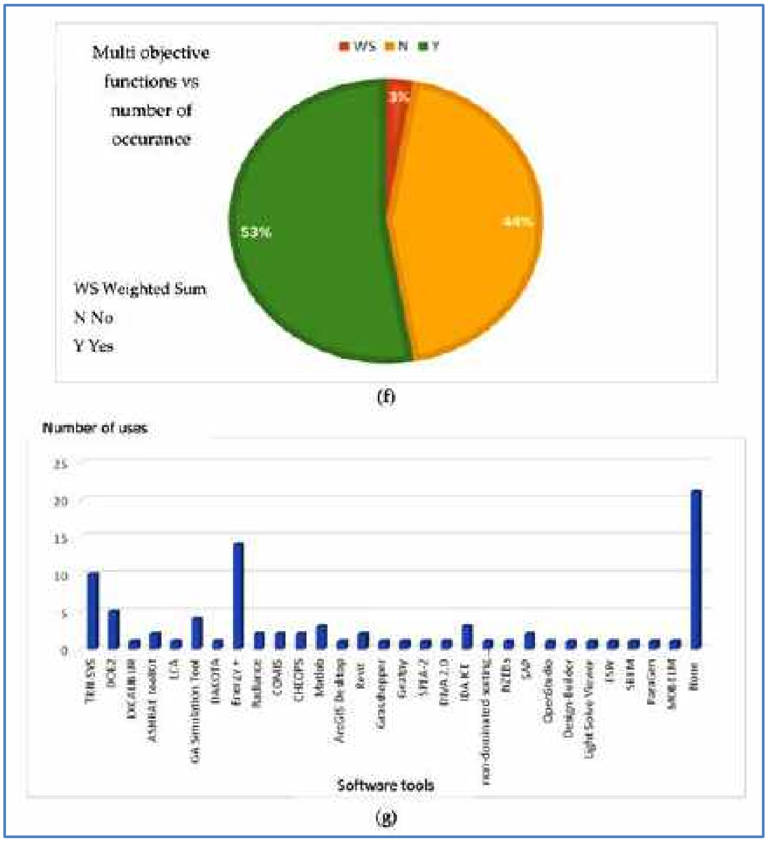

Figure 4

FUTURE SCOPE

As of my last knowledge update in January 2022, Genetic Algorithms (GAs) are a type of optimization algorithm inspired by the process of natural selection. They are used in various fields for solving optimization and search problems. The future scope of Genetic Algorithms is likely to evolve along with advancements in technology and the increasing complexity of problems in different domains. Here are some potential future directions and applications for Genetic Algorithms:

1. Multi-Objective Optimization: Genetic Algorithms are well-suited for solving multi-objective optimization problems where multiple conflicting objectives need to be optimized simultaneously. The future may see an increased focus on developing efficient algorithms and techniques for handling multi-objective optimization challenges in diverse domains.
2. Parallel and Distributed Computing: With the growing availability of parallel and distributed computing resources, the future may witness advancements in parallelizing and distributing Genetic Algorithms. This can lead to faster convergence and the ability to handle larger-scale problems.
3. Hybrid Algorithms: Hybrid algorithms, combining Genetic Algorithms with other optimization techniques or machine learning methods, can provide enhanced performance. The integration of GAs with deep learning, reinforcement learning, or other optimization algorithms may be explored for improved problem-solving capabilities.
4. Adaptive and Dynamic Systems: Developing Genetic Algorithms that can adapt to dynamic and changing environments is an ongoing area of research. Future work may focus on creating algorithms that can dynamically adjust their parameters, mutation rates, and selection strategies based on the characteristics of the problem at hand.

5. Explainable AI and Interpretability: As AI systems become more integrated into real-world applications, the need for interpretability and explainability is crucial. Future Genetic Algorithms may incorporate mechanisms to provide clearer insights into the decision-making process, making them more transparent and trustworthy.
6. Biomedical and Healthcare Applications: Genetic Algorithms can be applied to various challenges in the biomedical and healthcare domains, such as drug discovery, treatment optimization, and personalized medicine. The future may bring advancements in using GAs for solving complex biological and medical problems.
7. Autonomous Systems and Robotics: Genetic Algorithms have the potential to optimize the behavior and decision-making processes of autonomous systems and robots. Future applications might include the use of GAs in swarm robotics, path planning, and task allocation for autonomous agents.
8. Big Data Optimization: With the increasing availability of large datasets, Genetic Algorithms may find applications in optimizing and mining big data. Efficient algorithms that can handle high-dimensional and large-scale optimization problems could be a focus of future research.

It's essential to stay updated with the latest research literature and technological advancements to get insights into the evolving trends and applications of Genetic Algorithms. The field of optimization and evolutionary computation is dynamic, and new opportunities and challenges are likely to emerge in the future

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AI Enabled Human Computer Interaction

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***Abstract**: Traditional processors are not well-suited for tasks that require efficient, real-time decision-making and adaptation. Neuromorphic architectures, on the other hand, can process information in a massively parallel manner, mimicking the parallelism found in the human brain. This allows for faster and more energy-efficient computations. Neuromorphic computing is a promising solution for these challenges because it mimics the structure and functionality of the human brain.*

***Keywords**: Neuromorphic computing, Edge computing, Edge intelligence, Edge devices, Cybersecurity*

INTRODUCTION

Neuromorphic computing also enables edge intelligence, which means AI algorithms can run directly on the devices that interact with the users, instead of relying on cloud-based systems. This enables real-time, responsive interactions without the need for constant internet connectivity. For example, a vehicle with neuromorphic computing capabilities can have responsive voice control without relying on a cloud-based voice recognition system.

One key advantage of neuromorphic computing is its ability to learn from small amounts of data. Traditional AI systems typically require large amounts of labeled data to train, but neuromorphic systems can learn with just a few examples, similar to how humans learn. This allows for more efficient and faster training of AI models.

Overall, neuromorphic computing holds great potential for advancing AI capabilities in smart products and services. By taking inspiration from the human brain, we can design AI systems that are more energy-efficient, adaptive, and responsive, meeting the increasing expectations of users in the future.

Emerging Technologies

Edge computing also opens up possibilities for new applications and use cases that were previously not feasible due to latency and connectivity issues. For example, autonomous vehicles can leverage edge computing to process sensor data in real-time and make split-second decisions without relying on a cloud server.

However, there are challenges to implementing edge computing. It requires powerful processors and AI chips capable of running complex algorithms on resource-constrained devices. It also requires efficient data management and synchronization between edge devices and the cloud.

Nonetheless, as AI continues to advance and demand for real-time processing grows, edge computing is likely to play a crucial role in enabling AI everywhere. It offers a balance between performance, privacy, and connectivity, allowing smart products to integrate AI seamlessly into our daily lives.

WORKING MODEL

The term Neuromorphic Computing is used to describe a variety of computational technologies inspired by the brain. We're focused on systems using spiking neural networks, which we see as the most application-ready approaches in neuromorphic computing today.

Spiking neural networks are built from two components: the neuron model and the synapse model. The neuron model emulates the spiking activity of a biological neuron using a digital circuit. That means the neuron either fires a spike, or it's silent. In most computing systems, a large portion of energy is used moving information between processing cores or in and out of memory. But in a spiking neuron model, when a neuron is not spiking, it does not move any information and uses very little energy. SNNs can include millions of neurons, each working independently to aggregate input values and fire output spikes.

How do spiking neurons work?

A neuron receives input signals from sensors and other neurons over time. The neuron adds the inputs to its membrane potential (V) and subtracts a fraction of the value from the previous timestep (leak). If the integrated input values are large enough, V exceeds the threshold, causing the neuron to fire an output spike and reset V back to zero.

How do spiking networks learn?

Spike-timing dependent plasticity (STDP) enables SNNs to learn. Under STDP, the strength of each synapse is adjusted based on the precise time each connected neuron fires a spike. STDP works by learning associations in the input data. When the sending neuron spikes before the receiving neuron, the synapse is strengthened. If the two neurons spike in reverse order, the synapse is weakened. Variations on STDP can support many types of machine learning, including supervised learning, reinforcement learning, and other AI algorithms.

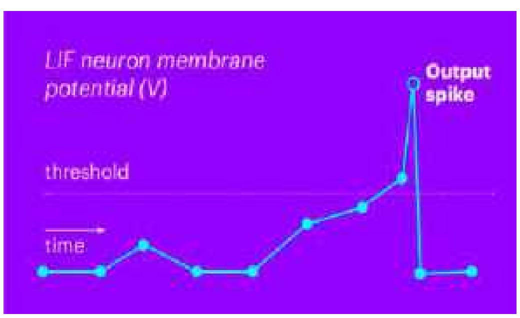

Figure 1 Working of spiking neuron

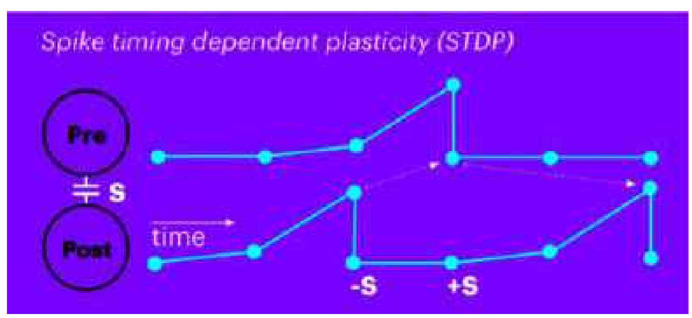

Figure 2 Learning of spiking networks

This approach is very different from the artificial neural networks (ANNs) powering most AI systems today. In those systems, nodes map input values to outputs with simple activation functions. ANNs don't process changing input signals continuously. Instead, input values are sent to the network in batches and the activation of the entire network is re-computed for each set of inputs in a batch. That can require trillions of operations per second, which is why current AI models run on power-hungry GPUs.

In spiking neural networks, connecting neurons is the job of the synapse model. The synapse model takes output spikes from each neuron and routes them to the inputs of other neurons. The synapse scales the signal by a factor called synaptic strength. The SNN learns from experience and adapts to an environment by adjusting synaptic strengths. Again, this is very different from ANNs which use a method called backpropagation to optimize connection strengths for a given problem.

APPLICATIONS

Responsive Voice Control for Smart Vehicles

Owners of smart vehicles have high expectations: they want functions like self-parking and summoning features, but they also want natural, seamless interfaces to control their interactions with the car. Voice-based controls, along with implicit intent recognition, can provide greater personalization and smoother interactions. They also help unclutter the car's dashboards and displays.

Neuromorphic technologies make efficient onboard AI possible. In a recent collaboration with an automotive client, we demonstrated that spiking neural networks running on a neuromorphic processor can recognize simple voice commands up to 0.2 seconds faster than a commonly used embedded GPU accelerator, while using up to a thousand times less power. This brings truly intelligent, low latency interactions into play, at the edge, even within the power-limited constraints of a parked vehicle.

AI Powered by Brain-Like Computing Architectures

Scientific understanding of how the brain works is not yet complete, but it is mature enough to uncover many core principles of neural computation. Researchers and engineers have worked together to develop algorithms and processors that replicate some of those core principles and mechanisms.

An average human brain contains 80 to 100 billion neurons that are each highly efficient. Activity in the whole brain is much sparser than traditional computer architectures. Complex sequences of spikes in organic nerve fibers are nothing like the 64-bit silicon data buses we see in general-purpose processors. In the brain, each neuron works asynchronously to provide massive parallelism— many different processes all happen at once—and to adapt quickly to rapid changes in the environment.

In the past several years, neuromorphic devices with these properties have become a reality, accelerating practical solutions to the increasing demand for smart products. These properties of biological brains are at the core of brain-like computing, which provides energy efficiency as Neuromorphic systems are several orders of magnitude more energy efficient than general purpose computing architectures.

Adaptive Control for Semi-Autonomous Robots

Many promising robotics applications need precise motor control before they're ready for practical use. Precision agriculture drones need to be able to target specific plants. Medical telepresence robots must be capable of navigating safely around patients and other healthcare workers. Current approaches work well for highly repetitive movements and controlled circumstances. But designing a robot with precise motor control that can also adapt to work in a variety of situations and contexts has so far proven out of reach.

Recent developments show promise in this area. Adaptive control algorithms inspired by the motor control structures of biological brains have shown an impressive ability to move precisely and compensate for a variety of unexpected conditions. These neuromorphic algorithms can also rapidly adapt to new applications. We're working with researchers from the Open University of Israel and ALYN Hospital to apply these algorithms to wheelchair-mounted assistive robot arms. These robots must be extremely precise and also adaptable to a range of daily tasks such as feeding and opening doors.

CHALLENGES IN NEUROMORPHIC COMPUTING

However, powering these increasingly sophisticated smart products presents some challenges. One key challenge is providing sufficient power to support the advanced features and capabilities of these products. Smart products often require more power than traditional devices, as they incorporate multiple sensors, processors, and connectivity technologies.

To address this challenge, advancements in battery technology are crucial. Batteries need to be smaller, lighter, and more efficient to meet the power demands of smart products. This requires advancements in materials and design to increase energy density and extend battery life. Additionally, there is a need for faster charging technologies to minimize downtime and provide convenience to users.

Another challenge is managing power consumption. As smart products become more interconnected and perform more tasks, their power consumption increases. This can lead to shorter battery life and frequent recharging, which may inconvenience users. To overcome this, manufacturers need to focus on optimizing power usage through efficient software algorithms and hardware design.

In some cases, smart products can draw power from external sources, such as electricity grids or connected infrastructure. This can provide a continuous power supply and reduce reliance on batteries. However, it requires the development of standardized power interfaces and infrastructure to support these smart products.

Overall, powering increasingly sophisticated smart products requires advancements in battery technology, power management, and infrastructure. As these advancements continue to evolve, we can expect to see even more innovative and capable smart products entering the market.

To overcome these limitations, the concept of edge computing has emerged. Edge computing brings AI capabilities closer to the devices themselves, reducing the reliance on offsite computing power and improving real-time performance. It involves processing data and running AI algorithms at the edge of the network, directly on the devices or on nearby servers.

By bringing AI to the edge, devices can make faster and more intelligent decisions without needing to rely on a constant network connection. This not only improves performance but also enhances privacy and cybersecurity since data doesn't need to be sent outside the device.

CONCLUSION

Recent advances in training neuromorphic systems have enabled rapid learning from very little data— near-biological capabilities which are beyond most conventional AI systems. The term Neuromorphic Computing is used to describe a variety of computational technologies inspired by the brain. The high cost of existing systems is a significant barrier; we expect the brain-inspired neuromorphic solution to allow a much lower cost robot to support the same range of tasks.

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CIVIL ENGINEERING DIVISION

CV_IEC 2023 TV 011

Exploring the Role of Machine Learning Algorithms for Smart Commuting in Smart Cities

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***Abstract**: Cities are developing with boundless boundaries, Policymakers and urban organizers are investigating ways to address smart Infrastructure in smart cities such as smart water management, Environmental monitoring, Green spaces, smart waste management, smart commuting, smart solution to traffic congestion and hassle-free day-by-day transportation. Smart commuting may be a key component of the smart framework, which points to making strides in efficiency, security, sustainability, and by and large quality of life in urban and country regions. Smart commuting leverages innovation and data-driven solutions to upgrade different angles of the transportation framework. Development in innovation such as IoT, Artificial intelligence, and Machine learning has invented various solutions for smart commuting in smart cities. Smart cities contribute capital in the present day and effective public transportation frameworks, including buses, metro, and rail systems. These frameworks regularly incorporate Traffic Monitoring, real-time tracking, ticket sales prediction, remote door unlocking, seat availability prediction and other advanced innovations to make commuting more helpful.Our paper investigate and discuss various ML algorithms and techniques to address traffic congestionproblems in smart cities using traffic prediction methods.*

***Keywords**: Classifiers;tomtom; Precision; Recall; TP Rate; FP Rate; Bayes; Naïve Bayes; Random Forest.*

INTRODUCTION

Machine learning algorithms can be very effective in designing models for solving traffic congestion problems. They can help with various aspects of traffic management and optimization by analyzing historical data, making predictions, and making recommendations.

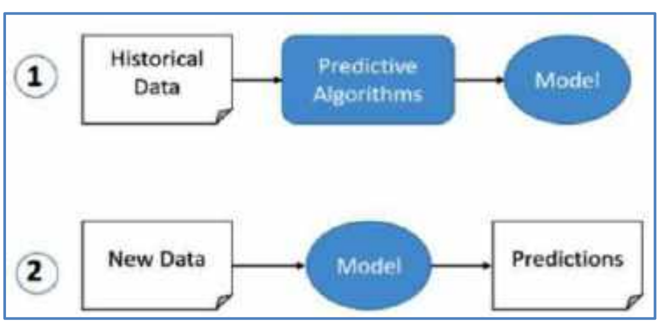

Figure 1 Model Devising

Some of the common cases are Traffic predictions, Traffic flow management, Demand Management, Parking optimization. Traffic prediction and control systems in smart cities are essential for managing urban congestion and improving overall transportation efficiency. Various machine learning and IoT-based models have been developed to address these challenges. Some of the existing approaches in this field are shown below.

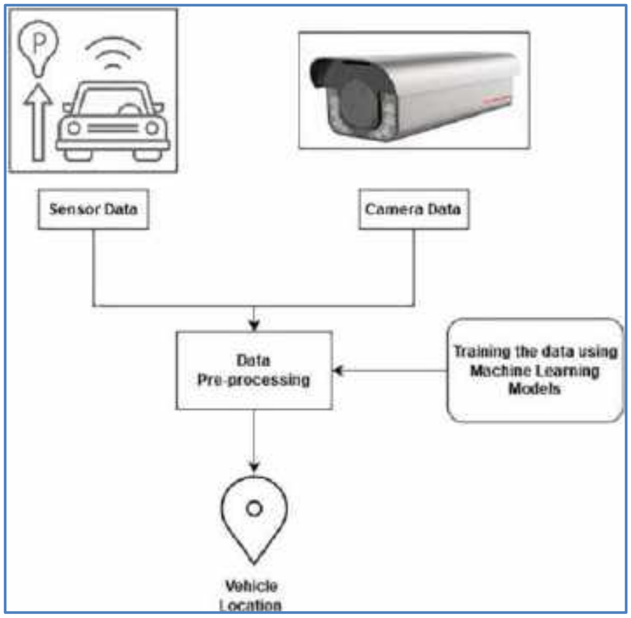

Figure 2 Data Processing Model (Courtesy : peerj.com)

IoT devices and sensors deployed across road networks can collect real-time data on traffic flow, vehicle speeds, and occupancy. By analysing this data, traffic prediction models can provide accurate and up-to-date traffic forecasts. Using real-time traffic data collected from IoT sensors, adaptive traffic signal control systems can adjust signal timings based on current traffic conditions. These systems aim to minimize congestion and improve traffic flow efficiency. By combining machine learning-based traffic prediction models with control algorithms, predictive traffic control systems can anticipate traffic conditions and adjust signal timings proactively. These systems help prevent traffic jams before they happen. Predictive machine learning models for smart transportation systems integrate data from various sources, including traffic cameras, GPS devices, and weather forecasts, to predict traffic congestion, optimize routing transit routes, increase the efficiency of public transportation, and improve the overall transportation experience. By analysing real-time and historical data, these models offer solutions such as traffic rerouting, recommending efficient logistics routes, forecasting public transport demand, improve security, revolutionizing the way transportation is managed and transform urban mobility for the better.

MACHINE LEARNING MODELLING

The machine learning algorithm includes the following steps for analysis.

1) Data Collection: IoT devices collect data from various sensors, such as traffic cameras, GPS devices, motion, or light sensors. The data can be collected continuously or at regular intervals and transmitted to a central server or cloud platform for processing.

2) Preprocessing: Raw data collected from IoT devices often requires preprocessing to remove noise, handle missing values, or normalize the data. This step ensures that the data is in a suitable format for further analysis.

3) Feature Extraction:Feature extraction involves identifying and extracting relevant features from the pre-processed data. Features are specific measurements or characteristics that capture the essential information for the intended analysis or application. For example, in a smart commuting, features could include speed, Num_Reads, Hour, Zip Codes, Region, Bus Count.

4) Selection and Dimensionality Reduction: Depending on the application, it may be necessary to select a subset of features or reduce the dimensionality of the data. This step aims to eliminate irrelevant or redundant features, improving computational efficiency and reducing the risk of overfitting in machine learning models.

5) Data Integration: In some cases, data from multiple IoT devices or sources may need to be integrated to derive meaningful insights. Integration can involve combining data from various sensors, time synchronization, or merging data from different locations or devices.

6) Data Analytics: Once the relevant features have been extracted and processed, various analytics techniques can be applied to gain insights or make predictions. This can include statistical analysis, data mining, machine learning algorithms, or artificial intelligence models.

7) Visualization and Reporting: The processed data and analytics results can be visualized using charts, graphs, or dashboards to provide a clear representation of the information. Visualizations aid in understanding patterns, trends, or anomalies in the data. Additionally, reports or alerts can be generated to notify users or stakeholders of important findings or events.

8) Real-Time Processing: IoT systems often require real-time processing to enable timely decision-making or immediate actions based on the collected data. Real-time processing involves analysing data as it arrives and generating responses or triggers in near real-time.

9) Feedback Loop: The insights or actions derived from the processed data can be used to provide feedback and optimize the IoT system's performance. For example, adjusting sensor thresholds, improving predictive models, or triggering automated responses based on the analysis results.

Overall, feature extraction and data processing using IoT play a crucial role in transforming raw data collected from IoT devices into meaningful information and actionable insights for various applications such as smart homes, industrial monitoring, healthcare, or environmental monitoring and traffic management. Using Rank and percentile approach for the feature selection the following six features were found to be most relevant attributes for the data analysis and modelling.

Table 1 Rank and percentile

Sl. No.	**Attribute Selection**		
	Attribute Name	**Rank**	**Percent**
1	Speed	1	95.00
2	Num Reads	1	95.00
3	Hour	3	85.00
4	Zip Codes	3	85.00
5	Region	5	55.00
6	Bus Count	5	55.00

To analyse different prediction models, performance metrics such as TP Rate, FP Rate, precision and recall were used. These parameters are derived from a confusion matrix that shows the different ways in which the classification model gets confused when making predictions.

True Positive (TP) as in [11]refers to the number of predictions where the classifier correctly predicts the positive class as positive.

True Negative (TN)refers to the number of predictions where the classifier correctly predicts the negative class as negative.

False Positive (FP)refers to the number of predictions where the classifier incorrectly predicts the negative class as positive.

False Negative (FN)refers to the number of predictions where the classifier incorrectly predicts the positive class as negative.

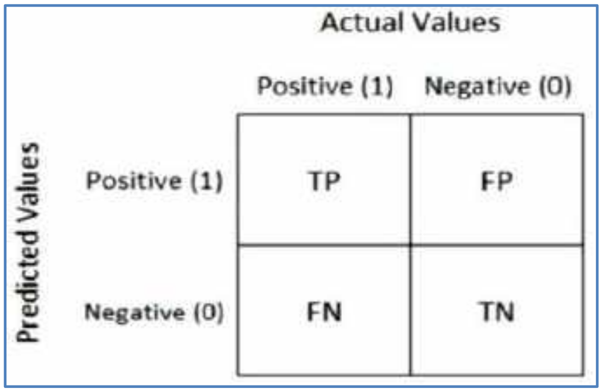

Figure 3 Confusion Matrix

ML PREDICTIVE MODEL ANALYSIS (LOW TRAFFIC)

Predictive machine learning models for smart transportation provide insights and data-driven solutions to solve complex urban mobility challenges. These models leverage large data sets from traffic sensors, GPS devices, and a variety of sources to predict traffic patterns, optimize routes, and improve public transportation systems. By leveraging real-time and historical data, they enable more efficient traffic management, reduce congestion, improve user experience, and promote sustainable transportation practices. Furthermore, these predictive models have the potential to play a central role in shaping future transportation policies and infrastructure developments for smarter and more accessible cities. The Weka tool is used to analyze Nine different classification machine learning algorithms. For the analysis of various predictive models, the performance measure like TP Rate, FP Rate, Precision and Recall were being used. Udaipur data set extracted from tomtom Server as in [12]was used with following features to analyze Machine Learning algorithms.

Table 2 Classifiers Performance Measure

Sl. No.	**Class Label: Low Traffic**				
	Classifier	**TP Rate**	**FP Rate**	**Precision**	**Recall**
1	Bayes Net	0.976	0.000	1.000	0.976
2	Naïve Bayes	0.971	0.060	0.996	0.971
3	Logistic	0.972	0.134	0.990	0.972
4	SM0	0.987	0.164	0.988	0.987
5	IBK	0.991	0.328	0.977	0.991
6	KStar	0.991	0.328	0.977	0.991
7	MultiClass Classifier	0.972	0.134	0.990	0.972
8	Random Forest	1.000	0.179	0.987	1.000
9	Random Tress	0.994	0.284	0.980	0.994

TP Rate as in[13]is used to measure the percentage of actual positives which are correctly identified by modelAccording to the performance measure TP rate for class label: Low Traffic it was found that the highest true positive rate was of the classifier Random Forest with value 1, followed by 0.994, 0.991 and 0.991 of Random Tree, IBK and KStar respectively whereas the lowest TP rate was found to be of the classifiers Naïve Bayes, Logistic and

Multiclass with values 0.971,0.972 and 0.972 respectively. Overall, it can be interpreted the most appropriate classifier based on the performance measure TP rate is found to be Random Forest. The "Random Forest" classifier appears to perform exceptionally well, with a TP Rate of 1.000, indicating perfect performance in distinguishing "Low Traffic" instances.

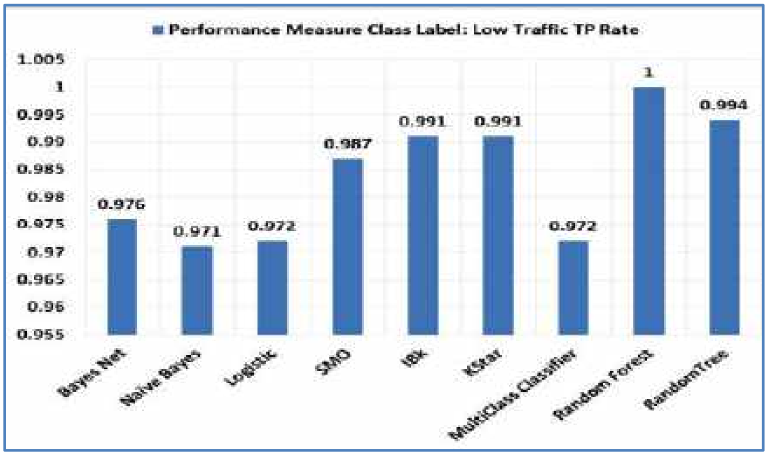

Figure 4 TP Rate for Class Label: Low Traffic

FP Rate also known as Type - I error is used to measure the percentage of actual positives which are incorrectly identified by model.Based on the performance measure FP rate for class label: Low Traffic it was found that the lowest false positive rate was of the classifier Bayes Net with value 0.000, followed by 0.06 of Navie Bayes whereas the highest FP rate was found to be of the classifiers IBK and KStar with values 0.328 each. Overall, it can be interpreted the most appropriate classifier based on the performance measure FP rate is found to be Bayes Net with lowest FP rate value.

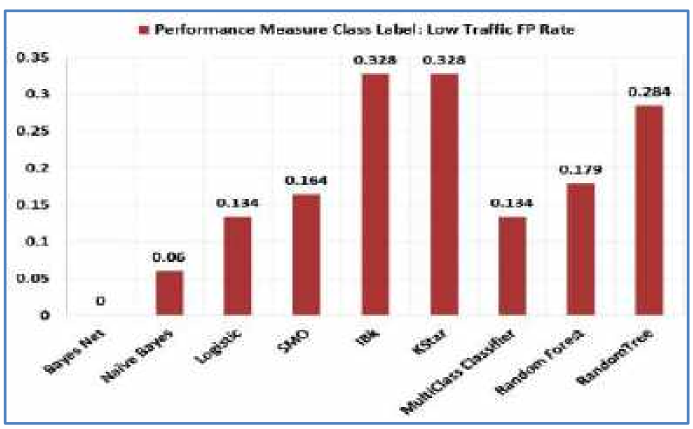

Figure 5 FP Rate for Class Label: Low Traffic

Precision as in [14] is the quality of a positive prediction made by the model. Precision refers to the number of True Positives divided by the total number of Positive predictions.

$$\text{Precision} = \frac{T_P}{T_P+F_P} \qquad (1)$$

According to the performance measure precision for class label: Low Traffic it was found that the highest precision value was of the classifier Bayes Net with value 1, followed by 0.996, 0.99 and 0.99 of Naïve Bayes, SMO and

Multiclass classifier respectively whereas the lowest precision value was found to be of the classifiers IBK and KStar with values 0.977 each. Overall, it can be interpreted the most appropriate classifier based on the performance measure precision is found to be Bayes Net.

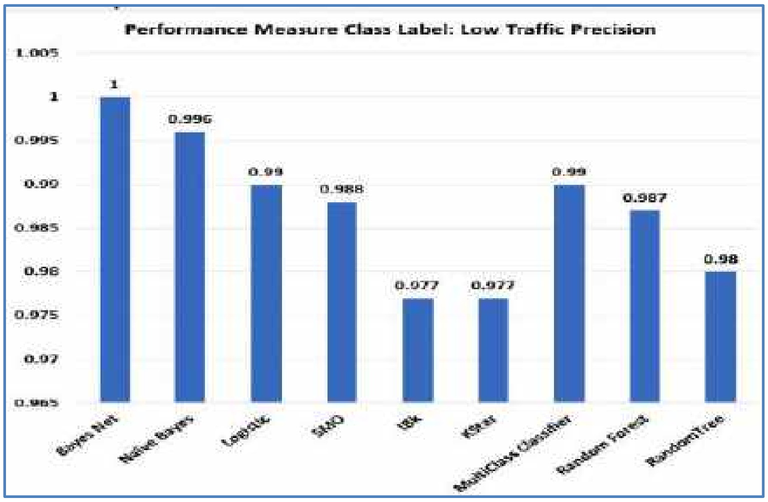

Figure 6 Precision for Class Label: Low Traffic

Recall as in[15]is the measures of how well a machine learning model can detect positive instances. It is also called as Sensitivity.Sensitivity refers to the number of true positives divided by the sum of True Positives and False Negatives. The model with high Sensitivity will have significantly fewer False Negatives.

Sensitivity or Recall = $\frac{T_P}{T_P + F_N}$ (2)

Based on the performance measure recall for class label: Low Traffic it was found that the highest recall value was of the classifier Randon Forest with value 1.00, followed by 0.991 and 0.991 of IBK and KStar respectively whereas the lowest recall value was found to be of the classifiers Navie Bayes, Logistic and Multiclass with values 0.971, 0.972 and 0.972 respectively. Overall, it can be interpreted the most appropriate classifier based on the performance measure recall is found to be Random Forest.

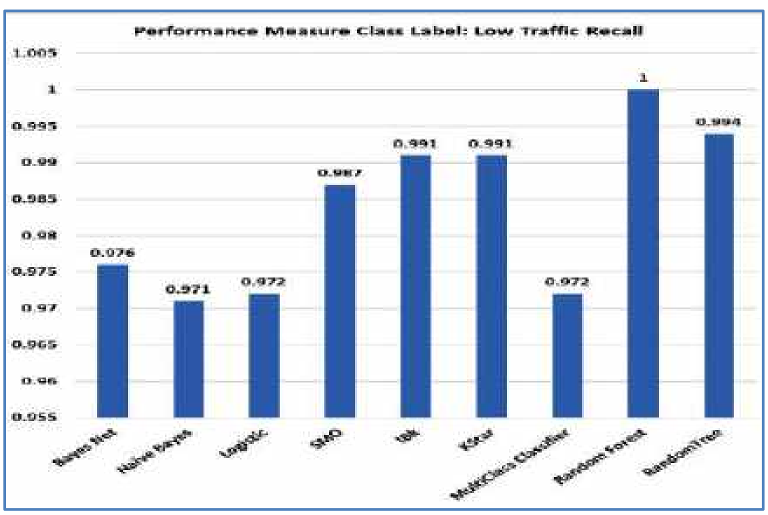

Figure 7 Recall for Class Label: Low Traffic

ML Predictive Model Analysis (High Traffic)

Sl. No.	Class Label: High Traffic				
	Classifier	**TP Rate**	**FP Rate**	**Precision**	**Recall**
1	Bayes Net	1.000	0.024	0.753	1.000
2	Naïve Bayes	0.940	0.029	0.700	0.940
3	Logistic	0.866	0.028	0.690	0.866
4	SM0	0.836	0.013	0.824	0.836
5	IBK	0.672	0.009	0.849	0.672
6	KStar	0.672	0.009	0.849	0.672
7	MultiClass Classifier	0.866	0.028	0.690	0.866
8	Random Forest	0.821	0.000	1.000	0.821
9	Random Tress	0.716	0.006	0.716	

According to the performance measure TP rate for class label: Heavy Traffic it was found that the highest true positive rate was of the classifier Bayes Net with value 1.0, followed by 0.94 , 0.866 and 0.866 of Naïve Bayes, Logistic and Multiclass respectively whereas the lowest TP rate was found to be of the classifiers IBK and KStar with values 0.672 each. Overall, it can be interpreted the most appropriate classifier based on the performance measure TP rate is Bayes Net.

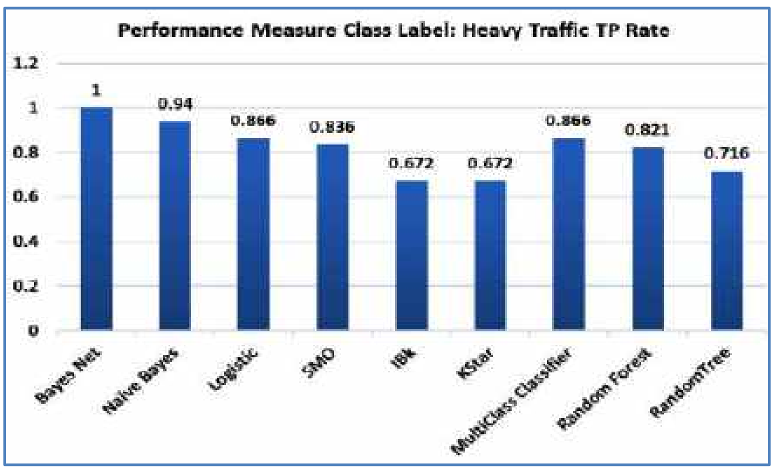

Figure 8 TP Rate for Class Label: Heavy Traffic

Based on the performance measure FP rate for class label: Heavy Traffic it was found that the lowest false positive rate was of the classifier Random Forest with value 0.00, followed by 0.006 of Random Tree whereas the highest FP rate was found to be of the classifiers Naïve Bayes, Logistic and Multiclass with values 0.029, 0.028 and 0.028 respectively. Overall, it can be interpreted the most appropriate classifier based on the performance measure FP rate is found to be Random Forest with lowest FP rate value.

According to the performance measure precision class label: Heavy Traffic it was found that the highest precision value was of the classifier Randon Forest with value 1.0, followed by 0.889, 0.849 and 0.849 of Random Tree, IBK and KStar respectively whereas the lowest precision value was found to be of the classifiers Logistic, Multiclass and Naïve Bayes with values 0.69, 0.69 and 0.7 respectively. Overall, it can be interpreted the most appropriate classifier based on the performance measure precision is found to be Random Forest.

Based on the performance measure recall class label: Heavy Traffic it was found that the highest recall value was of the classifier Bayes Net with value 1.0, followed by 0.94 , 0.866 and 0.866 of Naïve Bayes, Logistic and Multiclass respectively whereas the lowest recall value was found to be of the classifiers IBK and KStar with values 0.821

each. Overall, it can be interpreted the most appropriate classifier based on the performance measure recall is found to be Bayes Net.

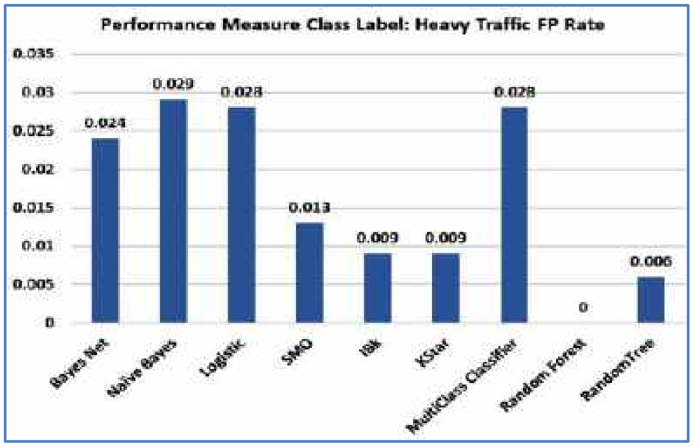

Figure 9 FP Rate for Class Label: Heavy Traffic

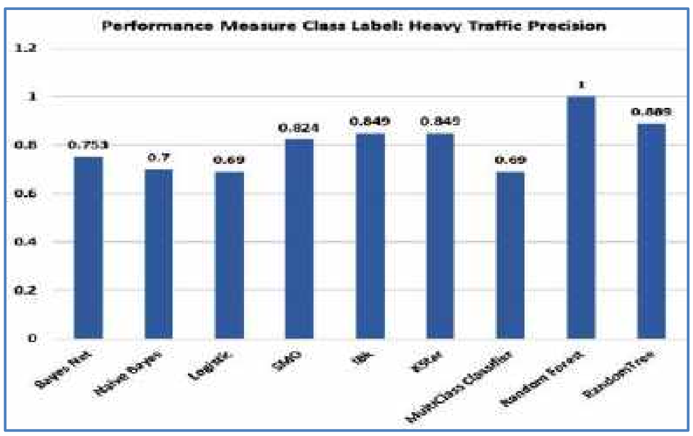

Figure 10 Precision for Class Label: Heavy Traffic

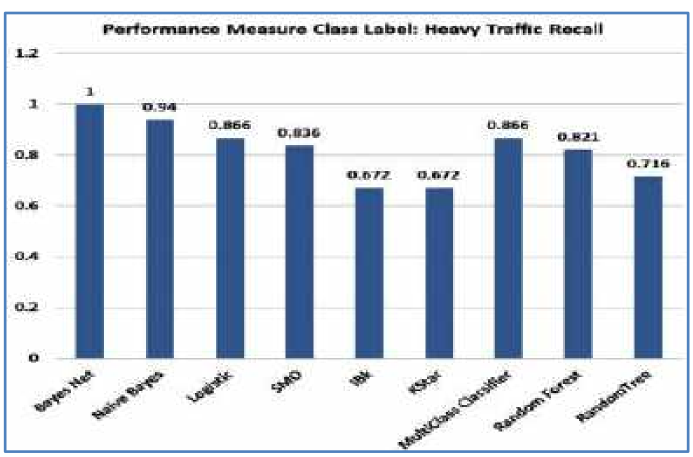

Figure 11 Recall for Class Label: Heavy Traffic

SUMMARY

The major findings related to the comparative analysis of machine learning predictive models using Weighted Sum Model (WSM) approach is shown below.

1. Random Forest is the best and most appropriate classifier for traffic congestion control and traffic flow as it is having the highest score of 0.98.

2. Bayes Net is the second most appropriate algorithm with score of 0.6530

3. The third best classifier being identified is SMO with score of 0.4871.

For predicting the Udaipur traffic flow Random Forest is the most appropriate algorithm.

Table 3 Weighted sum model

Classification Models	Score (Weighted Sum)
Random Forest	0.9800
Bayes Net	0.6530
SMO	0.4871
Random Tree	0.4110
Naïve Bayes	0.3111
KStar	0.1745
Logistic	0.1406
MultiClass Classifier	0.1406
IBK	0.0679

CONCLUSION AND FUTURE WORK

Machine learning algorithms provide powerful capabilities for a variety of tasks when provided with high-quality, validated data. Maintaining model accuracy over time requires continuous model monitoring and adjustment. This approach includes real-time data analysis, model retraining as data evolves, and automatic deployment of updated models to ensure sustained performance and relevancy. A K-fold cross-validation approach is required. A fold is a set of records in a dataset, and k is the number of folds that affects the performance and reliability of the model. In general, higher values of k increase variance and computational cost, but decrease bias.Furthermore, Data Analysis with class label of different traffic densities apart from Low Traffic and high traffic will increase the accuracy and reliability of the model.

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Bamboo Research and Training Centre

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***Abstract**: Based on the Sustainable, Bio remediation, eco-friendly, Low cement landscape, and creating local jobs the project, Bamboo Research and Training Centre was awarded to the Shift studio, New Delhi for Architectural planning led by Ar. Sanjay Prakash and designed by Skeleton Consultants Pvt Ltd. NOIDA. The project consists of Academic block and Canteen block. The buildings are located in Chandrapur, Maharashtra. Geometrical configuration of the buildings is of different type like inclined, curve and circular roof. The material used for these structures are Bamboo, RCC, Steel and Rammed earth. The modelling, analysis and design of the structure were done using STAAD Pro software and properties of the bamboo were manually calculated and were input in STAAD. Out of different species of bamboo available, 50mm diameter bamboo was chosen due to the ease of bending as per architectural view and 100 mm diameter bamboo was selected for straight members. The total built-up area is (144076 Sq. ft) 13385 Sq. m.*

***Keywords**: Bamboo; Sustainable construction; Eco-friendly; Rammed Earth Walls; B.bambos (Balcooa); D.strictus (Stocksii).*

INTRODUCTION

With the change in construction techniques, and the promotion of more sustainable construction and the use of ecofriendly materials in the advancement of civil and structural engineering construction techniques, Bamboo is no more seen as a poor man Timber. Nor it is considered as inferior and fit for only temporary construction. In its natural form, bamboo as a construction material is traditionally associated with cultures of South Asia, East Asia and South Pacific. Due to a distinctive rhizome-dependent system, bamboos are one of the fastest-growing plants in the world and their growth is three times faster than most of her species of plants. They are renewable and extremely versatile resource with multi-purpose usage.

Some of the latest bamboo constructions all over the world include: Bamboo Research & Training Center – Chandrapur;India Pavilion Expo in Shanghai; Green School, Bali; KontumIndochine Café,Guadua; Bamboo Car Park, Amsterdam; Sesa Goa Pavallion.

Bamboo has certain advantages and limitations over other construction materials:

Advantages:

1. Bamboo is a versatile resource possessing high strength-to-weight ratio and cost ratio and offers considerable ease in working with simpler tools.
2. Resilience (elasticity) coupled with light weight makes bamboo an ideal material for housing in disaster prone/earthquake prone area.
3. The bamboo culm has a tubular structure consisting of nodes and inter-nodes. In the internodes the cells are axially oriented while the nodes provide the transverse interconnections.
4. With good physical and mechanical properties, low shrinkage and good average density, bamboo is well suited to replace wood in several applications
5. Bamboo is highly flexible. During its growth, it can be trained to grow in unconventional shapes. Thus after harvest it can be bent and utilized in archways and other curved areas.

6. In each of its nodes, bamboo has a dividing or transverse wall that maintains strength and allows bending thus preventing rupturing when bent. Because of this fantastic characteristic a bamboo construction offers superior earthquake-resistance.
7. Bamboo is also extremely lightweight thus it requires simpler tools for construction and construction is also faster.
8. Bamboo is non-polluting and does not have crusts or parts that can be considered waste. Instead of adding to the problems of polluting land-fills like conventional building waste, any part of the bamboo that is not used is recycled back into the earth as fertilizer or can be processed as bamboo charcoal.

Limitations:

1. Bamboo has a high starch content thus in areas of high humidity it is susceptible to attacks from Insects, fungus, rot etc.
2. Matured bamboo of at least four years of age shall be used. The bamboo shall be used after at least six weeks of felling period. Thus it requires extra cost for storage and maintenance.
3. Since there is little regulation of bamboo thus quality of bamboo varies largely from region to region.
4. Shrinkage: Bamboo shrinks much greater than any other type of timber especially when it loses water.
5. It is often difficult to find trained skill manpower in the domestic market for construction of engineered bamboo housing.
6. Lack of design guidance and codes.

The buildings located at the Bamboo Research and Training Centre, Chandrapur consists of Academic block have ground and mezzanine floor. The Academic building is equipped with fire safety system, and designed for 25 minute fire rating, which is a major concern in bamboo construction, by installation of sprinkler system. Canteen blockis aground floor building. All buildings are analysed using STAAD-Pro software. The section properties were manually calculated and in the STAAD software for analysis and design.

MATERIAL AND METHODOLOGY

Material Specification for Bamboo:

Following are the properties of Bamboo adopted from IS 15912:2012. These values are provided for air dry condition of bamboo.

B.bambos (syn.B.arundinacea)

Modulus of Elasticity (E) – 8.96 x10^3 N/mm^2.

Density of Bamboo – 663 kg/m^3.

Max. Compressive strength – 53.4 N/mm^2.

Design life of bamboo structure – 30 years

Modulus of Rupture (E) – 80.1 N/mm^2.

D.strictus

Modulus of Elasticity (E) – 15.00 x10^3 N/mm^2.

Density of Bamboo – 728 kg/m^3.

Max. Compressive strength – 69.1 N/mm^2.

Design life of bamboo structure – 30 years

Modulus of Rupture (E) – 119.1 N/mm^2.

Table 1 Calculation of safe working stress

IN DRY CONDITION	**Ultimate strength N/mm^2**	**PERMISSIBLE STRESS N/mm^2**	**AFTER APPLYING modification FACTOR (N/mm^2)**	**FYLD USE IN STAAD (N/mm^2)**		**kN/m^2**
B.bambos (syn.B.arundinacea)						
modulus of rapture - (N/mm^2)	80.1	20.03	30.04	1.51x 30.04 =	45.52	45520
max compressive stength (N/mm2)	53.4	15.26	22.89	1.5 x 22.89 =	34.34	34335
D.strictus						
modulus of rapture - (N/mm2)	119.1	29.775	44.67	1.51x44.67 =	67.67	67670
max compressive stength (N/mm2)	69.1	19.74	29.61	1.5 x 29.61 =	44.415	44415

The strength factor for deriving safe working stresses of bamboo shall be as under: Cl. 6.1.1- IS 15912:2012

Extreme fibre stress in beams : 4

Max compressive stress Parallel to grain/ fibres : 3.5

For change in duration of load other than continuous (long term), the permissible stresses shall be multiplied by the following modification factor Cl. 6.3- IS 15912: 2012

For short- term loading

(Permanent + temporary load + wind load) : 1.5

Table 1 gives the calculated material strength values for safe working stress for B.bambos (Balcoa) and D.strictus (Stocksii).

There are certain values adopted from other source and literature for the purpose of designing.

Poission’s Ratio – 0.1

Critical Damping – 0.05

Shear Modulus (G) – 4.072 x10^3 N/mm².

Crushing & Shearing Strength of Bamboo is considered to be negligible.

METHODOLOGY

The irregular shape of the structure made it challenging to analyse and design. Geometry of the structure was modelled using pre-defined tubular sections and the material properties of bamboo such as modulus of elasticity, density, compressive stress, modulus of rupture, shear modulus and moment of inertia were calculated and replaced in place of existing steel section properties for the analysis and design of the structure using STAAD Pro software. Supports for bamboo supported on pedestal were hinged/pinned and fixed at bottom of pedestal. The building was designed as a RC-Bamboo hybrid structure. Superstructure is designed using Bamboo and rammed earth to give it a unique identity, whereas RCC is used in the substructure. A Bamboo column consists of three or more number of culms of 50mm and 100mm diameter with minimum 10mm thickness acting as an integrated unit. The columns are cast in various shapes i.e. in rectangular, square, circular and irregular shape. Roof of the structure are considered as non-structural member but load of the roof sheeting was considered during the analysis and design.

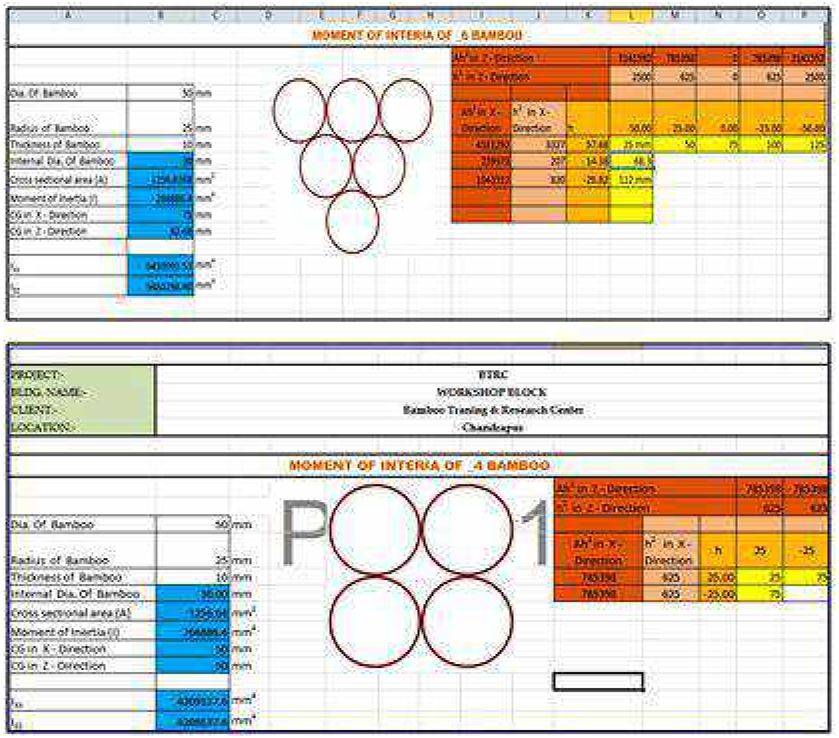

Figure 1 Moment of Inertia Calculation for Bamboo

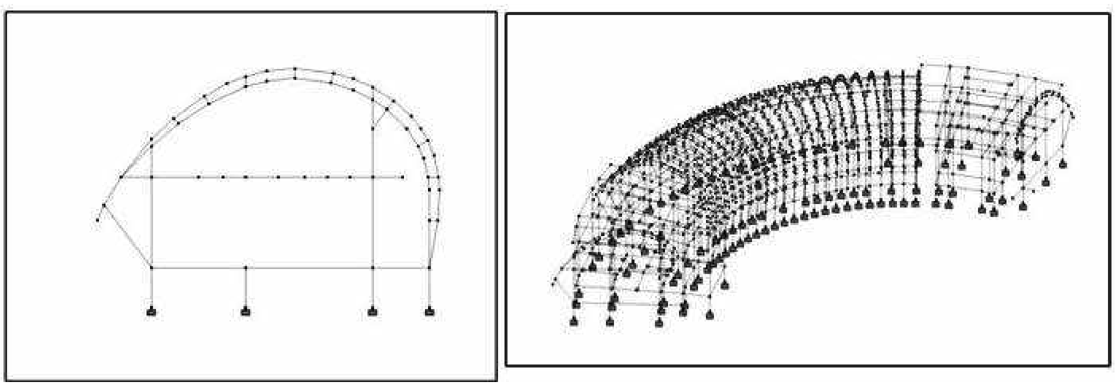

Figure 2 STAAD view

Foundation of these buildings are isolated, combined and strip footing with pedestals. The various key points of design and construction in this project give sharp view of the structure as well as the productivity of design. For mezzanine flooring, 50mm thickness IPS flooring is considered along with, 50mm thickness Bamboo board facia and 50mm thickness cement concrete is also considered in mezzanine flooring. Rammed earth wall of thickness 350mm were used as external walls on ground floor level of the bamboo structures.

STAAD model was prepared and analysed for this configuration with loadings of 40kg/m2, taking into account the weight due to rainy season moisture on roof.

Figure 3 Truss configuration

CHALLENGES

1. Among the different types of species of bamboo available, bamboos with diameter of 100mm were primarily used, due to the difficulty in bending of 100mm diameter bamboo, 50mm diameter was alternatively proposed, maintaining architectural aesthetic.
2. Geometry of the bamboo is not uniform throughout the length and tapered at the end and hence a conservative design approach is considered.
3. Length of bamboo is only 4.5 m which is insufficient from structural point of view and hence splicing is required.
4. Properties of bamboo are not readily available in STAAD pro. An in house spread sheet was developed for calculating the section properties of bunch of bamboo as per requirement and same has been replaced in STAAD for analysis and design purpose.
5. Density, elasticity and strength values of Bamboo vary with species.
6. Connections between bamboos are challenging. In order to have uniform behavior of bunch of bamboo, steel plate was inserted between bamboo and then were bolted together to act as a single unit.
7. During construction the bamboo were crushing and tearing, to prevent this number of bolts was increased and diameter of bolt was reduced.

Test on Bamboo

Both B Bambosbalcooa and D stocksii were tested and compared for the following properties in dry condition and green condition:

1. Compressive strength
2. Tensile Strength
3. Modulus of rupture
4. Modulus of elasticity
5. Shear strength

Treatment

1. Fire coating
2. Anti-termite
3. Made the bamboo sugar free by treatment with borax

SALIENT FEATURES

1. Inclined, Curve and Circular shape of buildings.
2. Bamboo as a design & construction material
3. Two types of Bamboo are used 50mm and 100mm diameter with 10mm thickness with different properties.
4. Zone 3 , Response Reduction Factor 4 for Bamboo structure and Damping ratio 5%
5. Rammed earth walls

Figure 4 View as on site

Figure 5 3D rendered view of Academic Block

ACKNOWLEDGMENT

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An Application of Artificial Intelligence in Construction Project Management

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***Abstract**: Artificial Intelligence (AI) refers to the simulation of human intelligence in machines that are programmed to think and perform tasks like humans. It involves the development of computer systems capable of performing tasks that typically require human intelligence, such as visual perception, speech recognition, decision-making, learning, and problem-solving. The primary goal of AI is to create machines that can mimic human cognitive abilities and execute complex tasks efficiently and accurately.*

Artificial Intelligence, often abbreviated as AI, refers to the capability of a digital computer or computer-controlled robot to perform tasks that typically require human intelligence. These tasks encompass a wide range of activities, such as visual perception, speech recognition, decision-making, learning, and problem-solving. AI is a multidisciplinary field that combines computer science, mathematics, engineering, and cognitive science to create intelligent machines.

It is essential to approach the development and implementation of AI responsibly, considering ethical considerations, fairness, transparency, and the potential societal implications of AI's widespread adoption. With responsible and mindful use, AI has the potential to contribute positively to various aspects of human life, transforming industries and creating new opportunities for innovation and progress.

***Keywords**: Artificial Intelligence (AI), Machine Learning, Decision Making, Problem Solving*

INTRODUCTION

Artificial Intelligence (AI) has been a topic of extensive research and study across various disciplines. The literature on AI spans several decades and covers many topics, including its history, theoretical foundations, methodologies, applications, and societal impacts. The recent scenario has seen increased applications of AI for safety and risk management, with AI-powered sensors and computer vision technologies monitoring construction sites to detect hazards. Predictive analytics and maintenance have been instrumental in optimizing equipment maintenance, while construction drones equipped with AI capabilities have become essential for site surveying and monitoring.

LITERATURE REVIEW

Artificial Intelligence (AI) has been a topic of extensive research and study across various disciplines. The literature on AI spans several decades and covers many topics, including its history, theoretical foundations, methodologies, applications, and societal impacts. Here is a brief overview of key themes found in the literature on AI:

The historical overview of Artificial Intelligence (AI) traces its roots back to ancient times when the idea of creating artificial beings with human-like capabilities was a topic of philosophical speculation.

The history of AI in the construction field dates back to the early application of computer technology and automation in construction processes. Over the years, advancements in AI and machine learning have significantly impacted the construction industry, making it more efficient, safer, and cost-effective. Here is an overview of the key milestones in the history of AI in the construction field:

1. Early Automation and CAD (1960s - 1970s): In the 1960s and 1970s, the construction industry began adopting early automation technologies, such as Computer-Aided Design (CAD).

2. Project Management Systems (1980s - 1990s): During the 1980s and 1990s, project management systems integrated AI capabilities to streamline construction project planning, scheduling, and resource management.

3. Robotics and Automation (Late 20th Century): Towards the end of the 20th century, robotics and automation technologies found their way into construction sites.

4. Building Information Modelling (BIM) and AI (2000s): The 2000s saw the rise of Building Information Modelling (BIM), which further revolutionized the construction industry.

5. AI for Safety and Risk Management (2010s): In recent years, AI has been increasingly applied to enhance safety and risk management in construction. AI-powered sensors and computer vision technologies monitor construction sites in real-time, detecting potential hazards and unsafe behaviours. This helps prevent accidents and promotes a safer working environment.

6. Predictive Analytics and Maintenance (2010s - Present): AI-driven predictive analytics has become instrumental in construction equipment maintenance.

7. Construction Drones and AI (2010s - Present): Drones equipped with AI-powered image recognition and 3D mapping capabilities have been used in construction to survey sites, monitor progress, and conduct inspections.

8. Autonomous Construction Equipment (Ongoing): The construction industry is exploring the use of autonomous construction equipment, such as self-driving excavators and bulldozers, to improve efficiency and reduce Labor requirements.

9. AI for Sustainable Construction (Ongoing): AI is being leveraged to enhance sustainability in construction practices. AI-driven simulations and optimizations help design energy-efficient buildings and assess the environmental impact of construction materials.

10. Smart Construction Sites (Ongoing): The integration of AI with the Internet of Things (IoT) has paved the way for smart construction sites.

SUMMARY OF LITERATURE

The summary provides an overview of the history of AI in general, covering its evolution from ancient times to the current state and future prospects.

In the construction field, AI has experienced significant advancements over the years. It began with early automation and the adoption of CAD in the 1960s and 1970s, followed by the integration of AI into project management systems in the 1980s and 1990s. Robotics and automation technologies were introduced in the late 20th century, leading to AI-powered robots performing various construction tasks. The rise of Building Information Modelling (BIM) in the 2000s further revolutionized the industry by incorporating AI algorithms for data analysis and design optimization.

METHODOLOGY ADOPTED

To find and identify suitable applications of Artificial Intelligence (AI) in construction projects, a systematic methodology can be followed. This approach involves several steps to gather information, analyze data, and make informed decisions. Here's a step-by-step methodology for finding AI applications in construction projects:

1. Understanding Construction Processes and Challenges: The first step is to gain a comprehensive understanding of the construction industry, its processes, and the challenges it faces.

2. Literature Review and Research: Conduct a literature review to explore existing research and publications on AI applications in the construction field. Look for case studies, academic papers, and reports that highlight successful AI implementations and their impact on construction projects. This step helps identify best practices and areas where AI has already demonstrated value.

3. Collaborate with AI Experts and Developers: Reach out to AI experts, data scientists, and developers who have experience in the construction industry or have worked on similar projects. Collaborating with AI professionals can provide insights into the feasibility and potential of AI applications in construction.

4. Analyse Data and Historical Project Information: Gather and analyse historical data from previous construction projects.

5. Identify Pain Points and Opportunities for Improvement: Based on the information collected and data analysis, identify specific pain points and opportunities where AI can bring meaningful improvements. These pain points may include project delays, cost overruns, safety risks, or inefficiencies in resource management.

6. Explore AI Use Cases and Solutions: Research and explore AI use cases and solutions that have been successfully applied in other industries and may have potential relevance to construction.

7. Prioritize AI Applications: Rank and prioritize the identified AI applications based on their potential impact, feasibility, and alignment with the organization's goals and objectives.

8. Conduct Proof-of-Concept (PoC) Studies: For the top-priority AI applications, consider conducting Proof-of-Concept (PoC) studies to validate the feasibility and effectiveness of the proposed AI solutions.

9. Implement and Monitor AI Applications: Upon successful validation of the PoC studies, proceed with the implementation of AI applications in selected construction projects. Continuously monitor and evaluate the performance and impact of the AI solutions, collecting feedback from project teams to make necessary improvements and optimizations.

10. Continuous Learning and Improvement: AI technologies are continuously evolving, and new advancements are made regularly. Stay updated with the latest trends, research, and developments in AI for construction.

By following this methodology, construction companies can effectively identify and implement AI applications that address specific challenges and improve overall project efficiency, safety, and productivity.

AIM AND OBJECTIVES

Need for Present Work

Finding applications of Artificial Intelligence (AI) in construction projects is essential for several reasons:

Efficiency and Productivity: AI can automate repetitive and time-consuming tasks in construction, leading to increased efficiency and productivity. By using AI to optimize project planning, scheduling, and resource allocation, construction projects can be completed faster and with better utilization of resources.

Cost Reduction: AI can help identify cost-saving opportunities by analysing data and making informed decisions. Predictive maintenance using AI algorithms can prevent equipment breakdowns and reduce costly downtime. Additionally, AI can optimize material usage, leading to cost savings in the procurement process.

Improved Safety: Safety is a critical concern in construction projects. AI can enhance safety by monitoring construction sites in real-time, identifying potential hazards, and alerting workers to unsafe conditions. Predictive analytics can also help in identifying safety risks before they escalate.

Enhanced Quality Control: AI can ensure better quality control by analysing construction data and identifying potential defects or deviations from design specifications.

Optimized Resource Management: AI can optimize the allocation of resources, including labor, equipment, and materials.

Data-Driven Decision Making: AI enables data-driven decision-making by analyzing vast amounts of construction data and providing valuable insights. It helps project managers and stakeholders make informed choices based on data, reducing reliance on intuition and subjective judgments.

Adaptation to Changing Conditions: Construction projects often encounter unexpected challenges and changing conditions. AI's ability to learn and adapt from data allows it to adjust project plans and strategies in response to dynamic situations, improving project outcomes.

Sustainability and Green Construction: AI can be used to design and optimize sustainable and energy-efficient buildings.

Improved Project Planning and Delivery: AI-powered tools can help in accurate project planning, scheduling, and risk assessment, leading to better project delivery and adherence to timelines.

Competitive Advantage: Embracing AI in construction projects can provide companies with a competitive advantage.

In summary, finding applications of AI in construction projects is crucial to harness the potential of this technology and drive innovation in the construction industry. AI can bring significant benefits in terms of efficiency, cost reduction, safety, quality control, and sustainability, ultimately leading to successful and competitive construction projects.

Objective of the Study

The main objectives for finding applications of Artificial Intelligence (AI) in construction projects are as follows:

[1] Enhancing Efficiency and Productivity
[2] Cost Optimization
[3] Improving Safety and Reducing Risks.
[4] Enhancing Construction Quality.
[5] Data-Driven Decision Making.
[6] Adopting Sustainable and Green Practices.
[7] Optimizing Resource Management.
[8] Improving Project Planning and Delivery.
[9] Embracing Innovation and Technology.
[10] Driving Continuous Improvement.
[11] Real-Time Monitoring and Reporting.
[12] Predictive Maintenance for Equipment
[13] Improved Resource Allocation.
[14] Risk Assessment and Mitigation.
[15] Enhanced Supply Chain Management.
[16] Collaborative Project Management.
[17] Automated Quality Inspections.

[18] Intelligent Building Systems.
[19] Optimized Construction Sequencing
[20] Enhanced Project Visualization.
[21] Regulatory Compliance and Documentation.
[22] Enhanced Bidding and Estimation.
[23] Improved Worker Training and Safety Awareness.
[24] Data Integration and Centralization.

The main objectives for finding applications of AI in construction projects revolve around improving efficiency, reducing costs, enhancing safety and quality, adopting sustainable practices, and driving innovation through technology. By achieving these objectives, construction companies can optimize their operations and deliver successful projects with better outcomes.

Scope of the Study

The scope of this study, focusing on the applications of Artificial Intelligence (AI) in construction projects, is broad and multi-dimensional. It encompasses various aspects related to the integration of AI technologies and methodologies in the construction industry. The scope can be summarized as follows:

[1] AI Applications in Construction
[2] Impact on Construction Efficiency
[3] Safety Enhancement and Risk Mitigation
[4] Construction Quality and Sustainability
[5] Data-Driven Decision Making
[6] Challenges and Limitations of AI
[7] Feasibility and Practicality of AI.
[8] Technological Advancements and Future Prospects
[9] Case Studies and Best Practices
[10] Ethical and Social Implications
[11] Adoption Strategies and Roadmaps
[12] ROI and Cost-Benefit Analysis
[13] Barriers to Adoption and Mitigation Measures
[14] Human-Machine Collaboration
[15] Legal and Regulatory Considerations
[16] AI Talent Environmental Impact and Sustainable Practices.
[17] Benchmarking and Performance Evaluation Stakeholder Engagement and Communication.
[18] AI Governance and Ethical Guidelines Scalability and Replicability.
[19] Impacts on the Future of Work
[20] Case Studies of AI Success and Failure

By addressing these objectives, the study aims to offer a comprehensive and in-depth analysis of the applications of AI in construction projects, covering various aspects critical for successful AI integration in the construction industry.

RESEARCH ORIGINALITY AND CONTRIBUTIONS

The research on the applications of Artificial Intelligence (AI) in construction projects contributes to the field in several ways, showcasing originality and generating valuable insights. Here are the key contributions and aspects of originality:

Comprehensive Analysis of AI Applications in Construction: The study provides a comprehensive and in-depth analysis of the diverse applications of AI in construction projects.

Integration of Real-World Case Studies: By incorporating real-world case studies of AI implementation in construction projects, the research offers practical examples and tangible results. This integration helps bridge the gap between theory and practice, demonstrating the actual impact of AI on construction projects.

Multi-Dimensional Evaluation of Benefits and Challenges: The research presents a multi-dimensional evaluation of the benefits and challenges associated with AI adoption in construction.

Roadmaps and Strategies for AI Adoption: The study goes beyond exploring AI applications and provides adoption roadmaps and strategies tailored to the construction industry.

Focus on Human-Machine Collaboration: The research emphasizes the importance of human-machine collaboration in construction projects. By highlighting how AI can augment human capabilities and foster synergistic collaboration, the study addresses concerns related to workforce displacement and ensures a human-centric approach to AI implementation.

Ethical Considerations and AI Governance: In addition to technical aspects, the study delves into ethical considerations and AI governance specific to the construction industry.

ROI and Cost-Benefit Analysis: The research provides a thorough ROI and cost-benefit analysis of AI adoption in construction projects. This analysis helps construction companies make data-driven decisions, understanding the financial implications and long-term advantages of integrating AI technologies.

Environmental Impact and Sustainable Practices: By exploring AI applications that promote sustainable construction practices, the study addresses environmental concerns in the construction industry. This contribution aligns with global sustainability goals and supports green building initiatives.

Implications for the Future of Work: The research assesses the implications of AI adoption on the workforce in the construction industry.

Data Integration and Performance Evaluation: The study emphasizes the importance of data integration, performance evaluation, and continuous improvement in AI applications. This contribution establishes benchmarks for success and provides a framework for ongoing performance assessment.

Innovative AI Implementation Strategies: The research introduces innovative AI implementation strategies tailored to the construction industry's unique challenges and requirements. It explores novel ways to leverage AI technologies effectively, fostering creativity and innovation within the construction sector.

Collaboration with AI Experts and Construction Professionals: The study involves collaboration with AI experts, data scientists, and construction professionals to ensure the research's accuracy, relevance, and practicality. This collaboration enhances the study's credibility and real-world applicability.

Focus on Smaller Construction Firms: In addition to large construction companies, the research considers the applicability of AI for smaller construction firms.

Addressing Construction-Specific AI Challenges: The research specifically addresses AI challenges unique to the construction field, such as dealing with complex 3D data, interoperability of construction software, and AI integration within existing workflows. It offers targeted solutions to overcome these domain-specific challenges.

Regional and Cultural Relevance: The study considers regional and cultural factors that may influence the adoption of AI in construction projects.

Long-Term AI Impact Assessment: The research examines the long-term impact of AI adoption on construction projects and the industry as a whole.

Education and Awareness Promotion: The study contributes to the promotion of education and awareness regarding AI applications in construction.

Risk Management Strategies for AI Integration: The research develops risk management strategies specifically related to AI integration in construction projects. It helps construction companies proactively identify and mitigate potential risks associated with AI adoption.

Interdisciplinary Insights: The study offers interdisciplinary insights by bridging AI expertise with construction domain knowledge.

Practical Toolkits and Resources: As part of the study's contributions, it provides practical toolkits, resources, and guidelines for construction companies to navigate AI adoption successfully.

Overall, in summary, the originality and contributions of this study lie in its comprehensive approach, real-world integration, consideration of ethical and sustainable dimensions, and the provision of practical guidance for AI adoption in construction projects. The study adds value to the existing body of knowledge, fostering innovation and promoting responsible and successful AI implementation in the construction industry.

EXPECTED OUTCOME

The expected outcome of this study on the applications of Artificial Intelligence (AI) in construction projects is to provide valuable insights, actionable recommendations, and a comprehensive understanding of the potential impact of AI on the construction industry. The study aims to achieve the following outcomes:

[1] Identification of Relevant AI Applications:
[2] Practical Roadmaps for AI Adoption:
[3] Assessment of AI's Impact on Efficiency and Productivity:
[4] Analysis of AI's Contribution to Safety and Quality
[5] Evaluation of Cost-Benefit Ratio and ROI
[6] Ethical and Sustainable AI Practices
[7] Identification of Barriers and Mitigation Strategies
[8] Recommendations for Human-Machine Collaboration
[9] Long-Term Impact Assessment
[10] Educational Resources and Awareness Promotion
[11] Toolkits and Guidelines for AI Integration
[12] Improved Project Delivery and Timelines
[13] Enhanced Risk Management and Safety
[14] Optimized Resource Allocation and Cost Savings
[15] Increased Construction Quality and Client Satisfaction
[16] Empowered Workforce through AI Upskilling
[17] Support for Sustainable Building Practices
[18] Increased Competitiveness and Innovation
[19] Data-Driven Decision-Making and Project Insights
[20] Facilitating AI Collaboration and Research
[21] Alignment with National and Global AI Initiatives
[22] Empirical Evidence for Policymakers
[23] Potential for AI Scalability and Replicability
[24] Future Prospects and Industry Transformation
[25] Fostering AI Ecosystem in Construction
[26] Accelerating Technological Advancements
[27] Empowering Small and Medium-sized Enterprises (SMEs
[28] Promoting Inclusivity and Diversity in AI Implementation
[29] Guidance for AI Vendor Selection
[30] Contributing to Industry Standards

[31] Informing Policy Frameworks
[32] Enhancing Collaboration and Networking Opportunities
[33] Educational Curricula and Training Programs
[34] International Collaboration and Knowledge Sharing
[35] Empirical Evidence for Industry Reports and Publications
[36] Supporting Sustainable Infrastructure Development
[37] Showcasing AI-Enabled Construction Projects

In conclusion, the expected outcomes of this study encompass a wide array of positive impacts on the construction industry, ranging from accelerated technological advancements to global sustainability contributions. The research is anticipated to foster collaboration, guide decision-making, and position the construction sector for a more efficient and innovative future by integrating AI technologies.

This study is to offer a comprehensive, evidence-based, and practical guide for construction companies and stakeholders to understand the potential of AI in construction projects. The study aims to help construction industry professionals make informed decisions, optimize project outcomes, and stay at the forefront of technological advancements in the field.

In summary, the expected outcomes of this study encompass a broad range of benefits, including improved project delivery, enhanced safety and risk management, cost savings, increased quality, and sustainability. The research will contribute to a better understanding of AI's potential in the construction industry, fostering innovation, and preparing construction professionals for the AI-driven future.

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Construction and Design Aspects of Beams Supporting Floating Columns A Case Study

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Abstract: *Innovation is demand of modern day architecture. With the densification of population in the urban are as ,increasing demand for parking spaces and similar ground is needed. The need to change the architectural layout of different floors where there is no room available for the column to rest on the lower floor is encountered. Resting of column on beams has become common in modern architectural practice .The name Floating column suggests the same practice. The main focus of this paper is to review the design and construction difficulties that were encountered while the construction off boating column with deep beams of a building in Miramar-Goa India. The use of ETABSs of t ware is done for the analysis of this structure. This study will greatly help in improving the design criteria off loating columns andtogainpracticalknowledgeregardingtheproblemsfacedonsiteduringtheircon struction to avoid similar problem sin the future. A highlight on the design methodology is also done to understand the design aspect of deep beams supporting floating columns.*

Keywords*-Floating column, Deep beams, Multi-storey building, ETABS.*

INTRODUCTION

Floating columns are the once which do not have its base resting on the soil foundation. It usually rests on a beams which are supported on columns. Ordinary beams are less capable of handling the heavy loads coming on them which is why deep beams are often used in supporting of floating columns. These beams are heavily reinforced with very larger dimensions as compared to normal RCC beams. The shear reinforcement required also exceeds permissible limits as compared to normal beams. Adequate measures are needed to be taken in order to safeguard the beams from shear failure due to heavy column loads. One of this method used is discussed in this paper. The floating column deep beam theory is highly debated in IScodes for its application and requires major research and development if to be used in future.

Deep Beams

The ISCode suggests that, when the ratio of effective span to overall depth of a beam is less than or equal to two, these beams are termed as deep beams. The use of such beam are extended to transfer girder wall foundation, foundation pile caps, floor diaphragm, shear walls etc.

Floating Columns

A column is a vertical member transferring ts loads from beams to column to foundation where else floating column is the one whose load transfer pattern is from column to beam to columns. This transfer pattern results in heavy load transfer from column member to beam member.

OBJECTIVES

The primary objectives of this work is

1. To review the design and construction difficulties that were encountered during the construction process of deep beam supporting floating columns of a multi-storied building at Miramar Goa.

2. To use ETABS software for the analysis of this structure and to calculate the optimum dimensions of beam required to carry safe loads on the sub structure.

3. To high light the design methodology so asto understand the design aspect of deep beams supporting floating columns.

DESIGNMETHODOLOGYANDSTRUCTURALMODELLING

Description of the Building

The structure is a RCCG+13 building with a total built-up area of 1200 square meters. The structure is to be designed to accommodate three parking floors and10 residential floors including a pent-house on the top floor.

Exterior Masonry: 20 mm thick

InteriorMasonry:20 mm thick

Environmental Exposure: Severe

Structural Concrete:M30

Max water to binderratio:0.4

MinimumCementContent:330kg/m^3

Table 1 Minimum Clear Cover

Structural Member	**Clear Cover**
Foundation	50 mm
Column & Shear Wall	45 mm
Beams	45 mm
Slab Solid	45 mm
Ribbed Slabs	45 mm
Water Tank	45 mm

Table 2 Material Quality and Grading

Materials	Grade
Concrete Foundation	M30
Concrete Superstructure	M30
Reinforcement	Fe 500D(TMT)

Table 3 Analysis and design values adopted in design

Load	**Load Value**	**Remark**
Dead Load	Software Calculated	
Floor Finishes	1.5 KN/m^2	IS 875 Part I – 1987
Imposed loads Vehicular load Bath and Toilet Sunk Wall Loads Water Tank Load	7.5KN/m^2 3KN/m^2 5 KN/m^2 As per requirement	
Seismic Loads	Considered for design	IS 1893 Part 1: 2016
Wind Load	Not considered for analytical purpose but is considered for design	IS 875 Part 3: 1987

Design of Main Steel Reinforcement

The modelling and analysis of structure is carried out by using ETABS software (Student Version).

This will be used to generate design data which was carried out in actual practice. Analysis carried out on ETABS and reinforcement area calculates is shown in **Figure 3**.

Most of the beams are designed such that the percentage of steel required in the beams does not exceeds 1.0 percent to avoid congestion of reinforcement. This resulted in larger dimensions of beams. However, the shear force was recorded to be very high in some places even reaching 4020 KN, as shown in **Figure 2**. To accommodate these shear partly composite sections were designed using MS steel plate as shear reinforcement. This design was manually done to obtain proper results. The shear reinforcement obtained was satisfactory and can be adopted in practice.

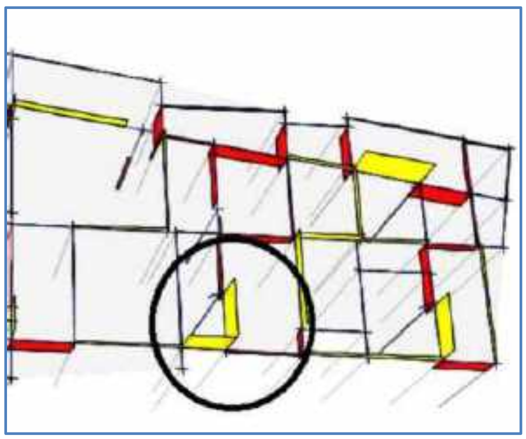

Figure 1 showing the proposed beam that is been designed

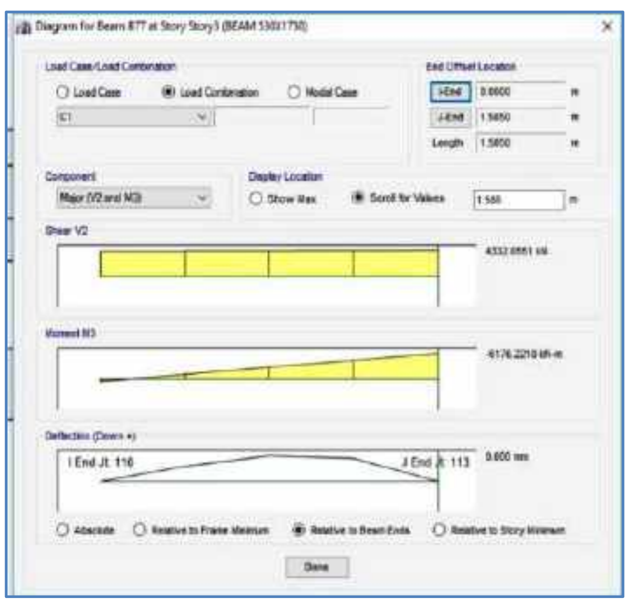

Figure 2 showing shear force, moment and deflection of beam to be designed

Design of Shear Reinforcement

The design of shear reinforcement is done in 3 stages.

1. Calculating shear capacity of the beam.
2. Calculation of Shear force resisting capacity of stirrups.
3. Calculation additional shear requirement (in the form of plates) required

Step 1

This is calculated by using table 19 of IS 456:2000. Calculate percentage steel embedded in concrete to find value of $\tau_c$bd.

Step 2

Find the capacity of stirrups to resist shear using the formula $V_{us} = 0.87 f_y A_{sv}\, d/s_v$ use 10 mm 4 legged stirrups @ 100mmc/c.

Vus = 0.87fyAsv d/Sv
Where Asv = 78mm2
Sv = 100mm
fy = 250 N/mm2
d = 1600mm
Vus= 1802 KN

Step 3

Calculate the area of the shear plates required as reinforcement.

1. To calculate area of shear plate, we need to find out the additional shear force required for beam for per meter length of the beam section.
2. Additional shear force (Vus) is calculated by deducting beam capacity and Shear force resisted by 4 legged 10 mm diameter stirrups at 10mmc/c spacing.

Calculate the area of the shear plates required as reinforcement.

Assuming 10mmx10mm mild steel bar to find total area of reinforcement required.

Sv = 0.87fyAsv d/Vus

Where Asv = 100mm^2

Vus= 2160 KN

fy = 250 N/mm^2

d = 1600mm

.’. Sv = 16.1 mm; say 16 mm c/c

Steel Required for 1m = 1000/16 +1

= 63.11; say 64 nos.

.’. Area of steel required for 1 m length = 64x 10 x 10 = 6400mm^2

.'. Plate thickness required = 6400 / (1000 x 2) =3.2 mm; say 5.00mm.

Hence provide 2 plates of 5 mm each on both sides

Note: The length of shear plate will be totally dependent on shear force diagram.

For heavy shear-force design the thickness of shear plate can be increased. Shear Reinforcement obtained from ETABS software is shown in **Figure 3**. A detailed drawing of beam with shear reinforcement in the form of plate as well as stirrups is shown in **Figure 4**.

Table 3 gives design details of beam B73 that has been designed for shear reinforcement using shear plates. It shows the design capacity of the section for which the shear reinforcement has been designed.

RESULTS

Design of Beams supporting Floating Column

From the design of beam, following results were obtained. Figure 3 shows main steel reinforcement of beams. This data is software calculated and can be adopted for design of steel.

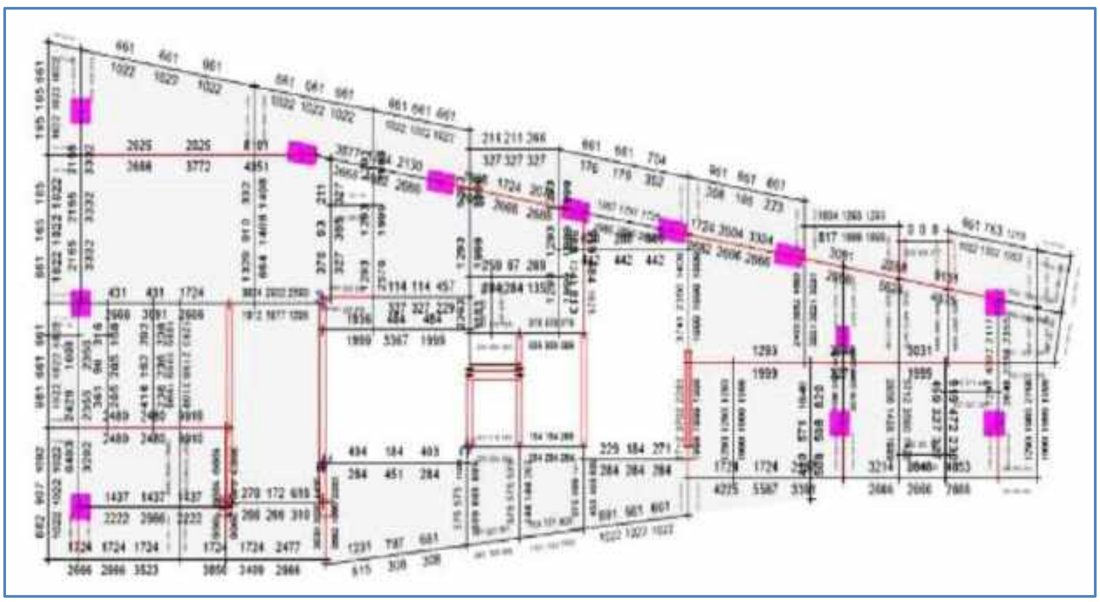

Figure 3 Shows shear steel requirements of the beams

Table 3 Shear Force carried by different component of the beam.

Beam No.	Design Shear Force (KN)	Shear Force resisted by the beam (KN) 50%	Capacity to Stirrups to resist Shear Force (KN) 4 legged 12mm stirrus@100mmc/c	Shear force to be resisted by shear plate (KN)
B73	4020	340	2580	1100

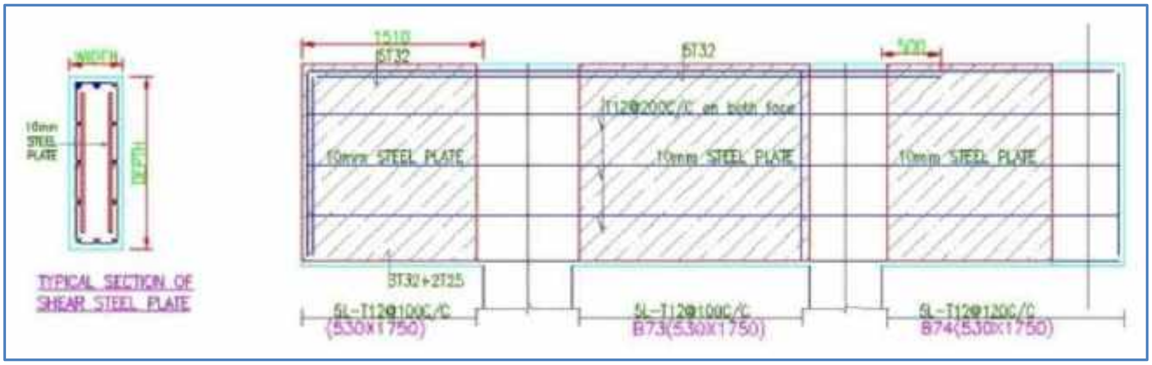

Figure 4 Drawing of Shear Reinforcement.

OVERVIEW OF THE CONSTRUCTION SITE

The site is located at Miramar, a coastal belt in the state of Goa India. The said construction is a commercial-residential building. It consists of three parking floors including basement and it houses eight residential floors above parking. The total floor area of the building is about 4800 m2. There is a difference in the layout of the parking and the residential floors and thus it gives rise to need for floating columns. The axial load coming on the beams supporting the floating columns is excessive that normal beams are not capable to withstand that load. This scenario has led to use of deep beams.

Visual observation

Field condition survey of a building is to research its present condition and performance. This is done by collecting data of the structure which may include building plans, design data, soil exploration data, material used and intended purpose of the building. This information combined with information of noted structural distresses or any other stability issue regarding the structure will be proven helpful in the improvement of the existing design of the structure.

Condition Survey

Condition survey before concreting was carried out and following points of were noted.

1) Need to Provide Floating Column

It was found that provision of floating columns made it necessary to provide heavy and congested reinforcement in the beams.

2) Provision of deep beams

The deep beams were provided to carry the high axial load coming on beams due to floating columns.

3) Requirement of Shear plates

M S Steel Plates of required thickness were provided in order to carry shear load coming on the deep beams.

Post Concreting Inspection

Post concreting inspection was carried to check the quality of work that was carried out during the process.

After the de-shuttering of formwork for beams and slab, the following problems were noted in the RCC slab of the second stilt floor.

1. Void in deep beams

   It was found that due to congestion of reinforcement many deep beams had voids in them. These voids were more likely to be noticed in beams having shear plates since on tapping the shear plates by metallic hammer a hollow type of sound was clearly noticeable.

2. Failure of concentrating operation of the sides of beams having Shear plates

3. It was found that the exterior side of the beams having shear plates, concretion operation was not well performed.

Figure 5 Drawing of Exposed Shear Reinforcement.

REMEDIALMEASURES

After a thorough examination of the post concreting problems, there pair methods were adopted as per the CPWDM annual of repair and retrofitting

1. The void sin concrete were filled with high density pressure grout. The material used for this method was epoxy based grouting material which .

2. The exterior of the shear plates were filled with high density cement material which was applied in the form of plaster.

CONCLUSION

The following conclusions can be made by the study conducted of deep beams and formwork technology adopted for its construction.

1. Improved detailing techniques are required to compensate for the congestion of reinforcement.
2. Alternative to lapping is steel must be used to avoid unnecessary congestion of reinforcement.
3. Exploration of other alternative for plain plates needs to be explored, like voided plates for better flow of concrete can be tried out.
4. Use of self-levelling concrete with 10mm downsize aggregates is preferable in such heavily congested areas.
5. The horizontal and vertical spacing provided for site was checked for adequacy and is found to be safe.
6. Extreme care needs to be exercised while concreting heavily reinforced beam such as the one studied in this work.
7. NDT tests are strongly recommended for such heavily reinforced RC elements to confirm their quality of concrete.

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Use of Cross Laminated Timber (CLT) for Sustainable High-Rise Buildings

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Abstract *: The demand for the sustainable high-rise building is increasing day by day. Using mass timber in place of traditional building materials like steel and concrete for the structures would allow the construction of such a sustainable high-rise building. The aim of this paper is to discuss concepts related to design of Cross Laminated Timber (CLT) multi storeyed building. A fifteen-storey building with floor plan dimensions 36 m × 20 m is considered for the study. The typical floor height is taken as 3.2 m and the total height of building is 48 m. The location of building is Ahmedabad falling under seismic zone III. A comparative study of Cross Laminated Timber multi storeyed building with conventional Reinforced Concrete (RCC) building with moment resisting frame is carried out. The modelling, analysis and design of buildings are carried out using ETABS. Appropriate mechanical properties of CLT, various loads and load combinations are considered while modelling the structure for analysis and design. Both the buildings have similar floor plan. The design of timber structural members is verified according to Eurocode-5. Finally, comparison of designed sections and analysis results for both the CLT and RCC buildings is presented in the paper.*

Keywords*: Cross Laminated Timber; High-rise Building; Sustainability; Moment Resisting Frame*

INTRODUCTION

Sustainable development is being emphasized all over the world. New materials are being developed to reduce carbon footprint of buildings. The use of Cross-Laminated Timber (CLT) as a structural building material has attracted the interests of Architectural, Engineering, and Construction community. CLT is an aesthetically beautiful product that provides users with an affordable, renewable, dependable, fire-resistant substitute for conventional building materials like concrete, masonry, as well as lighting framing. The adaptability of Cross Laminated Timber (CLT) makes it a great material for multi-story constructions. As compared to conventional reinforced concrete high-rise buildings, the use of mass timber lowers the CO_2 footprint. Only FSC-certified wood should be used in accordance with reforestation to ensure sustainability through a closed carbon cycle. Wood is lightweight; therefore, it can be lifted with greater efficiency, saving a lot of time during construction.The development of a wood-concrete skyscraper concept for extremely tall buildings is the result of the advancement of CLT, the construction of structures up to 9 storeys, and their strong performance under extreme loading conditions [8].This paper is a case study of comparison of design 48-meter tall, sustainable Cross Laminated Timber (CLT) high-rise with a Moment Resisting Frame (MR Frame) building in Ahmedabad. The analysis and design of MR Frame are performed using ETABS. The design of concrete building is carried out using software, while design of CLT building is performed done manually in compliance with Eurocde-5. A symmetrical plan of dimensions 36 m × 20 m is considered for a fifteen-story building. Dead load, live load, and superimposed dead load are applied together with wind load and seismic load according to IS 875 [3] and IS 1893 [4] respectively. Structural elements are designed considering governing load combination. A 250 mm thick shear wall is provided surrounding the staircase and elevators.Finally, comparison of designed sections, time period, base shear, story displacement, story drift, story shear for both the CLT and RCC buildings is presented in the paper.

STRUCTURAL DESIGN METHODOLOGY

The wooden building is completely made up of CLT material including the load bearing structural elements except the shear wall. To design load bearing sections, Eurocode 5 is briefly discussed in following subsections. In the Section 6 of the Eurocode the Ultimate Limit State method for the designis described [1].

Member subjected to Tension Parallel to Grain

$$\sigma_{t,0,d} \leq f_{,t,0,d} \quad (1)$$

where, $\sigma_{t,0,d}$ is the design tensile stress along the grain, $f_{t,0,d}$ is the design tensile strength along the grain

Member subjected to Compression Parallel to Grain

$$\sigma_{c,0,d} \leq f_{,c,0,d} \quad (2)$$

where, $\sigma_{c,0,d}$ is the design compressive stress along the grain, $f_{c,0,d}$ is the design compressive strength along the grain

Member subjected to Bending

$$\frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1 \quad (3)$$

$$k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1 \quad (4)$$

where, $\sigma_{m,y,d}$ and $\sigma_{m,z,d}$ are the design bending stresses about the principal axes; $f_{m,y,d}$ and $f_{m,z,d}$ are the corresponding design bending strengths

Factor k_m makes the allowance for redistribution of stresses and effect of inhomogeneities of the material

For rectangular sections, $k_m = 0.7$

Member subjected to Shear

$$\tau_v \leq f_{v,d} \quad (5)$$

where, τ_v is the design shear stress, $f_{v,d}$ is the design shear strength

For the verification of the shear resistance of members in bending, the influence of cracks should be taken into account using the effective width of the member given as:

$$b_{cf} = k_{cr}\, b \quad (6)$$

where, b is the width of section, $k_{cr} = 0.67$ for solid timber

Member subjected to Combined bending and axial tension

$$\left(\frac{\sigma_{t,0,d}}{f_{t,0,d}}\right)^2 + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1 \quad (7)$$

$$(\frac{\sigma_{t,0,d}}{f_{t,0,d}})^2 + k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1 \quad (8)$$

Member Subjected to Combined Bending and Axial Compression

$$(\frac{\sigma_{c,0,d}}{f_{c,0,d}})^2 + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1 \quad (9)$$

$$(\frac{\sigma_{c,0,d}}{f_{c,0,d}})^2 + k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1 \quad (10)$$

Fire Safety

Fire safety is critical for the structures. For ensuring fire safety, causes of fire are prevented and in case of fire proper access to fireman for extinguishing fire need to be provided. Safe refuge area in building is provided to recue people in case of fire. The majority of contemporary building standards have historically been founded on prescriptive rules, including minimum thickness requirements for particular materials. To provide better fire safety, EU rules have been changed from being prescriptive to being performance-based [7].

Design Data

The building is composed of 15 storey with an inter-storey height of 3.2m; the total height of the building is 48m. The structure is built using CLT panels for Walls and Slab. The dimensions are presented in **Table 1**. Rectangular sections for Beams & Columnsand concrete shear wall around staircase and elevators are considered. The shear walls are designed to support both gravitational and lateral loads developed due to wind and earthquake. The gravity loads, parameters for windloading [3]and parameters for earthquakeloading [4] are shown in **Table 2**, **Table 3** and **Table 4** respectively.

Table 1 CLT layup and thickness

	Element	Layup	Thickness
1	Slab	5	175 mm
2	Walls	7	210 mm

Table 2 Gravitational Loads

	Element	Live (kN/m^2)	SIDL (kN/m^2)	Wall kN/m
1	Slab	1.5	2	-
2	Beam	-	-	1.568

Table 3 Seismic Parameters

	Parameter	MRF	CLT
1	Response Reduction (R)	5	3
2	Importance Factor (I)	1.2	1.2
3	Seismic Zone Factor (z)	0.16	0.16
4	Time Perio in X Dir.	0.968	0.968
5	Time Perio in Y Dir.	0.72	0.72

Table 4 Wind Parameters

	Parameter	MRF	CLT
1	Basic Wind Speed (V_b)	39 m/s	39 m/s
2	k1	1	1
3	k2	1	1
4	k3	1	1
5	k4	1	1
6	Time Period in 1st Mode	2.074	1.541

MECHANICAL PROPERTIES

Cross-Laminated Timber (CLT) is a timber panel which is made up of several layers of lumbers oriented at right angle to each other. The grain direction of each individualmembers is orthogonal to each other. Type C16-C24 are classified timber planks which are commonly used and these timber planks are glued together. The CLT Panels have very high strength and dimensional stability. The only disadvantage of timber is that it is very sensitive to moisture changes but CLT Panel is not much sensitive as timber. The mechanical properties of CLT made of up C24 lumber are presented in **Table 5** [2].

Table 5: Mechanical Properties of C24 lumber CLT

	Strength and Stiffness Properties		
1	Bending Strength	$f_{m,k}$	24 N/mm^2
2	Rolling Shear	$f_{r,k}$	1.5 N/mm^2
3	In Plane Compression	$f_{c,k}$	30 N/mm^2
4	Compression perp. to plane	$f_{c,90,k}$	2.7 N/mm^2
5	In Plane Tension	$f_{t,k}$	16.5 N/mm^2
6	Shear Strength	$f_{v,k}$	2.7 N/mm^2
7	Modulus of Elasticity parallel to Grain	$E_{0,mean}$	12000 N/mm^2
8	Modulus of Elasticity perp. to Grain	$E_{90,mean}$	370 N/mm^2
9	Rolling Shear Modulus	$G_{R,mean}$	50 N/mm^2
10	Poisson Ratio	ν	0.3
11	Characteristic Density	ρ_k	350 kg/m^3

The mechanical properties of materials used in concrete building are presented in **Table 6.**

Table 6 Grade of Steel and Concrete used for RCC building

	Material	Grade	Element
1	Steel	Fe500	All
2	Concrete	M25	Slab
		M30	Beam Column Shear Wall

Floor Plan

A symmetrical floor plan of 36m × 20m is considered for both the CLT and RCC moment resisting frame Building as shown in **Figure 1** and **Figure 2**. A grid spacing of 4m is selected between the columns because of the limitations in CLT Panel Size. An area of 4m x 8m is provided for commercial purpose. A passage of 4m is provided.

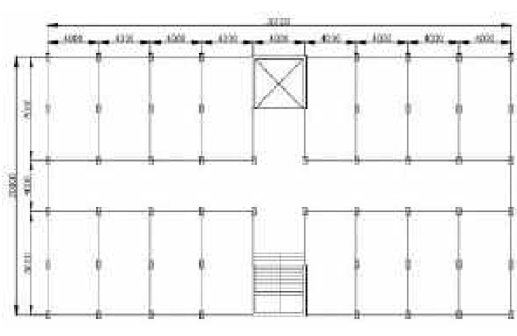

Figure1 Typical Floor Plan of building (dimensions are in mm)

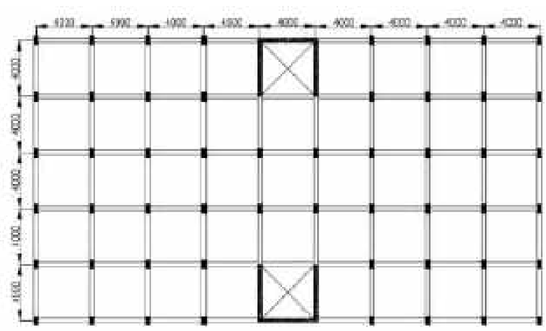

Figure 2 Beam Column Layout(dimensions are in mm)

DESIGN STRATEGY

A thee-dimensional model of the building is prepared in ETABS as shown in **Figure 3**. The structure has been designed for the ultimate limit state (ULS) load combinations as specified in Indian Standard Code. The concepts for design of CLT elements are presented in section 2. For comparison of CLT building, a traditional RCC building is also designed.

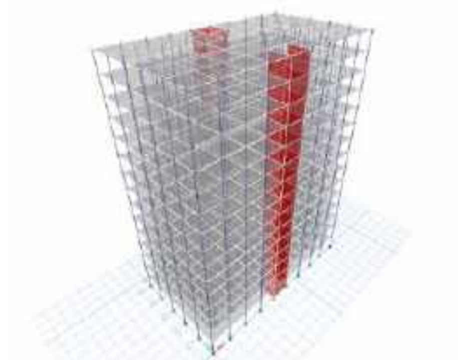

Figure 3A3-D Model of the Building

RESULTS AND DISCUSSION

In order to understand the performance of CLT building, analysis and design results of both the CLT (cross laminated timber building) and MRF (moment resisting concrete frame building) buildings are compared and presented in this section.

Section Sizes

Cross sectional dimensions of the structural elements for both the buildings are designed for the governing load combinations. The comparison of element sizes is shown in **Table 6**.

Table 6 Designed Section Sizes

	Element	Story	CLT(mm)	MRF(mm)
1	Slab	All	175	125
2	Walls	All	210	230
3	Beam	1 to 5	350 x 650	300 x 600
		6 to 10	350 x 600	300 x 600
		11 to 15	300 x 500	300 x 600
4	Column	1 to 5	500 x 800	400 x 600
		6 to 10	500 x 700	400 x 500
		11 to 15	500 x 600	400 x 450
5	Shear Wall	All	250	250

Base Reaction

Comparison of base reactions due to different types of load for both the buildings is shown in **Table 7**.

Table 7 Comparison of Base Reactions

	Case	CLT(kN)	MRF(kN)	% diff.
1	Dead	19799.18	76007.05	73.12 %
2	SIDL	20640	20640	0 %
3	Live	15480	15480	0 %
4	Wall	9878.4	61824	84.02 %
5	EQx	2425.29	4359.25	43.54 %
6	EQy	3253.93	5860.77	43.66 %
7	WLx	1331.72	1331.72	0 %
8	WLy	853.15	853.15	0 %

The % difference in base reaction due to gravity loading between the CLT & MRF is 62.17%. Reduction in gravity load reduces seismic forces as well as foundation dimensions.

Modal Analysis

Modal analysis is performed for both the buildings. A comparison of natural time period of first 3 modesof vibration is presented in **Table 8**.

Table 8 Comparison of Time Period

Mode	CLT (sec)	MRF (sec)
1	1.541	2.074
2	1.324	1.953
3	1.302	1.922

Modal Participating Mass Ratios

The modal participating mass ratio is the percentage of a model's structural mass that participates in a given mode of vibration and direction. For both the CLT and MRF buildings the first two principal modes are in translation y & x and third mode is in rotation about z.

Lateral Load

Lateral loads acting at each storey due to Earthquake and Wind are presented in **Table 9** and **Table 10** respectively. It is clear from **Table 9** that because of large self-weight of MRF Building, it attracts larger earthquake forces as compared to CLT Building. Whereas for lateral loads due to wind as listed in **Table 10** do not differ irrespective of the self-weight as it depends on the exposed area to wind. **Figure 4** and **Figure 5** illustrates the comparison of Lateral Loads on each storey graphically. It is observed that earthquake forces are governing as compared to wind forces.

Story Drift

As per IS 16700 (2023) [5], the inter-story drift ratio should be limited to 0.004. After the analysis and design for both CLT and MRF buildings, the maximum inter-story drift ratio is obtained as shown in Table 11.

Table 9 Lateral Load due to Earthquake

Story	CLT (kN)		MRF (kN)	
	EQx	EQy	EQx	EQy
15	402.79	540.42	751.81	1010.76
14	386.49	518.55	694.69	933.98
13	333.25	447.11	599.00	805.32
12	283.95	380.97	510.39	686.19
11	238.60	320.12	428.87	576.59
10	201.75	270.68	355.48	477.93
9	164.06	220.12	289.05	388.62
8	129.63	173.92	228.39	307.06
7	99.25	133.16	174.86	235.09
6	72.92	97.83	128.47	172.72
5	51.07	68.52	89.74	120.65
4	32.81	44.02	57.87	77.81
3	18.46	24.76	32.55	43.77
2	8.20	11.01	14.47	19.45
1	2.05	2.75	3.62	4.86

Table 10 Lateral Load due to Wind

Story	CLT (kN)		MRF (kN)	
	WLx	WLy	WLx	WLy
15	52.82	33.84	52.82	33.84
14	104.18	66.75	104.18	66.75
13	102.75	65.82	102.75	65.82
12	101.32	64.91	101.32	64.91
11	99.91	64.01	99.91	64.01
10	98.50	63.10	98.50	63.10
9	96.58	61.87	96.58	61.87
8	93.83	60.11	93.83	60.11
7	91.12	58.37	91.12	58.37
6	88.57	56.74	88.57	56.74
5	86.46	55.39	86.46	55.39
4	82.25	52.69	82.25	52.69
3	77.83	49.86	77.83	49.86
2	77.83	49.86	77.83	49.86
1	77.83	49.86	77.83	49.86

Story Displacement

As per IS 16700 (2023), the storey displacement should be limited to h/250 for factored earthquake load combinations. In the present case the maximum allowable displacement as per h/250 is 192mm. After the analysis and design for both CLT and MRF buildings, the maximum displacement is shown in **Table 12**.

Table 11 Maximum Inter-Story Drift Ratio

	CLT	MRF
Drift	0.003961	0.003933
Load Case	1.5(DL + EQy)	1.5(DL + EQy)
Story	12	9

Table 12 Maximum Top Story Displacement

Direction	CLT (mm)	MRF (mm)
X	74.74	91.40
Load Case	1.5(DL + EQx)	1.5(DL + EQx)
Y	149.15	152.28
Load Case	1.5(DL + EQy)	1.5(DL + EQy)

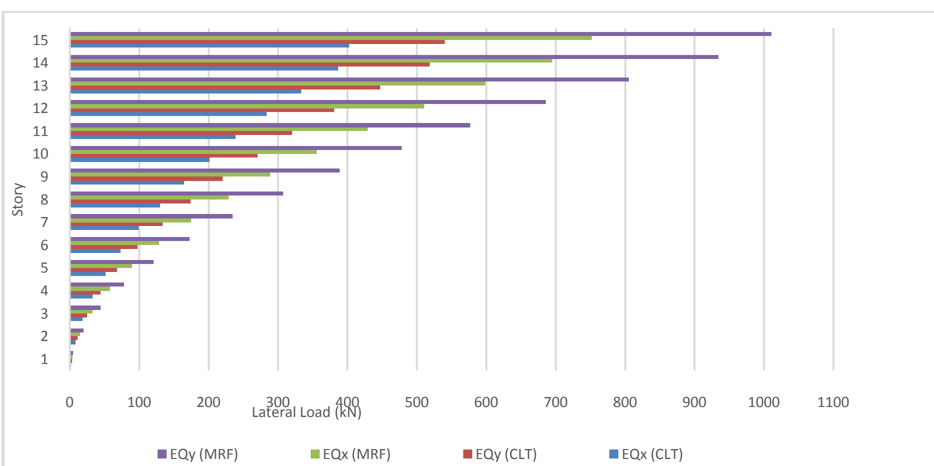

Figure 5 Lateral Load due to Earthquake

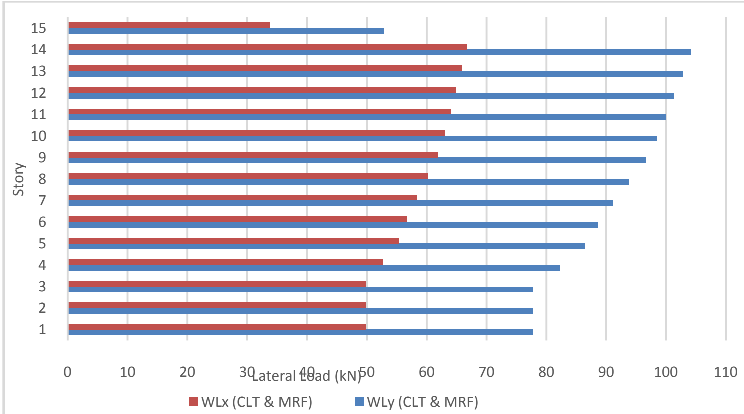

Figure 6 Lateral Load due to Wind

CONCLUDING REMARKS

This study presents the design of multi storey Cross Laminated Timber Building as per provisions described in Eurocode 5. Based on the comparison of analysis and design results of CLT and RCC moment resisting frame in terms of section sizes, base reaction, lateral story forces, time period, inter-story drift ratio, story displacement following concluding remarks are made:

- The dead weight of the CLT Building is much less in comparison to RCC frame Building because of lesser density of timber. Lower gravity loading results in lower seismic forces and lower forces at foundation level. Dimensions of foundation will be reduced due to lower gravity and seismic forces.
- Due to lower stiffness of timber as compared to concrete, the CLT building experiences higher lateral drift ratio and to controllateral drift the cross section of elements need to be increased.

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Development and Evaluation of Adjusted-NDSSI using Sentinel-2 Satellite Data: A Case Study of Mula Dam Reservoir, Maharashtra State, India.

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Abstract*: The study focused on assessing suspended sediment concentration (SSC) in Mula dam reservoir, employing the synoptic and cost-effective approach of remote sensing. Utilizing Sentinel-2 satellite data and band indices, Normalized Difference Suspended Sediment Index (NDSSI) and Adjusted-NDSSI, calibrated against observed SSC. Adjusted-NDSSI was developed based on in-situ spectral signatures obtained from SVC Spectroradiometer HR-1024i. Various calibration functions, including linear, power, quadratic, exponential, and logarithmic, were applied using 80% of the dataset. The exponential function for both NDSSI and Adjusted-NDSSI demonstrated higher R^2 values, chosen for subsequent estimation and validation. Comparison of estimated SSC using the exponential function of both indices with the observed SSC in the validation dataset (20%) involved visual interpretation, linear regression t-test, and student t-test. Statistical error and efficiency models (RMSE, MAPE, and NSE) were employed for NDSSI and Adjusted-NDSSI. The exponential function of Adjusted-NDSSI (RMSE=24.25 mg/L, MAPE=38.20%, NSE=39%) outperformed NDSSI (RMSE=15.847 mg/L, MAPE=32.5%, NSE=74%) in SSC estimation for Mula dam reservoir. The study suggests that the exponential function of Adjusted-NDSSI is suitable for spatio-temporal mapping of SSC in the reservoir using historic Sentinel-2 images.*

Keywords*: NDSSI; Spectral response; Suspended sediment concentration; t-test.*

INTRODUCTION

River sediment, comprising suspended and bed load, poses various challenges when trapped by dams, leading to storage loss, delta deposition, navigation issues, earthquake hazards, energy loss, and ecological disturbances. Dam-induced silt trapping affects downstream engineering and can cause problems like clogging, abrasion, and erosion. Addressing sedimentation issues demands site-specific management strategies due to the complexity of the problems and available solutions.

The aim of measuring suspended sediment is to assess the overall volume of suspended load, sediment concentration, and particle size distribution in rivers, lakes, or reservoirs. This process primarily focuses on quantifying sediment transport and understanding variations in suspended sediment levels over time. While field measurements are deemed more precise, they are also labour-intensive and time-consuming (Pavelsky and Smith, 2009).

Suspended sediment concentrations (SSC) exhibit significant spatial variability, and remote sensing, leveraging spectral reflectance data, provides accurate estimations by contextualizing point measurements. The interaction of solar radiation with subsurface water increases surface reflectance, forming the basis for remote sensing of SSC (Curran and Novo, 1988). Satellite technology, exemplified by the Landsat series and Sentinel-2, monitors SSC since the 1970s (Ritchie et al., 1976). Reflectance correlates with SSC, particularly in the 0-50 mg/l range, necessitating curvilinear relationships in longer wavelengths for higher concentrations (Ritchie and Schiebe, 2000). Remote sensing, especially in visible and NIR spectral ranges, is crucial for precise suspended sediment estimation

(Lodhiet al., 1997; Moridnejadet al., 2015). Indices like NDSSI (Hossain et al., 2010) and Sentinel-2 bands further aid in mapping SSC distribution (Muniret al., 2019).

In the present research, we studied the potential of remote sensing to develop an index and to determine co-efficient relating the index with SSC that can be applied in various water bodies, particularly when there is unavailability of in-situ measurements. The study involves multispectral data in the form of spectral bands (Sentinel 2) of different SSC and aimed i) to identify appropriate spectral bands for SSC retrieval in water body, ii) to develop sentinel 2 MSI index based SSC retrieval model iii) to evaluate the statistical efficiency and test the validity of developed index based model.

MATERIAL AND METHODS

In this study, in-situ water samples containing suspended sediment were collected from Mula Dam Reservoir, and corresponding latitude and longitude coordinates were recorded on the day of the Sentinel-2 pass over the reservoir.

Study Area

The Mula Dam Reservoir, situated in the Ahmednagar district of Maharashtra, India, spans the Mula River, a Pravara River tributary flowing into the Godavari River. Positioned at approximately 19º20’ to 19º35’ N latitude and 74º25’ to 74º36’ E longitude, the dam boasts a water storage capacity of 736.238 Mm^3 and a maximum depth of 67.97 m. With a catchment area of 2275 Km^2 and a semi-agricultural, semi-arid physiography, the reservoir serves Ahmednagar city and Rahuri/NewasaTahsil for drinking and irrigation. The study aims to assess SSC for ecological balance and reservoir management, crucial for sustaining water quality and diverse fish species.

In-situ data on suspended sediment in Mula dam reservoir

Fieldwork were carried from October 31st , 2021, to February 18th, 2022, with a survey of 110 sampling sites at intervals of approximately 700 to 1000 m on five different dates across the Mula Dam Reservoir. Water samples, collected during clear sunny days coinciding with Sentinel-2 passes, were gathered at a 15 cm depth using a 1-liter capacity bottle and a sampler. Locations were recorded via a Garmin Montana 680 GPS receiver, ensuring a distance of at least 20 m from the reservoir bank to avoid spectral mixing. To enhance in-situ data accuracy, the boat was turned off to minimize turbulence during measurements in a shadow-free area. Samples were taken where the depth exceeded 2 m to prevent bottom reflectance. The SSC of each water sample was measured gravimetrically (Pavanelli and Bigi, 2005) and expressed in milligrams per litre (ppm).

Generation of spectral signature using SVC-HR 1024i Spectroradiometer

During sample collection, the spectral response (350 nm–2500 nm) of all locations was recorded using the SVC-HR 1024i Spectroradiometer with a multispectral sensor (25º Field of View) attached to an optical fibre positioned 0.5 m above the targeted water surface. The spectral responses (shown in figure 1), obtained in three replications, were processed in SVC software for merging, overlapping, and resampling. Spectral reflectance for each sampling location across the entire spectral range (1 nm interval) was calculated using Equation (1).

$$R(\%) = \frac{SI_{target}}{SI_{reference}} \times 100 \qquad (1)$$

Where, R = Spectral reflectance of target in per cent, SI_{target} = Spectral Irradiance of target, $SI_{reference}$ = Spectral Irradiance of reference panel

Satellite Data Acquisition and Pre-Processing

The Sentinel-2A and 2B satellites share an identical Multispectral Instrument (MSI) featuring a 290 km field of view and 12-bit radiometric quantization. This MSI provides 13 spectral bands covering the Visible, Near Infrared (NIR), and Short Wave Infrared (SWIR) regions, with a 5-day temporal resolution and a spatial resolution of 10 m/ 20m/ 60m. The Level-2A processing involves scene classification and atmospheric correction, yielding orthoimage Bottom-Of-Atmosphere (BOA) corrected reflectance products. The Sen2Cor processor facilitates Level 2A product generation, including atmospheric, terrain, and cirrus correction. Pre-processed Level-2A Sentinel-2 satellite images from the specified dates were downloaded and further processed using ArcGIS.

Model Development

Out of 110 samples from the Mula Dam Reservoir, 80% (88 samples) were allocated for calibration, and 20% (22 samples) were reserved for validation through random number table selection. Linear, quadratic, and exponential models were calibrated against NDSSI and Adjusted-NDSSI using the calibration dataset. These calibrated models were then applied to estimate SSC values for the validation dataset. Assessment metrics, including R^2, MAPE, RMSE, and NSE, were calculated to evaluate the validation accuracy by comparing measured and estimated SSC values.

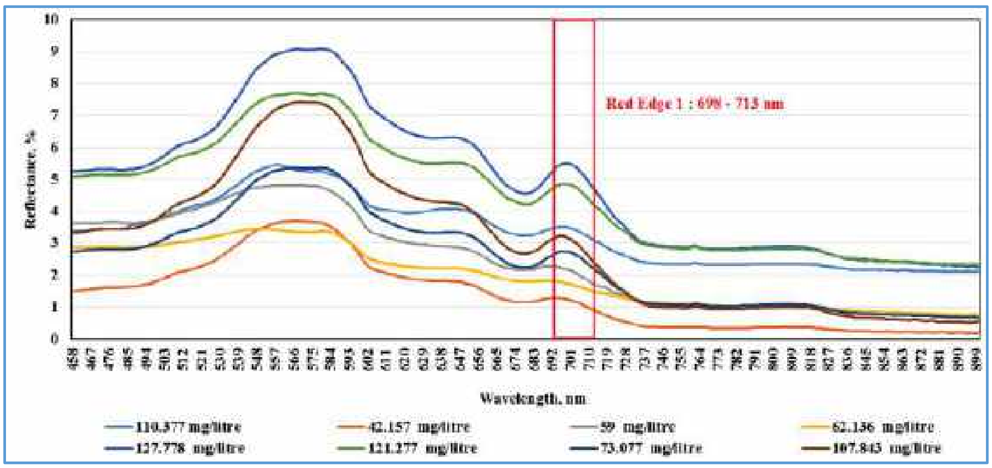

Figure 1 Spectral Response of different SSCs with emerging peaks in Red Edge 1 (698 – 713 nm) region

Normalized Difference Suspended Sediment Index (NDSSI)

Inspired by the concept of NDVI, Hossain et al, (2010) developed NDSSI using Landsat 7 ETM+ imagery by using Equation 2 given below.

$$\text{NDSSI} = \frac{\text{Blue} - \text{NIR}}{\text{Blue} + \text{NIR}} \qquad (2)$$

In this study, NDSSI values, derived from Sentinel-2 bands 2 (Blue) and 8 (NIR), were used for SSC estimation, where blue and NIR bands typically yield the highest and lowest reflectance for water. NDSSI values, ranging from -1 to +1, are inversely proportional to SSC. Empirical models were developed by correlating NDSSI with the calibration set of SSC data, drawing on previous works by Hossain et al. (2010) and Kavan et al. (2022), who achieved R^2 values of 0.78 and 0.45, respectively, for turbid waters and glacial lake sediment.

Adjusted - Normalized Difference Suspended Sediment Index (Adjusted - NDSSI)

Gholizadeh et al. (2016) observed increased visible region reflectance, especially in the red spectrum, correlating with higher water sediment or turbidity levels. Shifting from green to red indicated sediment increase. Literature suggests a single well-chosen band can reliably estimate turbidity (Pavelsky, 2009). Robert (2016) found near-infrared to red band ratio effective for SSC and turbidity assessment. Spectral signatures revealed peaks at 690 to 720 nm, prompting NDSSI adjustment (Equation 3) using Sentinel-2's Red Edge-1 band (698 to 713 nm). Maciel et al. (2019) proposed a satellite-derived model using Sentinel-2 MSI's Red Edge 1 band for precise total SSC retrieval. Adjusted-NDSSI values, like NDSSI, range between -1 and +1, inversely proportional to SSC.

$$\text{Adjusted NDSSI} = \frac{\text{Blue} - \text{Red Edge 1}}{\text{Blue} + \text{Red Edge 1}} \quad (3)$$

Calibration of relationship between NDSSI and adjusted NDSSI with observed SSC

NDSSI values from Sentinel-2 were correlated with real-time in-situ SSC measurements in Mula Dam Reservoir. Linear, logarithmic, quadratic, and exponential equations were explored, with NDSSI ranging from 0 to 0.5. Lower R^2 values were observed for linear (0.45), logarithmic (0.36), and quadratic (0.47) functions. The highest coefficient of determination ($R^2 = 0.57$) was observed for the exponential function of NDSSI [Equation 4 and figure 2(a)]. The coefficients from the exponential equation with the highest R^2 were deemed suitable for SSC estimation in Mula Dam Reservoir.

$$\text{SSC estimated} = 114.13 \times e^{-4.695 \times \text{NDSSI}} \quad (4)$$

Where, a = 114.13 and b = -4.695 are empirical coefficients.

Adjusted-NDSSI values from Sentinel-2 were correlated with real-time in-situ SSC measurements in Mula Dam Reservoir. Linear, quadratic, and exponential equations were employed, with Adjusted-NDSSI ranging from -0.2 to 0.3. Comparable coefficient of determination (R^2) values were observed for linear (0.589) and quadratic (0.590) functions, while a slightly higher R^2 was noted for the exponential function. Coefficients from the exponential equation with the higher R^2 were deemed suitable for SSC estimation in Mula Dam Reservoir, as illustrated in Equation (5) in **Figure 2 (b)**.

$$\text{SSC estimated} = 80.71 e^{-5.593 \times \text{Adjusted-NDSSI}} \quad (5)$$

Where, a = 80.71 and b = -5.593 are empirical coefficients.

Model testing and performance evaluation

The estimated SSC values are compared with corresponding in-situ SSC of validation dataset. The statistical analysis such as linear regression t-test, student's t-test, root mean square error (RMSE), mean absolute percentage error (MAPE), the coefficient of determination (R^2) and Nash-Sutcliffe model efficiency coefficient were calculated between observed and estimated values to select the best fitting and validation accuracy. The methodology used for applying linear regression t-test, student's t-test is discussed here. For calculating RMSE, MAPE, R2 and NSE standard formulae were used.

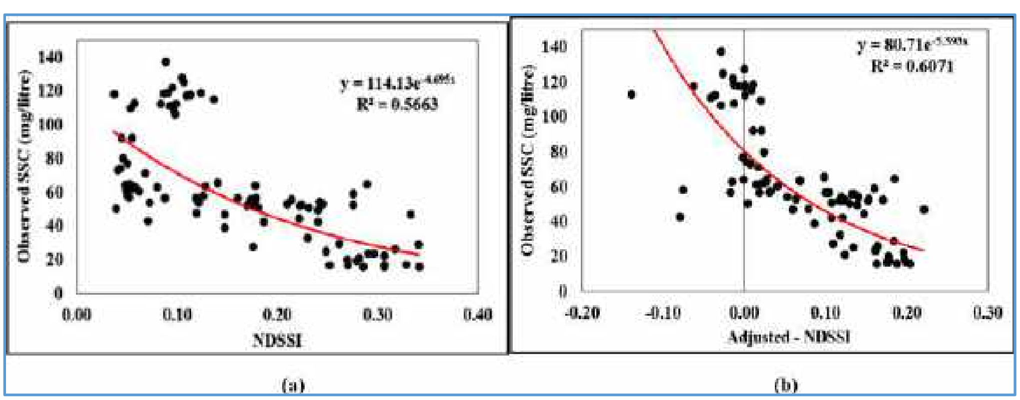

Figure 2 Exponential function between (a) NDSSI and Observed SSC (b) Adjusted NDSSI and Observed SSC using calibration set of data

Linear Regression t-test

The observed and estimated SSC values were treated as dependent (y) and independent (x) variables respectively for linear regression (equation 6),

$$y = a + b\,x \qquad (6)$$

Null hypothesis, Ho: a = 0 and b = 1

Alternate hypothesis: a ≠ 0 and b ≠ 1

Hypothesis test: t (a) and t (b) for (n-2) degrees of freedom at 5 % level of Significance, Where, t(a) = |a / SE (a) | and t(b) = | (b-1) / SE (b) |and if, t(a) < t table = 2.18 at 5 % LOS then 'a' is insignificant and t(b) < t- table = 2.18 at 5 % LOS then 'b' is insignificant

Student's t-test

The mean of observed and estimated SSC values was compared using student's t-test for (n-2) degrees of freedom at 5% level of significance. The t_{cal} (eqn7) less than t-table value 2.18 for (22-2=20) degrees of freedom at 5% level of significance indicates the difference between means of observed and estimated insignificant.

$$t_{cal} = \frac{\left|\overline{E_i} - \overline{O_i}\right|}{Var(O_i, E_i)\sqrt{n}} \qquad (7)$$

Where, Ei = Estimated SSC (mg/L) and Oi = observed SSC (mg/L), n = number of samples.

RESULTS AND DISCUSSION

In-situ Data

Out of 110 samples, 88 were used for calibration and 22 for validation. The average observed SSC for all samples, calibration, and validation datasets was 61.43 mg/l, 62.65 mg/l, and 57.04 mg/l, respectively. The observed SSC ranged from 15.62 to 137.65 mg/l across all datasets, with standard deviation (SD) and coefficient of variation (CV) values of 32.59 mg/l and 53.05%, respectively. Both calibration and validation datasets exhibited similar statistical characteristics to the overall dataset.

Table 1 Statistical parameters of datasets used in the study

Dataset	Number of Samples	Min	Max	Mean	SD (mg/L)	CV (%)
All	110	15.62	137.65	61.43	32.59	53.05
Calibration (80 %)	88	15.91	137.65	62.53	32.87	52.57
Validation (20 %)	22	15.62	121.43	57.04	31.78	55.72

Spatial distribution of observed SSC in the Mula Dam Reservoir was mapped using the Kriging method in ArcGIS, depicting higher SSC near the river inlet and lower values as it approaches the embankment (Fig 3), utilizing GPS locations and assigned SSC values.

Validation of Developed Relationships

Quantitative comparison of estimated SSC by exponential function of NDSSI and Observed SSC of validation dataset and estimated SSC by exponential function of Adjusted-NDSSI and Observed SSC of validation dataset is shown in the figure 4(a) and 4(b) respectively. Both the relations between observed and estimated values of SSC follows linear form of equation (equation 8) given in equation 9 and 10 below with R^2=0.445 and R^2=0.745 respectively.

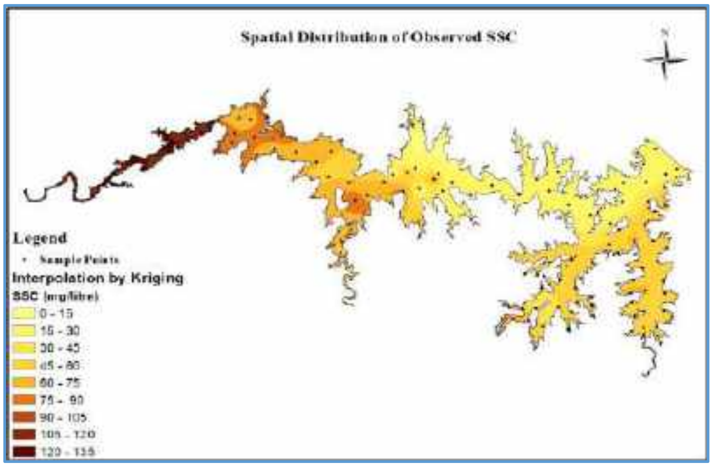

Figure 3 Spatial distribution of Observed SSC during October 2021 and February 2022

Validation of Developed Relationships

Quantitative comparison of estimated SSC by exponential function of NDSSI and Observed SSC of validation dataset and estimated SSC by exponential function of Adjusted-NDSSI and Observed SSC of validation dataset is shown in the figure 4(a) and 4(b) respectively. Both the relations between observed and estimated values of SSC follows linear form of equation (equation 8) given in equation 9 and 10 below with R^2=0.445 and R^2=0.745 respectively.

$$y = a + b\,x \quad (8)$$

$$y = 25.668 + 0.5927 \times x \quad (9)$$

$$y = 18.996 + 0.6711 \times x \quad (10)$$

Where, x = observed values of SSC and y = estimated values of SSC. Values of a = 25.668, b = 0.5927 in equation 14 and a = 18.996, b = 0.6711 in equation 15 are subjected to linear regression t-test discussed in the next section.

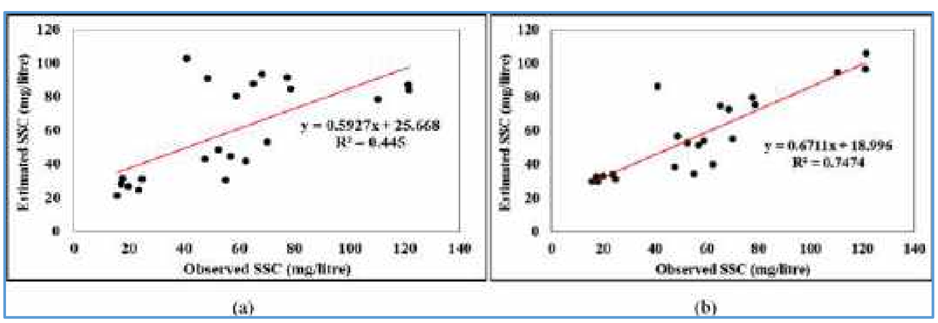

Figure 4 Observed SSC again estimated SSC with linear regression and R^2 for estimated SSC using (a) exponential function of NDSSI and (b) exponential function of Adjusted-NDSSI

Values of estimated SSC by both the exponential functions of NDSSI (Eqn.4) and Adjusted-NDSSI (Eqn.5) were compared [**Figure 5(a)** and **5(b)**] with observed values of SSC of validation dataset. Visual interpretation of these two plots clearly indicates more close association between observed SSC values and estimated SSC values by exponential function of Adjusted-NDSSI than that between exponential function of NDSSI.

Application of Statistical Tests to validate the relationship

To assess the accuracy of the models, t-tests were conducted on the linear regression coefficients 'a' and 'b' for NDSSI and Adjusted-NDSSI models (from Equations 9 and 10). The t-test results (**Table 2**) show that the calculated test statistics [t(a) and t(b)] for NDSSI and Adjusted-NDSSI are less than the critical t-table value of 2.18. Student's t-test for the exponential equations revealed a smaller absolute difference between the average of observed and estimated SSC values for Adjusted-NDSSI (0.234 mg/litre) compared to NDSSI (2.43 mg/litre). This indicates a more precise estimation of SSC with Adjusted-NDSSI, supported by the insignificant difference in t-tests at a 5% significance level (**Table 2**) and 20 degrees of freedom

Table 2 Summary of linear regression and student's t-test between observed and estimated SSC for validation set of data

Statistical Test	Model	
	$SSC_{estimated} = 114.13e^{-4.695 \times NDSSI}$	$SSC_{estimated} = 80.71e^{-5.593 \times Re\text{-}NDSSI}$
Linear Regression test		
t(a)	0.08	0.06
t(b)	2.01	1.54
Significant	No [t(a), t(b)less than 2.18]	No [t(a), t(b)less than 2.18]
Student's t-test		
t_{cal}	0.435	0.045
Significant	No [t_{cal}less than 2.18]	No [t_{cal} less than 2.18]

Model Evaluation

The exponential model of NDSSI yielded a coefficient of determination below 0.5, considered unacceptable (Sutari et al., 2020). Error statistics, including Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE), were assessed for both NDSSI and Adjusted-NDSSI-derived SSC estimations. The exponential model of Adjusted-NDSSI demonstrated lower RMSE (15.847 mg/litre) and MAPE (32.5%) compared to NDSSI (RMSE = 24.253 mg/litre, MAPE = 38.20%). Nash-Sutcliffe model efficiency (NSE) was higher for the exponential model of Adjusted-NDSSI (74%) than NDSSI (39%). Adjusted-NDSSI exhibited lower error susceptibility and higher efficiency, indicating superior performance in SSC estimation.

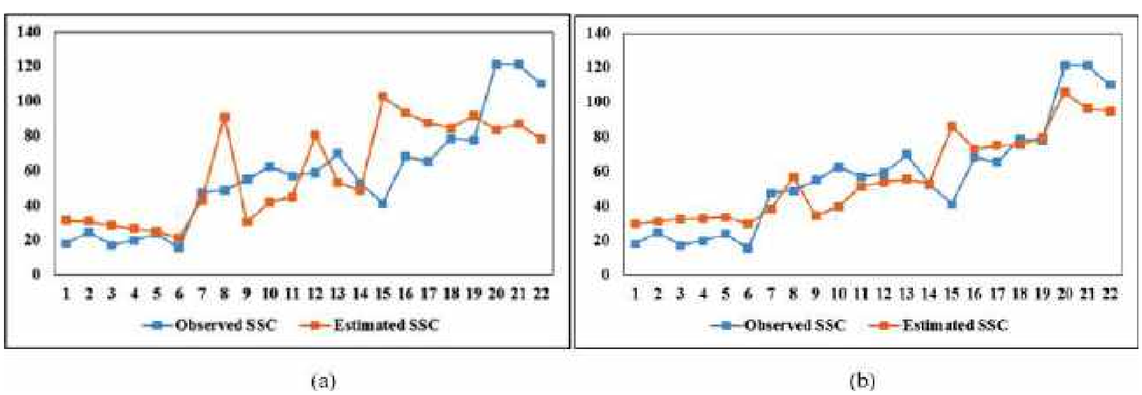

Figure 5 Observed and estimated SSC using exponential function of a) NDSSI b) Adjusted-NDSSI

Suitability of remote sensing for the assessment of suspended sediment

There are several advantages as well as limitations that must be considered for analysing the results. Each Sentinel-2 satellite crosses every point on Earth once every 10 days, while two Sentinel-2 (A and B) satellites are in operation making temporal resolution of 5 days. Temporal resolution represents the information of date acquisition of satellite data and the cloud cover. The cloud cover result in worse satellite image quality in the wet or monsoon season (June to September). The model is built using remote sensing data which has partial advantage in temporal resolution.

CONCLUSIONS

The necessity of regular monitoring and estimation of SSC is felt due to its importance for aquatic ecosystem, environment and water resource management. It is advantageous to use remote sensing as a tool for the estimation of suspended sediment in the water bodies where the data availability is scarce in developing countries like India. The research shows how SSC can be used to trace the spatial variation of SSC in Mula dam reservoir using SSC that can be predicted based on Sentinel 2 satellite image. Through a robust calibration/ validation process and statistical testing, this research produced a good accuracy of SSC estimation in Mula dam reservoir. We found that the SSC prediction based on Adjusted-NDSSI produces acceptable outcomes. Due to their high temporal and spatial resolutions of Sentinel-2 Satellite and the data for the band Red Edge 1 (B5 at 705nm) being available in the Sentinel 2 images, they are highly helpful for frequent and routine monitoring of SSC in water bodies and reservoirs. For managers, researchers, or other stakeholders involved in the assessment and sustainable use of surface water resources, it offers great promise as a source of information.

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Adapting to Change in Construction Projects Management - A Possible Solution

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***Abstract**: National Geospatial Policy, 2022 was notified by the Government of India on December 28, 2022. The policy identified nodal ministries for different areas of infrastructure, laid guidelines for strategy and approach and prescribed milestones for progress by 2025, 2035 and 2047 (Centenary of India's Independence). The Ministry of Housing and Urban Affairs is the nodal ministry for establishing an institutional framework to encourage innovation in Infrastructure Projects. Digital Twin Promotional Board is envisaged under this ministry, as an enabler, to build the framework for innovative use of Geospatial, Building Information Modeling (BIM) and Digital Twin Technologies in infrastructure projects. Use of Digital Twin Technologies in Infrastructure projects is on the increase for Planning, Design and Construction (PDC) activities to cut down delays, cost overruns, monitoring progress and redesign if problems are encountered during project grounding or upgradation to meet futuristic needs. Having a Digital Twin helps troubleshooting, foresee maintenance issues and in Asset Management.*

Scrum is an iterative process extensively used in software projects/products not only during product development but also for maintenance and upgrade. Adaptation of Scrum in construction projects to encourage innovation and discover the best use of developing technologies is advocated due to the flexibility in application, maximizing productivity of heterogeneous teams and ability to make course corrections to meet project objectives. It is amenable to modular concepts.

The definition of Scrum, the theory and the elements of the process are described. SWOT analysis of traditional practices of planning and project management and that of evolving practices using Geospatial, BIM and Digital Twin technologies in construction projects is made. The adaptability of Scrum in innovative use of emerging technologies for such projects is presented. The resources that are available in the public domain to encourage their use for the benefit of the society at large are mentioned. Typical use of Scrum in certain construction project scenarios and repurposing is also presented to advocate implementation.

***Keywords**: Geospatial; Digital Twin; Construction Projects; Scrum; Adaptation*

INTRODUCTION

National Geospatial Policy, 2022 was notified by the Government of India (GOI), Department of Science and Technology (DST) on December 28, 2022 [1]. DST is the nodal department for the policy. The policy, in Para 3 - Strategy and approach, emphasized that Geospatial technology and data are agents of transformation for achieving the Sustainable Development Goals (SDGs) to bring efficiency in all sectors of economy and instill accountability and transparency at all levels of governance and innovate to capitalize on opportunities arising out of continually evolving technologies. Geospatial Data Promotion and Development Committee (GDPDC) is the apex body for the policy implementation with Surveyor General, Survey of India (SOI, DST) as member secretary. National Fundamental Geospatial Data themes and responsibility matrix are specified in Annexures II and III in the policy. Survey of India (SOI) is the nodal agency for Geospatial data. National Geospatial Data Registry (NGDR) is to be developed and operated by SOI with Unified Geospatial Interface (UGI) in association with Bhaskaracharya Institute for Space Applications and Geoinformatics (BISAG-N), Ministry of Electronics and Information Technology (MeitY), GOI.

The vision is to develop a coherent national framework for a Geospatial Knowledge Infrastructure (GKI) with integrated geospatial data and information framework by 2030 using the emerging technologies in Geospatial arena, Building Information Modelling (BIM), and Digital Twin amongst others. Development of a National Digital Twin of major cities and towns by 2035 is a goal set under the policy. The Ministry of Housing and Urban Affairs (MH & U) is the nodal Ministry for establishing an institutional framework for Buildings & settlements and physical infrastructure in urban areas and the Ministry of Panchayat Raj (M PR) in rural areas (items 8 and 10 respectively in Annexures II and III of the policy). Digital Twin Promotional Board is envisaged under MH & U to encourage innovation in the construction projects adapting the emerging digital technologies. National Digital Twin is to be at the core of this initiative.

SCOPE AND LIMITATIONS

The theme of the 38th Indian Engineering Congress (IEC 2023) is “Reimagining Tomorrow: Shaping the future through Disruptive and Interdisciplinary Technologies”. The field of development of physical Infrastructure and management of these physical assets through their life cycle is witnessing a sea change in conceptualization, planning, construction and maintenance with the progress in technologies in the areas of Surveying, Geospatial data, Building Information Modelling (BIM), Digital Twin, Real time communication links, Satellite imagery amongst others. This paper attempts to present the increasing use of these technologies in Construction Projects Management in India. “SCRUM” process is proposed as a possible solution to manage change and to discover the maximum potential.

The scope of this paper is limited to the Construction Projects Management of physical infrastructure from the conceptual stage to asset management through its life cycle, leveraging the potential of digital technologies in Geodetic survey, Geospatial data capture, dissemination and use, BIM and Digital Twin with participation of all stakeholders. The information available in the public domain is the source for this paper.

GLOSSARY OF TERMS

The International Standards Organization (ISO) brought out the ISO 19650 series of specifications “Organization and digitization of information about buildings and civil engineering works including Building Information Modelling (BIM) [2]. Part 1 (2018) covers the Concepts and principles, Part 2 (2018) the Delivery phase of the assets, Part 3 (2020) the Operational phase of the assets. The security of data in a digital built environment and smart asset management is covered in Part 5. Part 6 covers Health and Safety information. This series of standards contribute in achieving Sustainable Development Goal 9 (SDG 9) in Infrastructure and Industrialization.

Construction Projects are a subset of physical infrastructure projects in the areas of transportation, water supply and irrigation, power and civic services. Physical infrastructure in the areas of terrestrial and space communications (digital) is outside the scope of the discussion. Four elements of a project are Scope, Time, Money and Resources.

Construction Projects Management is the process of management of the projects from concept stage, survey, plan, design, construct and maintenance through the life cycle. It is also the practice to term the same as Asset Management.

Building Information Modelling (BIM) is a 3D representation of the Building/Physical asset.

Digital Twin is a virtual model of the physical asset which is dynamic and can provide real time status and performance with bi-directional communication.

Traditional Practices in Construction Projects define the scope, estimate money and time requirements in a Preliminary Project Report (PPR) on location reconnaissance/survey. After receipt of administrative approval, Detailed Project Report (DPR), Detailed Survey, Design/construction Drawings are prepared. Progress of construction is monitored through Generalized Activity Normalization Time Table charts (GANTT charts), Programme Evaluation and Review Technique (PERT), Critical Path Method (CPM). After completion of the construction, Completion/Built Project drawings (final) are prepared to assist asset management through the service life.

Digital technologies: Light Detection and Ranging(Lidar), Satellite imagery, 2D and 3D CAD, BIM, Digital Twin

The “SCRUM” - What is it?

“SCRUM” is defined as a lightweight framework that helps people, teams and organizations to generate value through adaptive solutions for complex problems [3]. It is an iterative process for which Scrum Master has to create an enabling environment. It is widely used in software projects, though conceptually it can be used in any domain and any activity because of the flexibility in application, incremental approach to optimize productivity, modular nature and agility for adaptation.

Ken Schwaber & Jeff Sutherland, the Authors of “The Scrum Guide - The Definitive Guide to Scrum: The Rules of the Game, November, 2020” [3] welcome the increasing use of Scrum beyond software projects in various other domains. The Scrum process can be adapted with ease to manage the change and capitalize on the opportunities arising out of continually evolving technologies in construction projects domain because of its simplicity, flexibility and adaptability of its principles. Team comprises Developers, Product Owner and Scrum Master. Scrum Master can be termed as “Sutradhar”. It underlines the importance of Transparency, Inspection and Adaptation. It values Commitment, Focus, Openness, Respect and Courage.

Sliger, M.(2011), in the conference paper “Agile Project Management with Scrum” at PMI ® Global Congress 2011-North America, Dallas, TX of Project Management Institute compared the traditional methods in Project Management of fixing requirements to control time and cost against an agile process of scrum which fixes time and cost to control requirements [4]. On the face of it, one may wonder as to how the requirements can be modified. The process/product can be subdivided into smaller events/components called “sprints” to be executed by a team which are inviolable incremental agreements fixing the time and costs. The Sutradhar’s (Scrum Master) role is very critical in the coordination between the teams and the product owner and not to lose track of the overall project objectives/deliverables. The iterative incremental approach helps in optimizing predictability because of transparency, inspection and adaptation to meet the challenges in change management and make course corrections at the earliest detection of deviations. The strategy adopted by Indian Space Research Organization (ISRO) in Solar Mission Aditya-L1 to put the solar probe satellite with seven payloads around the Lagrangian Point L1 is the best example [5]. The incremental corrections made with the onboard motors helped in modifications of the orbital parameters in stages to put the satellite on its way to trajectory to L1 point. It is expected to reach L1 point by mid January 2024 after a journey of 110 days from the earth.

The Digital Technologies in construction projects Management - Use and progression:

Digital Twin Strategy for Indian Infrastructure (2023), has been prepared under the aegis of Non-Executive Think tank on Digital Twin Strategy for Indian Infrastructure with participation and collaboration of various stakeholders [6]. The document presented case studies on Statue of Unity, Sardar Sarovar Dam, Kevadia, Gujarat-393155 (2018), The India International Convention and Expo Centre (IICC), New Delhi (2022), Kempegowda International Airports Second Terminal, Bengaluru, Karnataka (2022), Chenab Rail Bridge, J & K (2023) amongst others. The case studies highlight the project challenges, digital technology resources used and value propositions.

Andreani, L., et al., in the article “Implementing integrated digital twin modeling and representations into the Snap4City platform for smart city solutions” (2023) brought out the technological solutions and tools used in the implementation of integrated digital twin modeling and representation [7].

Disney, O., et al., in the paper “Total BIM on the construction site: a dynamic single source of information”, (2023) presented as to how the Total BIM concept applies a new dynamic way of working where there is a single source of connected information for an integrated approach [8]. On site limitations and challenges of four BIM projects, 2013 Rofors Bridge Project, 2016 Norwegian Urbygningen Project-Refurbishment of a building at the Norwegian University of Life Sciences, 2017 Oslo Airport Terminal 2 Project - New Terminal building and the ongoing Slussen

Project in Stockholm involving rebuilding a large lock were presented. The challenges are cost of creating a high quality BIM, interoperability issues between software programmes, geometry, competency at site and software and hardware limitations. The technological developments over the decade 2010-2020 eased the implementation of Total BIM projects, - Celsius Project Office and Laboratory Building completed in Sweden in 2020; Glasblokken Trinn 2, an ongoing hospital project; Lumi and SB 47 ongoing building renovation projects. The case studies showed that 2D drawings are no longer necessary and the Total BIM concept could support model based construction processes and a dynamic single source of information towards the construction site's digital twin.

Dolla.T., Jain.K., Kumar Delhi.V.S., in the paper "Strategies for digital transformation in Construction Projects: Stakeholders' perceptions and Actor dynamics for Industry 4.0", (2023), present a road map of Industry 4.0 for the Indian construction industry with particular reference to project management practices [9]. The top four strategies identified are, stakeholder integration; process re-engineering; training activities and generating federated data. The study indicated that while project management principles remain the same, the practices are obliged to change to respond to technological developments. The top four strategies identified are crucial interventions required in PM practices. The magnitude of interventions required differ depending on organizational sizes and resources. Larger the size of the organization, it is more difficult to change the practices. One important aspect identified is to have cross functional teams and eliminate the process of independent working in silos. In other terms, the teams shall be diversified in skill sets than specialist teams. More the practices are agile, more dynamic would be response to technological developments and help change management. Adapting "Scrum" in such a scenario would be beneficial.

Obinna C. Madubuike., et al., in the paper "A review of Digital Twin applications in Construction", (2022), reviewed 20 articles on the development and implementation of digital twin technology (DT) [10]. Adoption of Digital Twin (DT) in the construction industry is assessed to be negligible in comparison with that in the areas of Manufacturing, Automotive, Telecommunications, Healthcare, Aerospace and Wind energy turbines. Promising trends in adoption of DT in the construction industry is observed. Possible reasons for low adoption could be those observed by Dolla, T.,et al.,(2023) [9]. Tweaking of construction management practices would be beneficial to improve on the adaptation of DT and respond to dynamics of technological developments in Digital Twin Technology (DT). An important suggestion was to start implementing DT in the Design phase to analyze the feasibility of a design before construction. Once implemented in the design phase, application of DT can be extended to the Construction phase to monitor progress, identify deviations from plans and respond to make necessary course corrections. Scrum process, with the digital twin acting as an artifact providing transparency and opportunity for inspection and adaptation, could be the solution to improve predictability on cost and time overruns. Scrum process, being agile, would help decision making and change management. DT could then be extended to operations and maintenance phases of the assets through its life cycle. In cases of retrofitting or renovation projects of heritage structures, DT can be implemented successfully as has been presented by Disney, O., et al., (2023) [8].

SWOT Analysis:

SWOT Analysis of the traditional practices and evolving practices in construction projects is made in **Table 1**.

Resources:

- Geospatial Knowledge Infrastructure (GKI) with Unified Geospatial Interface (UGI)
- National Institute of Geo-Informatics Science & Technology, Hyderabad, Survey of India under National Data Sharing and Accessibility Policy, 2012 (NDSAP)
- National Geospatial Data Registry (NGDR), Survey of India
- Bhuvan, National Remote Sensing Center (NRSC), Hyderabad, ISRO
- NavIC (Navigation with Indian Constellation) services of ISRO.

Table 1 SWOT Analysis

	Traditional Practices	Evolving Practices
Strengths	● Evolved over time, skills absorbed in Guru-Shishya parampara or as family traditions/learnings ● Traditional methods commensurate with human resources, local materials and environment friendly ● Society involvement	● Use of new and developing technologies ● Can be documented and used through the asset life cycle
Weaknesses	● Slow progress ● Dependant on leader's quality and initiatives ● Requires specialist manpower if locally not available ● Limitations in the resources ● Inaccuracies of estimates of cost and time	● Dependant on skilled personnel availability ● Cyber security ● Dependant on robust bi-directional communication links ● Materials used may not be environment friendly ● Society involvement absent, may lead to unrest ● Training requirements
Opportunities	● Parallel growth ● Commensurate with local society requirements	● faster development ● Control on cost and time overruns
Threats	● Social inequalities ● Skewed development ● Documentation deficiency ● Project delays when key personnel quit	● Monopoly

CONCLUSIONS

The challenges are surmountable. Industry 4.0 can be extended to construction projects as well to enhance productivity, efficiency and flexibility to derive benefits of progression in digital technologies. The resources mentioned above are to be made available in the public domain with participation of all stakeholders by 2025 as per National Geospatial Policy (2022) [1]. The vision is for best use of emerging technologies. Scrum in view of its adaptability can be deployed in multidisciplinary teams to manage change with the digital technologies and re-engineer the construction management practices and beat any monopolistic trends.

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Innovative Building Integration: Unveiling Solar Windows as Invisible Solar Panels through Cutting-Edge Technology

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Abstract: *In this paper, Cutting-edge technology approaches are emerging to revolutionize power generation in a world growing more conscious of climate change and the environmental effects of conventional energy sources. One such innovative technology that could transform common windows into renewable and clean energy sources is the solar window. The market for solar windows is expanding quickly; this paper examines its advantages, disadvantages, and prospects for incorporation into our built environment.Solar windows use cutting-edge materials and engineering to capture sunlight and turn it into electricity. They are also referred to as transparent photovoltaics or solar glass. These windows can be used as regular windows or as energy-generating devices, utilizing solar energy to create electricity while letting natural light in. This dual functionality has enormous potential for use in home and business settings. The state-of-the-art technology known as transparent solar collects and harnesses light energy from any glass surface, including windows, at any angle. It could be a game-changer in terms of expanding solar's application.A critical review of the state of several emerging and current energy harvesting technologies for building integration is given, along with information on their potential applications in the future.*

Keywords*: renewable, solar windows, cutting-edge, transparent solar, energy generating*

INTRODUCTION

In recent times, there has been a growing interest in finding innovative approaches to enhance energy efficiency. Notably, in countries such as the United States and China, buildings presently contribute to more than 41% and 28% of overall energy consumption, respectively (Xia et al. 2014). The substantial portion of energy consumed in buildings is attributed to the necessity of establishing a thermally and visually pleasant environment for occupants. This requirement involves the utilization of ventilation, heating, cooling, and artificial lighting services, collectively responsible for over 70% of the total energy demand in buildings (Abdallah et al. 2015; Ruparathna et al. 2016). Within the spectrum of building components, windows exert a noteworthy influence on both energy consumption and the indoor environment.Optimizing the design and glazing of windows has the potential to decrease energy consumption in residential buildings by 10% to 50% across various climates.

Furthermore, in the context of commercial, institutional, and industrial structures, a well-designed fenestration system has the capacity to lower lighting and air-conditioning expenses by 10% to 40% (Cuce et al. 2015; Cuce and Riffat 2015; Ihara et al. 2015; Vanhoutteghem et al. 2015; Gorgolis and Karamanis 2016; Mangkuto et al. 2016). Substantial improvements in the thermal transmittance (U-value) of fenestration products are attained by incorporating multiple glass panes with enclosed air or inert gas, reducing conduction and convection. Additionally, applying low emissivity coatings to glass surfaces mitigates long-wave heat exchange (Jelle et al. 2012a). Techniques for manipulating the spectral response of glazing have also been developed, including simple approaches like introducing tint to absorb radiation or applying thin film coatings to reflect radiation (Jelle et al. 2012a; Manasrah et al. 2021).

Intelligent windows, designed to modulate the transmission of solar and long-wave radiation in response to various stimuli such as heat (thermochromism), electricity (electrochromism), and light (photochromism), show significant potential for reducing energy consumption in buildings, as demonstrated by studies (Nitz and Hartwig 2005; Cuce and Riffat 2015; Gorgolis and Karamanis 2016). Furthermore, when integrated with photovoltaic (PV) systems, these windows can contribute to electricity generation. Beyond providing aesthetically pleasing features and generating energy, these integrated PV systems can serve as blinds to shield against direct sunlight, thereby reducing the need for air conditioning.

This work presents an examination of current technologies related to windows for electricity generation. The review encompasses traditional approaches involving the integration of photovoltaic (PV) systems into windows and facades, exploring their component applications. The study delves into various types of solar cells applicable to these scenarios, such as Si, thin-film, organic, and dye-sensitized solar cells. It also evaluates the thermal, optical, and electrical performance of building-integrated PV systems, discussing their implications for overall building performance.

Furthermore, the review covers intricate systems like solar thermal PV windows, building-integrated concentrating PV windows incorporating organic dyes, and luminescent solar concentrator (LSC) windows based on quantum dots.

Lastly, it introduces recent research on smart window-integrated PV systems designed for electricity generation. These systems have the capability to dynamically control the solar radiation entering indoor spaces through window systems. In summary, the aim of this review paper is to provide a comprehensive overview of how the integration of smart window technologies can potentially impact the energy efficiency of buildings.

BUILDING INTEGRATED PV (BIPV) SYSTEMS

Overview of PV Technologies for Building Integration

Traditionally, photovoltaic (PV) power plants were typically located in expansive rural areas, necessitating long transmission lines to connect them to urban load centers (Ikkurti and Saha 2015). However, this spatial constraint can be circumvented by directly incorporating PV systems into or mounting them onto buildings, known as building-integrated photovoltaics (BIPV). Beyond their primary role in power generation, BIPV systems can serve the dual purpose of replacing certain building elements, such as façades, windows, or shading devices, leading to potential savings in materials and labor costs (Fossa et al. 2008). Consequently, integrating BIPVs can not only contribute to economic benefits for the building envelope but also result in reduced electricity expenses (Jelle and Breivik 2012).An emerging trend involves the integration of PV technology into building windows or glazed façades, offering buildings not only energy efficiency but also aesthetically pleasing features, reflecting the increasing popularity of this approach (Makrides et al. 2010).

Figure 1 showcases various photovoltaic (PV) technologies, many of which can be applied to windows. Crystalline silicon (c-Si) solar cells have demonstrated an efficiency of approximately 22% (ITRPV 2014), and as of 2017, they held a market share of about 90% (ITRPV 2018). Gallium arsenide (GaAs) solar cells exhibit low non-radiative energy loss, high absorption, and a direct bandgap aligned with the solar spectrum (ITRPV 2014), achieving efficiency levels between 24% and 28% (Kayes et al. 2011; Mattos et al. 2012). Despite their impressive efficiency, GaAs technologies, including III (Al, Ga, In) - V (N, P, As, Sb) multi-junction solar cells, face constraints due to high manufacturing costs, even though they can reach efficiencies as high as 44.7% (Dimroth et al. 2014; Jean et al. 2015). In contrast, thin films consist of thin semiconductor layers supported by a solid backing material, resulting in reduced material requirements and, consequently, lower production costs compared to traditional Si cells (Lechner and Schade 2002; Parida et al. 2011).

Thin-film varieties encompass a-Si, recognized as the most commercially viable film owing to its abundance and non-toxic nature. It facilitates flexible module production and boasts a low substrate cost, resulting in efficiencies ranging from 5% to 7%. However, it is prone to degradation (Chopra et al. 2004; Parida et al. 2011).Cadmium telluride (CdTe) represents a stable compound characterized by a direct bandgap and a substantial absorption coefficient. This leads to cell efficiencies of 21% (First Solar Press Release 2014). CdTe can be synthesized through various methods, although there is notable parameter variation in identical devices (Jäger-Waldau 2004; Lee and Ebong 2017).

Traditional silicon photovoltaic (Si PV) cells have become a widely accepted technology, and there is a growing trend in utilizing them for semi-transparent photovoltaics (STPV) to replace conventional glazing in buildings. This technology involves embedding standard solar cells between glass panes using ethylene vinyl acetate (EVA) film. The transparency of the glazing is manipulated by adjusting the separation distance between the PV cells at various intervals (Skandalos and Karamanis, 2015). Thin PV films have garnered significant attention due to their cost-effectiveness and high optical absorbance. They offer a combination of energy production and exceptional transparency when compared to Si cells, making them suitable for integration into buildings to enhance indoor conditions. However, their lower efficiencies currently limit their widespread adoption (Lechner and Schade, 2002). **Table 1** provides examples of building integration, efficiencies, and transmittance for various photovoltaic technologies, including Si mono- and poly-crystalline, amorphous Si, thin films (CIGS and CdTe), organic PV, and dye-sensitized solar cells (DSSC).

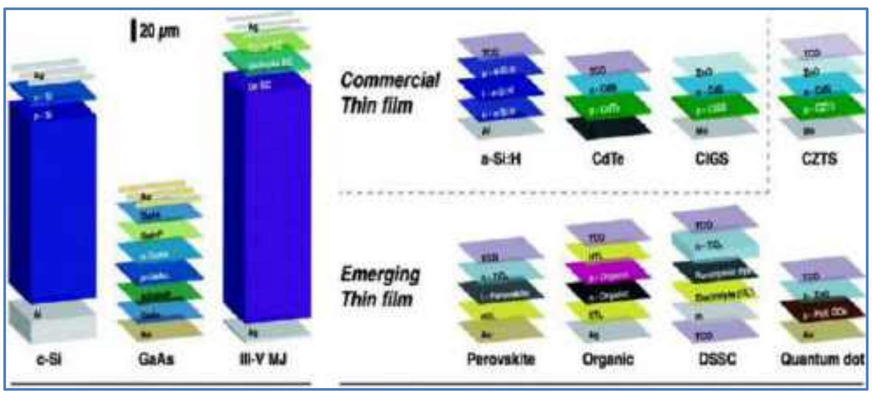

Figure 1 PVtechnologiessuitableforwindowintegration.Wafersc-Si,GaAs,III-Vandthinfilms

PV Windows

Semi-transparent photovoltaic (PV) windows offer an efficient solution by simultaneously generating electricity and providing daylighting, allowing for varying degrees of solar heat and natural light penetration (Wah et al., 2005). However, it is crucial to ensure that these PV windows exhibit strong electrical performance while maintaining appropriate transparency levels and colors to meet visual needs and comfort standards. As highlighted by Hee et al. (2015), the primary objectives for optimizing PV window performance are enhancing daylighting and energy production.

Furthermore, the interplay between PV windows and buildings is a significant consideration. Numerous simulation tools are available to predict the performance of PV windows and assess their impact on building performance, encompassing aspects such as indoor comfort, onsite electricity generation, and energy requirements for heating, cooling, and artificial lighting. Notable tools in this domain include Daysim, EnergyPlus, Ecotect, DesignBuilder, ESP-r, PVsyst, COMFEN, PROMETHEE, and StatSoft.

In the design phase of PV windows, various parameters must be taken into account. These include the window-to-wall ratio (WWR), orientation, transmittance, and power conversion efficiency, as each parameter plays a pivotal role in determining window performance and consequently influences overall building performance.

PV-thermal (PV/T) Collectors

The integration of photovoltaic (PV) and thermal collector (PV/T) technologies has garnered considerable attention due to its ability to address the challenge of undesired overheating in solar cells, which can lead to decreased efficiency caused by an increase in resistance (Michael et al., 2015; Sahota and Tiwari, 2017). PV/T systems are specifically designed to dissipate heat from the PV cells, effectively cooling them and enhancing efficiency by reducing resistance (Da Silva and Fernandes, 2010; Buker and Riffat, 2015; Lämmle et al., 2017). Solar collectors are broadly categorized into two types: non-concentrating (stationary) and concentrating (dynamic). Stationary collectors feature flat surfaces for solar ray absorption, while concentrating collectors employ concave reflecting surfaces to focus solar rays onto a smaller receiving area (Kalogirou, 2004; Tyagi et al., 2012). **Figure 2** illustrates schematics of both a stationary collector and a parabolic-trough collector equipped with a tracking system.

The development of PV/T collector technologies involves combining crystalline or amorphous silicon PV with liquid or air collectors, utilizing flat plates or solar concentrating devices, with or without a transparent cover (Hansen et al., 2018). Moreover, the absorber structure varies based on system requirements, including flat plate tubes, extruded heat exchangers, rectangular tunnels with or without fins, sheet-and-tube structures, roll-bond heat exchangers, and micro-channel heat pipe arrays or heat mats (Wu et al., 2017). To evaluate the performance of a PV/T module, its electrical efficiency, based on a measured I-V curve, while thermal efficiency can be determined (Chow, 2010).

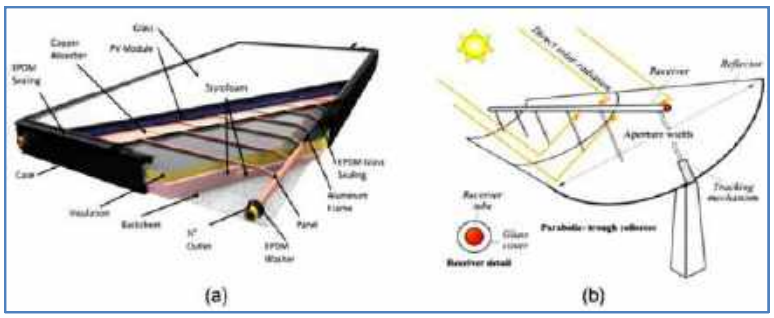

Figure 2(a) Components comprising a stationary PV/T (b) schematicdesignofaparabolic-troughcollectorwithtrackingsystem

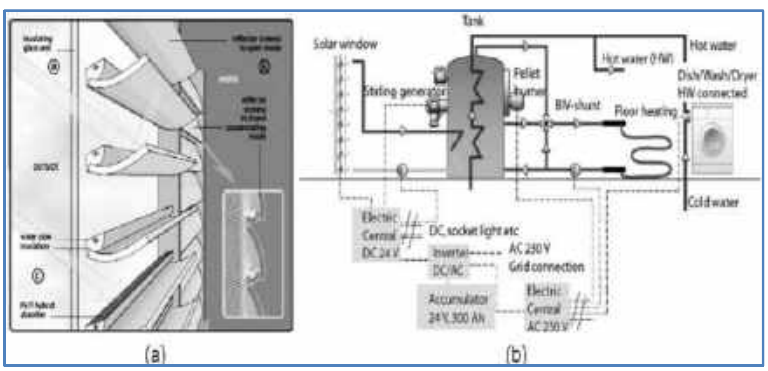

Figure 3 Depictionof(a)thehybridsolarwindowand(b)fullPV/Tsystem

Davidsson et al. (2010) pioneered the development and modeling of a hybrid solar window. This innovative design comprised photovoltaic (PV) cells for electricity generation, water pipes for thermal energy collection, and tiltable reflectors for solar concentration and daylighting control. The reflectors, when in closed or open mode, directed incoming radiation either onto the PV cells or into the indoor space, thereby regulating the amount of daylight entering the building. Active water cooling on the backside of the PV cells maintained high PV efficiencies, and the resulting hot water was utilized for domestic purposes. Simulation results demonstrated a remarkable 35% increase in electricity generation compared to flat PV modules.

In a subsequent project by Davidsson et al. (2012), the solar window was connected to a 620 L thermal storage tank, as illustrated in **Figure 3**. The study explored the intricate relationship between the PV/T window and the building. The findings revealed a reduction of 1000 kWh in the building's auxiliary energy load when using individual solar collectors and PV modules on the roof instead of the PV/T window. Furthermore, if the solar collector was omitted, the auxiliary energy load increased by approximately 600 kWh compared to when the PV/T window was in use.

Ulavi et al. (2014) introduced a PT/V window integrated with compound parabolic concentrators (CPCs) coated with a wavelength-selective film. This design allowed the visible sunlight portion to illuminate buildings while concentrating the infrared portion onto the PV/T absorber for electricity generation and hot water production. Monte-Carlo ray-tracing simulations analyzed the optical performance of the PV/T device in vertical and horizontal positions, serving as a window and skylight, respectively. The south-facing window with CPC geometries ranging from −25° to 45° for the nominal half-acceptance angle (θc) achieved thermal efficiencies between 18% and 24%.

Sabry et al. (2014) employed a computational fluid dynamics (CFD) model to predict the performance of a double-pane window integrated with PV/T solar collectors. This system featured water-cooled GaAsP/InGaAs quantum well square (QWSC) solar cells with a power conversion efficiency of approximately 32% and two-axis tracking solar concentrators with a concentration ratio of 500×. Under specific conditions, including an incident solar radiation of 800 W/m2, an ambient temperature of 273 K, a water inlet temperature of 283 K, and a water flow rate of 0.01 kg/s, the temperature of the water passing through the PV/T solar collectors increased by 5 K.

Building Integrated Concentrating PV (biCPV) Systems

Concentrating photovoltaic (CPV) technology involves integrating photovoltaic cells or modules with an optical system, commonly referred to as a solar concentrator. This concentrator is employed to amplify the solar flux reaching the PV area, operating at higher irradiation levels than conventional PV arrays and resulting in enhanced conversion efficiency (Algora and Rey-Stolle, 2016; Lamnatou and Chemisana, 2017). CPV systems can be categorized based on their geometric concentration ratio (Cg), which is the ratio of the concentrator aperture area to the PV aperture area. The classification includes low concentration PV systems (Cg < 10×), medium concentration PV systems (Cg = 10–100×), high concentration PV systems (Cg = 100–200×), and ultra-high concentration PV systems (Cg > 2000×) (Shanks et al., 2016).

High CPV systems necessitate precise mechanical tracking systems with low tolerances, typically below 0.2°, and require more installation space, complicating building integration. Medium CPV systems also require tracking systems, but by reducing the geometric concentration ratios, they enable more feasible building integration. In contrast, low CPV systems (Cg < 4×) do not rely on solar tracking. Instead, they utilize non-imaging optics with wide half-acceptance angles, allowing the collection of both direct and diffuse radiation (Sarmah et al., 2011; Li et al., 2013; Baig et al., 2014b). Consequently, low CPV systems can remain stationary, making them well-suited for applications in facades and windows (Sarmah et al., 2011; Li et al., 2013; Baig et al., 2014b).

PARABOLIC CONCENTRATOR BASED CPV GLAZING SYSTEMS

Analyzing the integration of a photovoltaic (PV) system into a window necessitates a careful assessment of which technology aligns best with the specific needs of the building, considering the uniqueness of each scenario and location (Shanks et al., 2016). Overcoming challenges such as concentrator geometry design and the elimination of tracking systems paves the way for concentrating photovoltaic (CPV) windows to emerge as a compelling choice for generating clean onsite energy (Sellami and Mallick, 2013). Furthermore, CPV technology can serve dual purposes by functioning as shading devices, offering diverse integration possibilities to curtail energy consumption in buildings.Technologies like compound parabolic concentrators (CPC) and V-trough reflectors demonstrate considerable potential for integration into buildings due to their efficient solar concentration performance and reduced usage of PV cells compared to conventional PV panels (Singh et al., 2016). Innovative designs of 2D and 3D CPCs are recognized as among the most effective stationary solutions for this purpose.

Abu-Bakaret al. (2015b) assessed the performance of alowCPVsystemwithageometricalconcentrationratioof 3.6×, which consisted of a 1 cm × 1 cm monocrystallinelaser grooved buried contact Si solar cell and a rotationallyasymmetrical compound parabolic concentrator (RACPC).The RACPC had an optical efficiency of 84% at a normalincidenceandahalf-acceptanceangleof43°.TheI-Vcharacteristics of the CPV system were measured at thestandardtestconditions(AM1.5,1000W/m^2and25°Ccell temperature), showing that the RACPC increased themaximum power output of the system by up to 3.33× incomparisontoanon-concentratingcell.

The outdoor characterisation of a 300 mm × 300 mmCPVmodulewaspresentedbySarmahandMallick(2015), which consisted of Dielectric Compound ParabolicConcentrators (DiACPCs) with two strings of 14 solar cellsconnected in series. The DiACPC module had a geometricconcentration ratio of2.8×andhalf-acceptanceangles of0°&55°.TheCPVmoduleandasimilarnon-concentratingsystemweretestedinEdinburghindifferentweatherconditions. The results showed that the DiACPC modulehadaveragemaximumpoweroutputsof0.13Wand5.88Wduringthetestedrainyandsunnydays,respectively,being 2.17 and 2.27 times higher than those of the counterpartsystem,respectively.

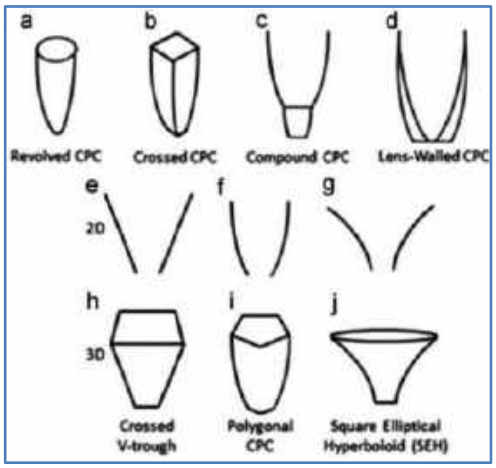

Figure 6(a)TherevolvedCPC;(b)thecrossedCPC;(c)thecompoundCPC;(d)thelens-walledCPC;(e)V-trough;(f) CPC; (g) compound hyperbolic concentrator; (h) 3D square apertureV-trough; (i) polygonal aperture CPC; (j) hyperboloid with anelliptical entry aperture and square exit aperture (Shanks et al.2016)

Electricity – Generating Smart Window Systems

The application of smart windows can lead to the lowertotal energy consumption of buildings by controlling thesolar heat and light transmitted through the windows intoindoor spaces, with associated reduction in cooling, heatingand/orelectriclightingloads(Baetensetal.2010).Comparedwith traditional windows, the interaction of smart windowswith the internal and external environments can be com-plicated,therebycarefulwindowdesignandpre-applicationresearchareimperative.Additionally,smartwindowsshouldfulfil aesthetic and economic requirements as part of thetechnical solution for producing net-zero energy buildings(DiCarloetal.2018).

Smartwindowscanbeclassifiedintotwomajortypes: active and passive. Active smart windows includeelectrochromic windows, suspended particle device (SPD)windowsandpolymer-dispersedliquidcrystals(PDLC)windows,inwhichopticalandthermalpropertiescanbecontrolledbyapplyingelectricalstimuliasdemanded byusers(Casini2018).Passivesmartwindowsincludethermochromic/ thermotropic windows and photochromaticwindows,whichautonomouslyrespondwithvaryingthermo-opticalpropertiestotemperatureandlightintensity,respectively(Casini2018).

Smart windows can be integrated with PV cells to formhybridsolarwindows,knownaselectricity-generatingsmartwindowsoropticallyswitchablePVwindows.Therearetwomajor configurations: (1) a stacked structure of PV layer,smart material layer and glass panes, and (2) mounting PVcells at the edges of a smart window. The sections belowdescribe existing active and passive smart windows withintegratedPVs,whichcancontroldaylighttransmissionandgenerateelectricityonsite.

Active Smart Windows Intergrated with PV cells

Debije(2010)presentedanenergy-generatingsmartwindowconsistingofafluorescent-dye-dopedliquid-crystalsolutionsandwiched between electrically conductive glass panelswith PV cells mounted at the window edges, as shown in **Figure 10**. Such configuration realised the control of lighttransmissionaswellaspowergeneration.Inthelightabsorption (dark) mode, the fluorescent dyes which guestedin the liquid crystals at a rest state absorbed incident lightand re-emitted light at a longer wavelength, a fraction ofwhichwastrappedinthewindowbytotalinternalreflectionand collected by the edge-attached PV cells. In the lighttransmission(bright)mode,anexternalvoltagewasappliedon the electrically conductive glass panels to change the tiltangleoftheliquidcrystalsandfluorescentguestmolecules,consequently,allowingmorelighttopassthroughthe window into theroombeyond.The resultsshowed thatthelightabsorptionbytheK160-typefluorescentdyeswith 0.5% concentration decreased by 31% when voltagewas applied, whereas the usable light for power generationdecreasedbyjust11%,whichindicatedanincreasedemission efficiency of the dyes when they were alignedmore homeotropically. The results revealed that the smartwindowcangenerateelectricityinbothmodes,withasmallloss in electricity generation for a more significant decreasein light transmission when the window switched from thedarkstatetothebrightstate.

Wangetal.(2012)developedanenergystoragesmart window (ESS) comprised of a supercapacitor andelectrochromismfunctionintegratedbypolyanilinenanowirearrays (electrodes). The addition of a solar cell permits thedevicetoharness,storeandusegeneratedenergyefficiently.Whenthesunlightisstrong,thewindowdarkensandblocksth esunlightfromenteringtheinternalspacewhichisinsteadconvertedintoelectricityandstoredelectrochemically in the window. When the stored energyruns low, the window lightens. The ESS window showshigh stability asa supercapacitorand can be used as apowersourceforelectricity-consumingdevicessuchasLCDscreens.

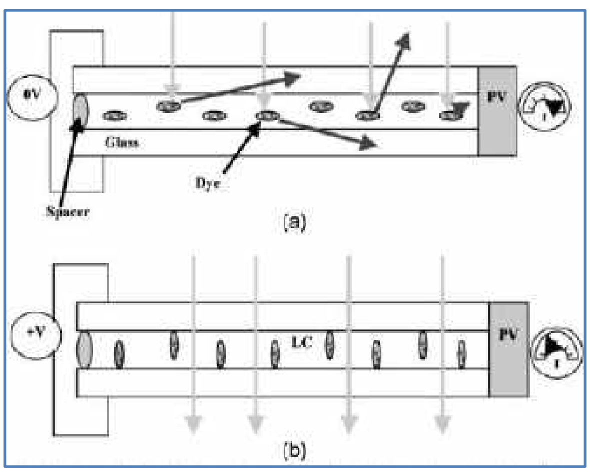

Figure 7 luminescent-dye-doped liquid crystal smart window in (a)a light absorption mode and (b) a light transmission mode, withPV cells mounted at the window edges for electricity generation(Debije 2010; reprinted with permission ©2010 John Wiley andSons)

Huang et al. (2012) designed a device composed of asemi-transparentSithin-filmsolarcell(Si-TFSC)substrate,anelectrochromicsolutionandatransparentnon-conductivesubstrate. The PV-electrochromic device is a self-poweredsmart glass with electricity supplied by the integrated solarcell.Uponreceivingsolarradiation,themonolithicallyintegrated Si-TFSC module produces electricity, a fractionof which induces the redox reaction of the electrochromicsolutionpromotingthecolourchangeofthedevice.Figure11showsthereactionmechanismdiagramandthep hotoofa PV-EC device with an active area of 5.5 × 5 cm^2withSi-TFSC strips, each of which has an area of 5 × 0.5 cm^2.The photoelectric conversion properties of an individualSi-TFSCweremeasured:V_{oc}=0.93V,J_{sc}=12.3mA/cm^2,fillfactor = 73.23 %, P_{max} = 20.94 mW and power conversionefficiency = 8.38%. Moreover, the device uses an anodiccolouring*N,N,N′,N′*-tetramethyl-*p*-phenylenediamine(TMPD)solutionwithatransmittancechange(ΔT%)ofaround70% at 590 nm, with periods of 200 seconds for a completedarkening process but 160 min for a complete beachingprocess. The device can be connected to an external loadvia a DC/AC inverter or to a DC charge storage device, touseorstorethedirectcurrentproducedbytheSi-TFSC.

CONCLUSIONS

Theintroductionofnewtechnologiestoachievezero-emission buildings has opened the door for the advancedwindowsdevelopmentsuchasbuildingintegratedPV(BIPV), building integrated concentrating PV (BICPV) andelectricity-generating smart windows. In the last decades,thesetechnologieshaveevolvedindifferentwaystosuitthecustomers' needs and compete with conventional windowsin terms of saving energy and improving visual comfort.This paper intends to provide a comprehensive review ofwell-establishedandemergingPVglazingtechnologiesfromworkingprinciples,previousresearchfindings,optimisationmethods,andfutureresearchopportunitiesperspectives.

The use of semi-transparent PVs (STPVs), such as a-Siand dye-sensitised solar cells, as part of building envelopescan serve to transmit daylight whilst providing electricitygenerationandsomeextentofsolarshadingandglareprotection. However, a fundamental challenge is to achieveboth high power conversion efficiency and transparency ofan STPV at the same time. Alternatively, STPV glazingscan be manufactured by employing high-efficiency PVssuchasc-Sisolarcellsinnarrowstrips,whichcanprobablyimprovetheuniformityofindoordaylightdistribution,viewing and aesthetics in comparison with traditional PVglazings that are typically made of large c-Si solar cellsarrangedinasquarepattern.TheinfluenceofSTPVglazingson building energy performance is mainly reflected in thereduction of cooling load but the increase of heating load,due to their relatively low SHGCs. Therefore, using STPVglazings can be beneficial for reducing the total energyconsumption of buildings in cooling-dominated areas, butmaybenotincoldclimaticregions.Inaddition,theeffectof STPV glazings varies depending on architectural designparameters such as WWR, orientation and inclination. Acost-effective approach to evaluate the applicability andenergy-saving potential of STPV glazings which has beenadopted in numerous studies is conducting building energysimulationwithparametricanalysis. SmartwindowintegratedPVisanemergingtechnologythat enables adaptive control of daylight transmission andelectricity generation simultaneously. It can be constructedbylaminatingamonolithicsemi-transparentPVwithalayer of smart material (e.g., electrochromic material) oroptically bonding PV cells around the edges of a smartwindow. In the latter configuration, the embedded smartmaterial needs to be highly transparent in its clear state andhighly scattering in its cloudy state, in order to achievegood daylighting, solar energy modulation and electricalperformance. Thermotropic hydrogels consisting of hydro-xypropyl cellulose biopolymer hold great potential for theapplication due to their strong light-scattering ability, largeoptical transmittance modulation, simple synthesis process and low cost,butneedtobeoptimisedintermsoflong-termfunctionality.

CurrentresearchesonBICPVglazingandenergy-generatingsmartwindowareorientedtowardsmaterialdevelopmentandwindowcharacterisationwithlessattentionon their building integration. Future research is encouragedto assess developed window technologies on the buildingscale,tocomprehensivelyunderstandtheireffectsonbuildingenergy performance, indoor environmental conditions andcomfortsofoccupants.

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Influence of Geocell Shape on the Load Carrying Behaviour of Reinforced Sand Beds

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***Abstract**: The influence of shape of geocell on the ultimate bearing capacity of the geocell-geogrid reinforced sand bed is investigated numerically. It can be seen that the load carrying capacity for different shape has been much larger than that of unreinforced case. Pressure settlement curve for the different shape of geocell reinforcement i.e., diamond, square, circular, and a real honeycomb has been presented, it can be seen that the load carrying capacity is maximum found for honeycomb and minimum is found for diamond followed by square structure. Further it can be seen that the pressure settlement curve behaviour for circular structure is different than the other, it is because the circular geocell mobilizing load until the certain displacement and beyond which the punching failure is taking place as a column of soil is getting punched through the circular pocket size of the geocell reinforcement.The honeycomb-shaped geocell performs better than the square and diamond-shaped geocells, this is because there is a lot of stress in the corners of a diamond-shaped geocell, but there will be much less stress in a real honeycomb shape because it is curvature. Geocells modelled as a square and cylindrical form do not distribute the stresses uniformly along the perimeter of the geocell. The curvature or honeycomb features equally transfer stresses around the geocells edges and leads to give good confinement effect. Therefore, the majority of commercially available geocells feature honeycomb shape. From the shape comparison curve, it is cleared that the honeycomb shape Geocell has maximum bearing capacity after honeycomb shape, square shape performs better than that of diamond shape geocell.*

***Keywords**: Geocells, Ultimate Bearing Capacity, Reinforced Sand Bed, Honeycomb Shape, Pressure Settlement Curve.*

INTRODUCTION

Due to an ever-increasing need for suitable land for urbanisation, geotechnical engineers have to develop more efficient methods for turning relatively weak soil into a usable form. As a result, the development of methods for changing the state of weak soil into a condition that is competent and acceptable is a major task for the field of geotechnical engineering. In view of this, the idea of "reinforcing the soil" is well understood and often used. Straw, reed, bamboo, logs, timber planks, etc. have been used for ages to "reinforce the ground. Soil reinforcement has changed over time based on needs and new ideas, in terms of the materials used, the shapes, and the sizes. The metallic strip reinforcements were replaced by sheet-type reinforcements and then by a variety of adaptable geosynthetics, such as geotextiles, geogrids, and geocells. In recent decades, planar and/or three-dimensional soil-reinforcement has been widely used in civil engineering. When compared with the planar form, the three-dimensional "Geocell" is a relatively new development in the field of soil reinforcement. In general, geocells can be used for foundations, slope protection, retaining walls, pavements, and embankments. These are three-dimensional expandable panels created of high density Polyethylene and it is honeycomb-like cellular confinement system comprised of geotextiles or geogrids. Due to the fact that it is constructed in a three-dimensional (3D) box-like manner, geocell offers an increased level of confinement to the soil. Geocells provide quicker, cheaper, sustainable, and ecologically friendly geotechnical solutions. Many researchers have used it for model studies to demonstrate the beneficial effects of geocells (Sitharam et al. 2005; Dash et al. 2007; Moghaddas Tafreshi and Dawson 2010; Tanyu et al. 2013; Hegde and Sitharam 2014a; Hegde et al. 2014; Hegde and sitharam 2015). Due to the difficulties of modelling the honeycomb structure of geocells, only a few researchers have tried numerical modelling. In recent past years, the geocells have been modelled using the equivalent composite technique and in which the geocell–soil composite is considered as the soil layer with enhanced strength and stiffness values (Madhavi Latha and Rajagopal 2007; Madhavi Latha and Somwanshi 2009; Hegde and Sitharam 2013). Despite the simplicity of this technique, it is unreasonable to represent geocells as the soil. It is always suitable to represent geocells using a three-dimensional framework since geocells have a three-dimensional structure.(Han et al.2008) simulated a uniaxially compressed single-cell geocell in FLAC3D and in this study due to the difficulties of simulating the real form, the geocell was represented as a square box.(Pokharel et al. 2009)conducted experimental study to evaluate the influence of shape of geocell such as circular and elliptical for single geocell-reinforced sandand reported thatthecircular shape geocell has a better bearing capacity and rigidity than elliptical shape geocell.(Yang et al. 2010) modelled the single cell geocell's having actual 3D honeycomb shape in their study. (Hegde and Sitharam 2014b) used circular pockets to represent a single cell geocell under uniaxial compression and found a difference between experimental and numerical pressure–settlement responses at greater settlement. This abnormality attributed due to the circular shape of geocell used in the modelling, hence the need of accurate modelling of real shape of geocells was highlighted. (Hegde and Sitharam 2015a; 2015b) modelling of actual 3D honeycomb shape of the multiple cell geocell using FLAC3D software. (Mandal and Dutta 2016)the effects of the height, tensile stiffness, diameter, and breadth of the whole mattress are depicted, using circular shape geocell made up of plastic bottle and fly ash as infill material. (Rajagopal et al. 2021) has conducted parametric study using actual honeycomb shape of geocell.

Although, extensive work has been performed to study influence of geometry of geocell reinforcement on the load carrying capacity of reinforced soil beds. But very few studies have been reported on the comparison of shapes of geocell and the influence of infill materials on the load-settlement behaviour of geocell reinforced soil system.

In contrast to the previous works,in this paper the detailed numerical analysis has been carried out tocompare the influence of various shapes of geocell (i.e., circular, diamond, square, honeycomb) on the load carrying capacity of reinforced sand beds using three-dimensional finite element analysis (PLAXIS 3D).

METHODOLOGY

In the current investigation, numerical analyses were carried out using PLAXIS 3D, because of the software's high processing capacity and simple interface. PLAXIS 3D uses the finite element method and has material models and structure elements. To study the pressure settlement behavior of geocell-geogrid reinforced soil three dimensional model has been created in, PLAXIS3D. The model dimensions and material properties were retained same to the experimental work done by Hegde and Sitharam (2015a). For this a soil model of 1000mm x 1000mm x 600mm are taken, and geocell and geogrid are used as a reinforcing material to strengthen the soilas shown in **Figure 1**. A typical pressure settlement response obtained from numerical analysis using PLAXIS 3D has been compared with the experimental results of Hegde and Sitharam (2015a) for unreinforced and reinforced respectively as presented in **Figure 2**. Existing studies have employed numerical software other than PLAXIS 3D to simulate the three-dimensional real form of geocell. Initially, in the simulation, the geocells utilised in the experimental research were constructed in AutoCAD (Autodesk, 2022) utilising images and dimensions of the geocells, and then imported into PLAXIS 3D.Asgeocell-geogrid reinforced sand is used in the study, the imported geocell and geogrid surfaces acquired geogrid structural elements. The material properties of sand, geocell, geogrid, and plate was adopted from literature (Hegde and Sitharam 2015a) are shown in **Table 1**. The geocell and geogrid was simulated using a linear-elastic model and mohr-coulomb soil model was used to simulate the sand material and fine meshing is chosen for the analysis. From the **Figure 2**, it can be clearly seen that the results from numerical analysis and experimental work by Hegde and Sitharam (2015a) are in good agreement with each other for geocell geogrid reinforced sand bed. But a marginal error is observed between experimental and numerical analysis in case of unreinforced sand. This marginal difference is possibly due to the result of error in soil properties, which may be occurred during its evaluation in the laboratory.

RESULTS AND DISCUSSION

The behaviour of geocell-geogrid reinforced soil under footing has been investigated in the present study. For this, a numerical model in PLAXIS 3D has been developed. Initially, the accuracy of developed model has been checked by validating it with the existing experimental study (Hegde and Sitharam, 2015a). Subsequently the detailed numerical analysis has been performed to study the effect of several shape of geocell such as square, circular, honeycomb, diamond, on the load carrying behaviour of square footing placed over the geocell-geogrid reinforced soil beds has been shown below.

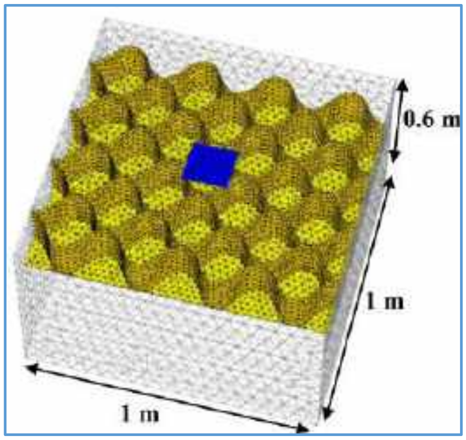

Figure 1 Geocell-Geogrid reinforced sand bed inPLAXIS 3D

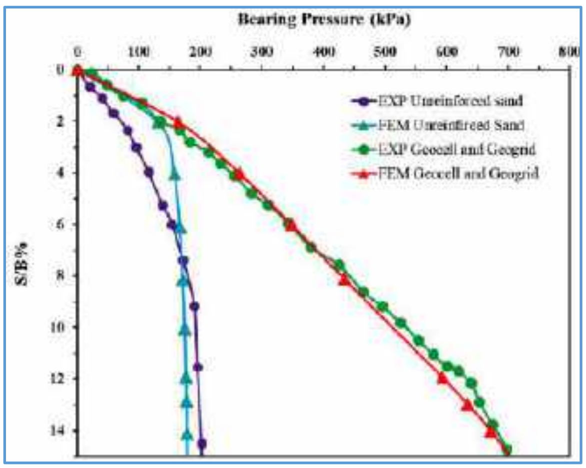

Figure 2 Bearing pressure vs. footing settlement response for unreinforced & reinforced

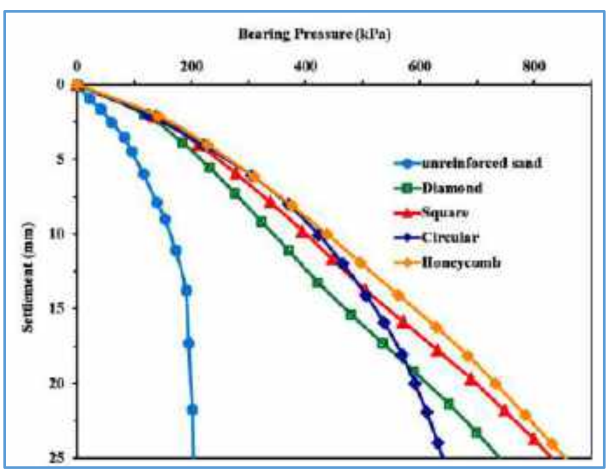

Figure 3 Variation in the shape of geocell

Table 1 Properties of materials used in modelling(Hegde and Sitharam 2015a)

Parameters	Values
Sand	
Young Modulus, E (MPa)	15000
Poisson's ratio	0.3
Cohesion, C (kPa)	0
Friction Angle(ϕ)	36
Unit Weight (kN/m^3)	20
Dilation angle	6
Geocell	
Axial stiffness EA (kN/m)	412.5
Shear stiffness GA (kN/m)	142.24
Geogrid	
Axial stiffness EA (kN/m)	315
Shear stiffness GA (kN/m)	118.42
Plate	
Young Modulus, E (MPa)	200×10^6
Material Type	Elastic
Unit weight, γ(kN/m^3)	

Pressure settlement curve for the different shape of geocell reinforcement i.e., diamond, square, circular, and a real honeycomb has been presented in figure 3. From the figure it can be seen that the load carrying capacity is maximum found for honeycomb and minimum is found for diamond followed by square structure. Further it can be seen that the pressure settlement curve behaviour for circular structure is different than the other, it is because the circular geocell mobilizing load until the certain displacement up to 10mm beyond which the punching failure is taking place as a column of soil is getting punched through the circular pocket size of the geocell reinforcement which lead to the suddenly reduction in the load carrying capacity. Hence it can be says that for lower deformation level circular shape of geocell can also be very efficient. However for the larger deformation honeycomb is giving much better performance than that of other shape.

The honeycomb-shaped geocell performs better than the square and diamond-shaped geocells, this is because there is a lot of stress in the corners of a diamond-shaped geocell, but there will be much less stress in a real honeycomb shape because it is curvature. Geocells modelled as a square and cylindrical form do not distribute the stresses uniformly along the perimeter of the geocell. The curvature or honeycomb features equally transfer stresses around the geocells edges and leads to give good confinement effect. Therefore, the majority of commercially available geocells feature honeycomb shape. From the shape comparison curve, it is cleared that the honeycomb shape Geocell has maximum bearing capacity irrespective of any settlement ratio. After honeycomb shape, square shape performs better than that of diamond shape geocell.

CONCLUSION

1. Four different shapes of geocell that is diamond, square, and real honeycomb, and circular is investigated. The best shape is found to be real honeycomb because this stress distribution is uniform and it gives a good confinement effect. That leads to wider distribution of load.
2. It can be seen that the pressure settlement curve behaviour for circular structure is different than the other, it is because the circular geocell mobilizing load until the certain displacement, beyond which the punching failure takes place which leads to decrease the load carrying capacity of footing.
3. There is a lot of stress in the corners of a diamond & square shaped geocell, but there will be much less stress in a real honeycomb shape because of its curvature, it shows better performance of honeycomb shape geocell.
4. When compared to the unreinforced case, the inclusion of the geocell layer into the sand dispersed the applied load to a smaller depth and bearing capacity is increased by 4 times.

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Load-Settlement Behavior of Square Footing Resting on Reinforced Fly Ash-Sand Beds Subjected to Static Load

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***Abstract**: The paper presents a study of the behavior of model square footings supported on a loose sand and effect of the partial replacement of a fly ash layer and inclusion of geosynthetic reinforcement. Studied parameters including depth of replaced fly ash layer, number of geogrid layers & vertical spacing between the geogrid layers in fly ash beds. To investigate the influence of these parameters on the performance of footing on unreinforced and reinforced two-layer system subjected to static load model tests were conducted. The load-settlement behavior of the model footing supported on unreinforced loose sandy soil, unreinforced and reinforced replaced fly ash deposits overlying the loose sand were obtained and compared. The results indicate that the load carrying capacity of footing increases as the depth of replaced fly ash increases and also inclusion of reinforcement in the fly ash significantly increases the stability of the two-layer system. The improvement in the load carrying capacity increases as the number of reinforcement layer increases with decrease of spacing between the reinforcement and also in failure mode was observed.*

***Keywords** : Sand; Fly ash; Geogrid; Two-Layer System; BCR.*

INTRODUCTION

The engineering properties of soil can be improved in several ways, including by adding reinforcements, replacing weak soil with strong soil up to a significant depth, and/or densifying weak soil up to a significant depth. Numerous studies on the bearing capacity of double-layered soil systems have been reported by different researchers by taking different types of soil in layered form and reinforcement material were used in between the two layer or placed in the top layer of two-layered soil [1-2]. And it is concluded from the various studies that the type of filling material, the thickness of the top layer, type of reinforcement material, and reinforcement distribution parameters like depth of reinforcement, number of reinforcement, spacing between the reinforcement were affect the improvement in the bearing capacity. Industrial waste materials such as pond ash, fly ash alone are used as a filling material beneath the foundation is preferable from both an environmental and economic standpoint. Based on the earlier investigation it is found that fly ash has good potential for use in geotechnical application. [3] conducted series of large size laboratory test to obtain load-settlement response of square footing on geogrid reinforced layered granular beds. The load improvement factors were proposed for various cases i.e., aggregate layer overlying sand (case 1), reinforced sand alone (case 2) and reinforced aggregate layer overlying sand (case 3). The load improvement factors ranged from 1.3 to 1.9, 1.1 to 1.8 and 1.3 to 2.7 for the three cases, respectively, corresponding to footing settlement ratios ranging from 5 to 15%. [4] conducted the study on load-settlement response of circular footing resting on unreinforced and geogrid reinforced aggregate overlying on a sandy soil layer. The bearing pressure for case of aggregate sand layered system increases by 95% compared to the bearing pressure for the case of sand only for aggregate thickness ratios (H_1/B) equal to 1. The optimum depth reinforcement was found to be 0.45 times width of footing.

Also, only few investigations are done by using coal ash with soil in layered form that is pond ash overlying soft clay [5], pond ash overlain by sand [6], and fly ash overlying soft clay [7] in order to improve the bearing capacity of weak bottom layer. And they concluded that the bearing capacity of the reinforced double layer increased significantly with inclusion of reinforcement in the top layer and at the interface of double layer.

The objective of presents study to determine behavior of model square footings supported on a loose sand and effect of the partial replacement of a fly ash layer and inclusion of geosynthetic reinforcement. Studied parameters including depth of replaced fly ash layer, number of geogrid layers & vertical spacing between the geogrid layers in fly ash beds. To investigate the influence of these parameters on the performance of footing on unreinforced and reinforced two-layer system subjected to static load model tests were conducted.

Materials and Methods

Backfill Materials: Locally available poorly graded sand (SP) is used in the present investigation. Experiments are conducted on sand compacted at relative density of 35% which indicates the sand in loose state. This sand is used as bottom layer in two-layer system. Fly ash layer was replaced by sand layer at varying depth, in order to improve the load carrying capacity of loose sand. The non-pozzolanic fly ash was used. Based on its chemical composition this fly ash is classified as class F according to ASTM C618, and based its physical properties it is classified as ML according to IS classification system. The properties of sand and fly ash is shown in **Table 1**.

Table 1 Sand and Fly ash Properties

	Properties	Sand	Fly ash
1	Sand Size Fraction (%)	100	17.4
2	Silt and Clay Size Fraction (%)	-	82.6
3	Liquid Limit (LL) (%)	-	25
4	Plastic Limit (PL) (%)	-	--
5	Plasticity Index (PI) (%)	-	Non-plastic
6	Specific gravity, G_s	2.64	2.07
7	Maximum Dry Density (MDD) (gm/cm^3)	1.68	1.40
8	Minimum Dry Density (MDD) (gm/cm^3)	1.46	-
9	Optimum Moisture Content (OMC) (%)	-	18
10	Cohesion (c), (gm/cm^2)	-	51
10	Φ (degrees)	34	31
11	Type of Classification	SP	ML

Reinforcement material: Polypropylene biaxial geogrid is used in the present investigation. This geogrid is denoted by the G40. Based on the trial test G40 geogrid are selected as reinforcement material in the present study. The properties of geogrid are shown in the table II.

Table 2 Specification of Geogrid)

Properties	Values
Grid type	G40
Structure	Biaxially Oriented
Polymer type	Polypropylene
Aperture shape	Square apertures
Aperture size (mm * mm)	38 * 38
Peak tensile strength (kN/m)	40

METHODOLOGY

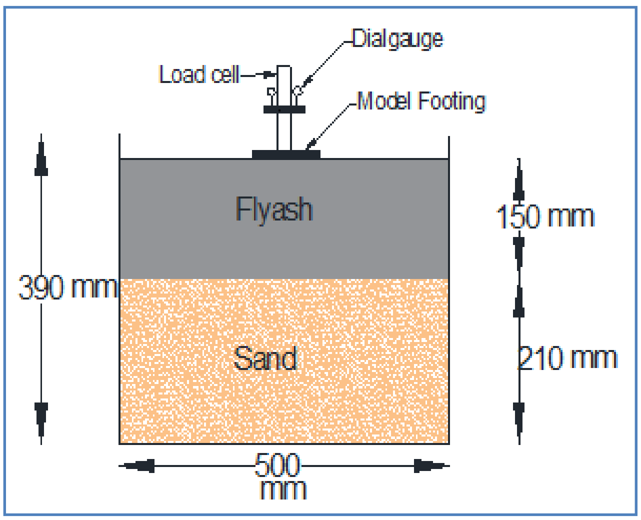
The reinforced and unreinforced fly ash-sand beds are subjected to static loading in a Load frame of capacity 500 kN. Loads are applied by means of a mechanical screw jack through a calibrated proving ring of 50kN capacity with a least count of 0.0603 kN/div. Settlement is measured using three dial gauges. The sensitivity of the dial gauges used was 0.01mm. Load is applied continuously and the deformation is recorded.

Test Tank and Model Footing

Experiments were conducted in mild steel circular tank having the diameter of 500mm and height of 390mm. Tank to footing size ratio of 5 is maintained to prevent the effect of lateral confinement. Mild steel square footing having the dimension of 100mm width and 10mm thickness was used as model footing.

Test bed Preparation

Test beds were prepared for three condition (i) Homogeneous sand bed: sand beds are prepared by manual compaction at its required relative density (i.e., Dr=35%)sample is compacted up to a height of 360mm in 3 equal layers of 120mm thick. (ii) Fly ash-sand beds: for two-layer condition the sand bed is replaced by fly ash bed by varying the thickness of fly ash layer as H/B equal to 0.3, 0.6,0.9,1.2&1.5. Thickness of fly ash layer is denoted by H and B is the width of the footing. This fly ash is prepared by manual compaction at its optimum moisture content, to maximum dry density. (iii) Reinforced fly ash-sand beds: for this condition beds are prepared for the bottom sand at Dr=35% of height 210 mm and top fly ash at its OMC, to MDD of H/B=1.5 and reinforcements are placed at predetermined spacing in the top fly ash layers.



(a) **Figure. 1** Line diagram of Fly ash-Sand beds

RESULTS AND DISCUSSION

Thickness of Top Layer

Figure 2 shows the bearing pressure versus settlement ratio for footing on sand only and on layered system for various thickness of fly ash layer (H/B=0.3,0.6,0.9,1.2&1.5). Bearing pressure-settlement plots show a peak behavior was not observed for footing on sand only. While, for fly ash layer overlying a sand layer, the peak behavior was observed for settlement ratio of footing in the range 18 to 9 % as the thickness of fly ash layer H increase from 0.3B to 1.5B.

Bearing pressure increased with increase in the thickness of the fly ash layer, it was observed that the ultimate bearing pressure(q_u) of loose sand was 136kPa, whereas this qu increased to 618kPa to 1236kPa with an increase of fly ash thickness from 0.3B to 1.5B because for H equal to 0.3B,0.6B, 0.9B & 1.2B the stress distribution developed beneath the footing plate gets obstructed by the underlying loose sand bed. For H=1.5B complete stress distribution may develop within the fly ash bed leading to a improvement in pressure-settlement response of footing. Also, according to earlier researchers[3-4], the top stiff layer absorbs significant portion of the load applied on the surface of footing and similar observations were made in the present study.

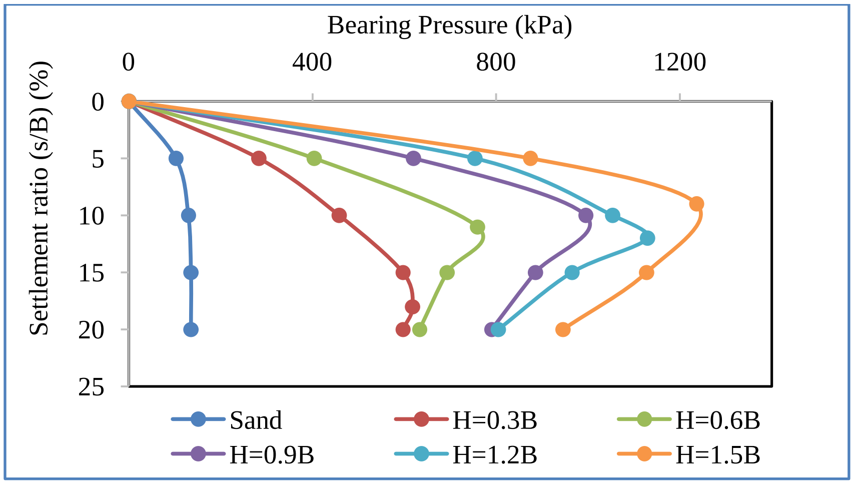


Figure 2 Bearing pressure-settlement ratio(s/B)(%) curves for sand and unreinforced fly ash overlying on sand (for different H/B values)

Geogrid Reinforced Fly Ash Layer Overlying Sand

Inclusion of reinforcement in the fly ash layer improves the load carrying capacity of the two-layer system. In such case it is essential to determine the optimum spacing between the reinforcement (h/B) and optimum number of reinforcement (N) in fly ash layer. In this study, the number of reinforcement (N) in fly ash layer was varied from 2 to 4 for the case of h/B=0.3,0.4 and 0.5. Due to the practical reasons(because of the fixed depth of the replaced fly ash i.e., H=1.5B) test were restricted to N=3 for h/B=0.5.

Effect of Number of Reinforcements

Figure 3 to **5** presents the variation of bearing pressure with settlement ratio for unreinforced and various number of geogrid in the fly ash layer overlying sand, experiments were conducted on reinforced two-layer with 2, 3 and 4 number of geogrid with 0.3B, 0.4B and 0.5B geogrid spacing respectively. It can be inferred that as the number of geogrid increases from 2 to 4, the bearing pressure also increases.

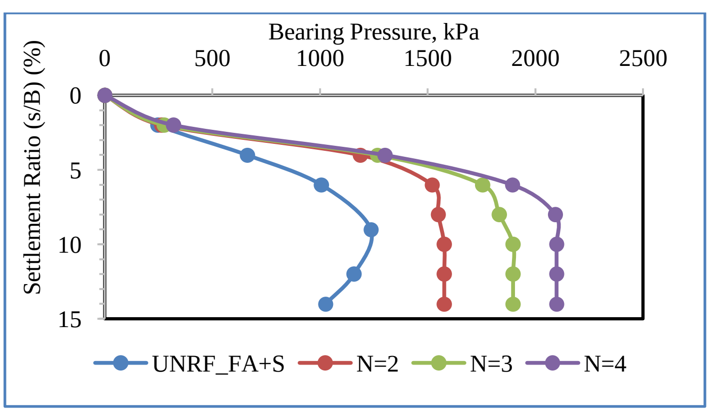


Figure 3 Bearing pressure-settlement ratio (s/B) (%) curves for unreinforced and reinforced fly ash overlying on sand (H=1.5B;U=0.3B;h=0.3B)

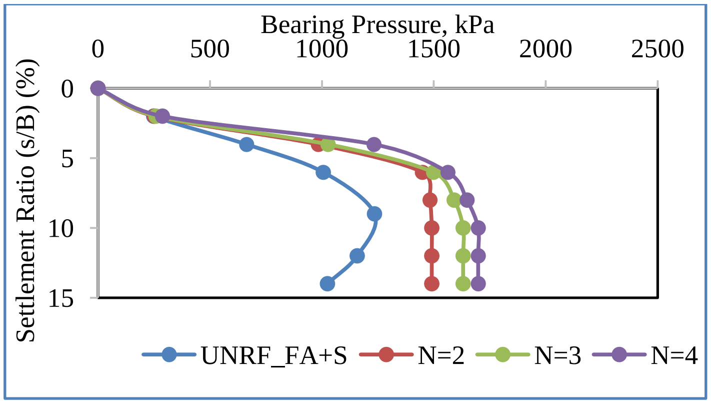


Figure 4 Bearing pressure-settlement ratio (s/B) (%) curves for unreinforced and reinforced fly ash overlying on sand (H=1.5B;U=0.3B;h=0.4B)

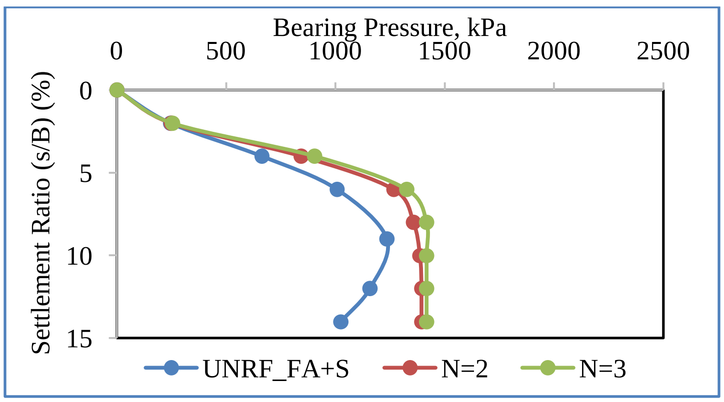


Figure 5 Bearing pressure-settlement ratio (s/B) (%) curves for unreinforced and reinforced fly ash overlying on sand (H=1.5B;U=0.3B;h=0.5B)

For instance, from **Figure 3** the ultimate bearing pressure of unreinforced fly ash-sand beds was 1236 kPa where as its counter parts with 2,3 & 4 layer geogrid reinforcement having reinforcement spacing 0.3B exhibit 1577, 1897 & 2098 kPa respectively. This clearly shows that inclusion of reinforcement in the fly ash significantly increases the stability of the two-layer system. Similar trend of results is observed in **Figure 4** and **5**. Hence by seeing these figures the result clearly confirms that the optimum number of reinforcement layer is 3 (for h=0.5B) and 4 (for h=0.3B & 0.4B). This is as per the accepted trend of results by earlier researchers. It was also observed from these figures the failure mode for unreinforced two-layer system was general shear failure this changes to punching shear failure in case of reinforced fly ash-sand beds this is because, there is an increase in the stiffness of fly ash,due to the provision of geogrid hence there was change in failure mode was observed.

Effect of Spacing of Reinforcement

Figure 6 to **8** presents the variation of bearing pressure with settlement ratio for unreinforced and reinforced fly ash layer overlying sand, experiments were conducted on reinforced two-layer with 0.3B, 0.4B and 0.5B geogrid spacing for N=2, 3 & 4 respectively. It can be seen that as the spacing between reinforcement decreases the bearing pressure increases. For instance, from **Figure 6** the ultimate bearing pressure of unreinforced fly ash-sand beds was 1236 kPa where as its counter parts with geogrid reinforcement having reinforcement spacing 0.3B, 0.4B & 0.5B for N equal to 2 exhibit ultimate bearing pressure of 1577, 1491 & 1393 kPa respectively.This clearly shows that reduction in the spacing between reinforcement gives the lateral confinement in fly ash layer hence significantly increases the stability of the two-layer system. Similar trend of results is observed in **Figure 7** and **8**. Hence by seeing these figures the result clearly confirms that the optimum spacing of reinforcement layer is 0.3B. This is as per the accepted trend of results by earlier researchers.

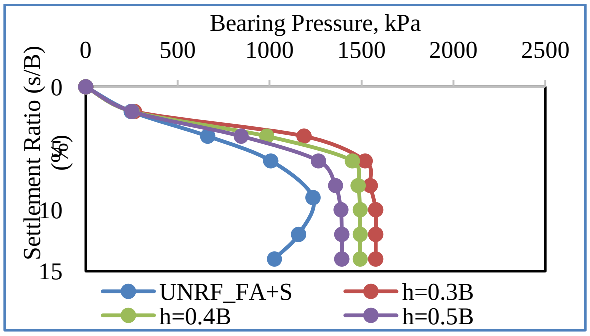


Figure 6 Bearing pressure-settlement ratio (s/B) (%) curves for unreinforced and reinforced fly ash overlying on sand (H=1.5B;U=0.3B;N=2).

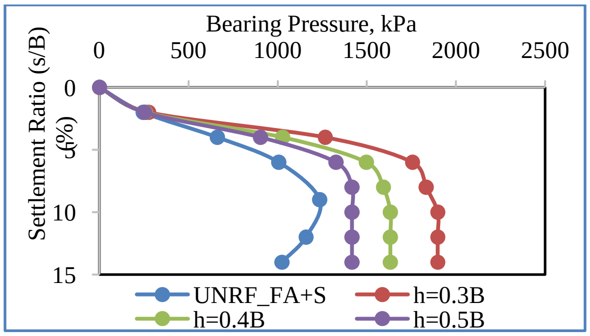


Figure 7 Bearing pressure-settlement ratio (s/B) (%) curves for unreinforced and reinforced fly ash overlying on sand (H=1.5B;U=0.3B;N=3).

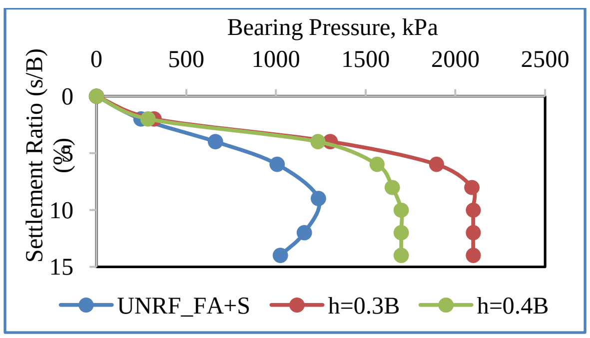


Figure 8 Bearing pressure-settlement ratio (s/B) (%) curves for unreinforced and reinforced fly ash overlying on sand (H=1.5B;U=0.3B;N=4).

Bearing Capacity Ratio (BCR)

The improvement in the performance of footing due to provision of geogrid in fly ash layer was quantified by using a non-dimensional parameter, BCR $_{(Layered\ RF)}$ (Kumar A etal., 2007), defined as

$$BCR_{(Layered\ RF)} \frac{\text{Ultimate Bearing Capacity of Reinforced Layered Soil}}{\text{Ultimate Bearing Capacity of Unreinforced Layered Soil}} \qquad (1)$$

Figure 9 shows the variation of BCR with number of reinforcement (N) for different h/B ratio. It was observed from the figure that for N equal to 2 the BCR increase from 1.13 to 1.21 and 1.28 as h/B decrease from 0.5, 0.4 and 0.3 respectively. Similarly for N=3, the BCR value was 1.15, 1.32 and 1.53 for h/B equal to 0.5, 0.4 & 0.3 respectively. And for N=4, the BCR was 1.37 and 1.70 for h/B equal to 0.4 & 0.3 respectively. By observing from these values, the BCR for N equal to 4, h/B=0.3 was higher compare to all the condition. And for h/B =0.5, as N increase from 2 to 3 there was not much variation in the BCR value observed. From the results it was observed that as the N increase and decrease in the spacing between the reinforcement (from 0.5B to 0.3B) there is increase in the lateral confinement in the reinforced layer this improves the load carrying capacity of footing. Hence N equal to 4 and h/B=0.3 was the optimum reinforcement distribution in Fly ash-sand beds.

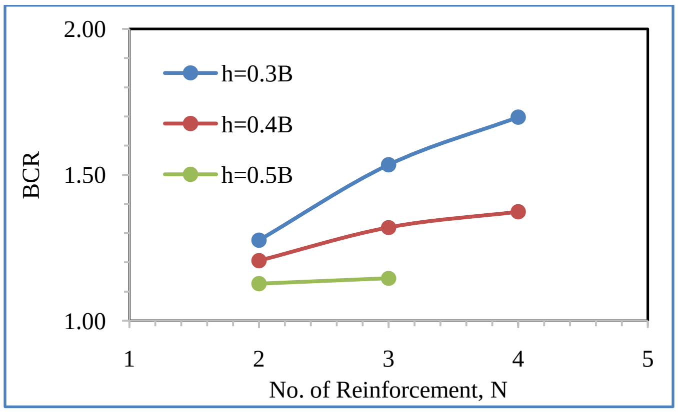


Figure 9 Variation of Bearing Capacity Ratio for reinforced fly ash layer overlying sand.

CONCLUSIONS

A series of laboratory model test were conducted to study the load-settlement response of model square footing supported on unreinforced loose sandy soil, unreinforced and reinforced replaced fly ash deposits overlying the loose sand. The following conclusions can be drawn from the study.

1. Bearing pressure increased with increase in the thickness of the fly ash overlying the sand layer compared to homogeneous sand. For sand ultimate bearing pressure was found to 136kPa, there was increase in the ultimate bearing pressure to 618kPa and 1236kPa for two-layer system for H=0.3B and 1.5B respectively.

2. For the case of reinforced fly ash overlying sand, the optimum N and S/B was found to be 4 and 0.3 respectively. When reinforcement was placed at optimum condition, the bearing pressure was found to increase by 1.69 times compared to the unreinforced case.

3. The improvement factor BCR was proposed for reinforced fly ash layer overlying sand. The BCR for N=4, h/B=0.3 shows higher value that is 1.7 compared to all other conditions.

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CV_IEC 2023 TV 132

Seismic Analysis of G+20 RC Framed Multi-Storey Structure with Different Plan Configuration in Zone III

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***Abstract**: The multi-storey R.C. Structure is facing a major earthquake. The researchers of this manuscript found that the leading cause of R.C. structural failure is an abnormal distribution of weight, stiffness, and strength or due to irregular geometric adjustments. Many of the existing buildings contain defects due to operational and aesthetic requirements. However, previous records of earthquake show the magnitude of the earthquake is light. This is due to the ignorance of inadequacy in designing seismic design methods with seismic codes (IS 1893: 2016, U.B.C. 1997, NBCC 2005, etc.). This paper presents the behaviour of multi-storey R.C. structures such as T-shaped, C-shaped, and H-shaped according to the earthquake conditions proposed in I.S.: 1893-2016 using STAAD. V8i profile. The analysis involves load calculation and analysis of the entire structure in the STAAD Pro V8i version for dynamic analysis, namely, spectrum response analysis, confirming the I.S.code. The researchers performed this analysis by taking seismic zone III into account, and in each case, the behaviour was assessed by taking a firm position with soft soil. Post-analysis of the structure includes different responses such as upper floor displacement etc. The effects of different plan irregularities on the seismic response and carrying response spectrum analysis (R.S.A.) are the focus of this work.*

***Keywords**: Earthquake, Seismic response,seismic zone, Response spectrum analysis (R.S.A.)*

INTRODUCTION

Spokes of weakness are where structural failure begins during an earthquake. The discontinuity in the structure's geometry, mass, and stiffness are the causes of this weakness. Uneven buildings are those with this kind of discontinuity in their construction. Unusual constructions make up a sizable percentage of urban infrastructure. The vertical irregularities during earthquakes is one of the main causes of the failures. The collapse were those with soft storeys. Thus, the impact of vertical irregularities on a structure's seismic performance becomes noteworthy. The dynamic characteristics of these buildings differ from those of a regular building due to variations in stiffness and mass across heights. The uneven distribution of the building's mass, stiffness, strength, and height could be the cause of the asymmetry in the structures. The analysis and design become more complex when such facilities are built in high seismic zones. Two categories of irregularities exist:

1. Horizontal/Plan

2. Vertical

Where horizontal irregularities can be further subdivided into various types i.e. torsion irregularity re-entrant corners, diaphragm discontinuity and vertical irregularities can be further subdivided into various types i.e. Stiffness Irregularity (soft storey and extreme soft storey), Mass Irregularity, Vertical Geometric Irregularity. Even though irregular structures are preferred because they meet functional and aesthetic requirements, they can offer unique and exotic designs that are in high demand as client expectations for buildings rise. When compared to conventional buildings, these asymmetrically shaped structures typically convey amazing impressions of the future. These structures are easily recognizable as architectural icons, and occasionally they have a direct bearing on the distinctive identity and philosophy of the stakeholders. The Indian code gives specific recommendations for assessing the degree of irregularity and corresponding penalties and restrictions. It is essential to understand that these recommendations discourage and make the designer aware of the potentially detrimental effects of anomalies.

Therefore, earthquake hazards present special challenges for engineering design because the most severe loading that most structures could possibly experience is from a strong earthquake. The best engineering solution for this is to build structures that will not collapse during the strongest earthquakes, preventing fatalities but acknowledging the risk of damage.

METHODOLOGY

A. Overview

In this study, three RC buildings are considered. Building No. 1 is an H-shaped multi-storey building; it is a twenty-storey building with an inter-story height equal to 3m for each level. The size of the columns is 500x500 mm. The size of the beams is 350x500mm. The grade of concrete used is M-25, and Fe-500 steel is used. Building No. 2 is a C-shaped multi-storey building; it is a twenty storey building with an inter-story height equal to 3m for each level. The size of the columns is 500x500 mm. The size of the beams is 350x500mm. The grade of concrete used is M-25, and Fe-500 steel is used. Building No. 3 is a T-shaped multi-storey building; it is a twenty storey building with an inter-story height equal to 3m for each level. The size of the columns is 500x500 mm. The size of the beams is 350x500mm. The grade of concrete used is M-25, and Fe-500 steel is used.

1) Steps Involved in Modelling

STAAD Pro V8i software is used to create the model, and the following flow chart illustrates how the structure is modelled:

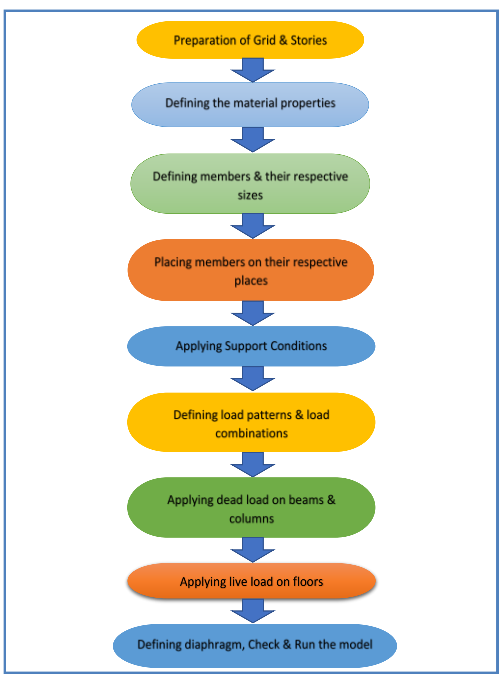

Figure 2.1 Represents the flow chart of steps involved during modeling in STAAD Pro

B. Methods of Seismic Analysis

Depending on the kind of structural model chosen, the external action, and the behavior of the structure or structural materials, we can carry out the analysis. It is possible to classify the analysis process. We can arrange the analysis method based on the variables that are taken into consideration. We can further categorize the analysis as linear dynamic analysis, linear static analysis, non-linear static analysis, or non-linear dynamic analysis based on the type of external action and behavior of the structure. For regular structures with a height restriction, we can apply equivalent static analysis or linear static analysis. Either the elastic time history method or the response spectrum method can be used to carry out linear dynamic analysis.

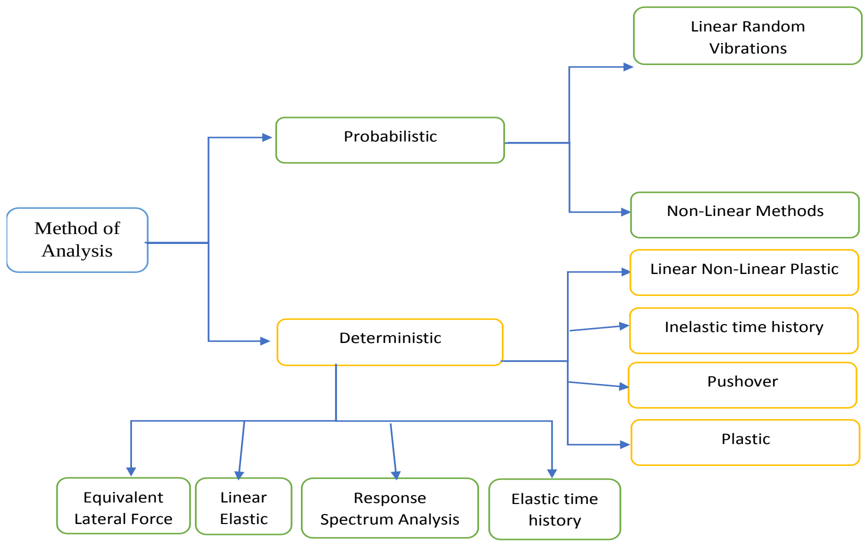

Figure 2.2 Different methods of analysis

1) Response Spectrum Analysis

The modal method or mode superposition method are other names for this technique. The approach is applicable to those structures whose response is substantially influenced by modes other than the fundamental ones. The approach is typically used to analyze the dynamic response of asymmetrical frames or those with discontinuities or irregularities in their linear behavior range. The analysis of forces and deformations in multi-story buildings caused by medium intensity ground shaking, which results in a moderately large but basically linear response in the structure, is one area in which it is particularly applicable. Every mode reacts with a unique modal damping, modal frequency, and deformation pattern (mode shape). By studying an SDOF oscillator with characteristics selected to represent the specific mode and the extent to which it is excited by the seismic motion, we can calculate the time history of each modal response. In general, the responses. Because lower vibration modes are primarily responsible for the response to an earthquake, they only need to be determined in the first few modes. Using the response spectrum method, the seismic response (or design) spectrum can be used to determine the peak response of a structure during an earthquake. Although the peak response provided by this process is approximate, it is perfectly accurate for applications involving structural design. We consider a building's multiple modal responses in this approach. Each mode's response from the design spectrum depends on its modal mass and modal frequency. Through the use of modal combination methods, such as complete quadratic combinations (CQC), the square root of the sum of squares (SRSS) method, or the absolute sum (ABS) method, the responses of various modes are combined to provide an estimate of the total response of the structure. Using modal combination methods, i.e., complete quadratic combinations (CQC), absolute sum (ABS) method, or square root of the sum of squares (SRSS) method, the responses of various modes are combined to provide an estimate of the total response of the structure.

2) Methodology used in software for response spectrum analysis

- • STAAD Pro calculates the design lateral shear force at each floor in each mode in accordance with IS 1893(Part 1) 2016.The following equation is taken into account

$Q_{ik}=A_k \times \phi_{ik} \times P_k \times W_i$

Where A_k and W_i are values that the user inputs.

- The user provides the value $\frac{Z}{2} \times \frac{I}{R}$ As a factor for the input spectrum.
- The software calculates time-periods for 1st six modes or as specified by the user.
- The software calculates $\frac{Sa}{g}$ for each mode utilizing time-period and damping in every mode.
- The software calculates the design horizontal acceleration spectrum A_k for different modes.
- The software calculates modal participation factors for different modes.
- Each floor's peak lateral seismic force in each mode is computed. All response quantities for each mode are calculated.
- • After that, the peak response quantities are combined using techniques, such as CQC, SRSS, ABS, or CSM, as defined by the user to get the final results. In this thesis work, the CSM method is used.

If V_b (RSA) $<$ V_b' (ESA), in that case, All response quantities obtained in RSA (for example, member forces, displacements, story forces, story shears, and base reactions) shall be multiplied by V_b'/V_b.

ANALYSIS AND RESULTS

A. Overview

For the current project, a 20-story (G+20) building with a total storey height of 3 meters and a 27 x 27 meter plan is used. There are nine 3 m bays in the X and Y directions of the building. The IS code has been taken into consideration when modeling irregular buildings. The live load for each structure is calculated as follows: 4 KN/M2 for floor levels, 1.5 KN/M2 for roof levels, and 150 mm for slab thickness. Every codal provision is taken into consideration when modeling all three models in Staad Pro V8i (Select series 6). Details of the building are provided in Tables 1-4 below.

Tables I (I- IV) show the plan, material, load, and seismic properties that are considered in designing

Plan properties	Specifications
Details of Building	G+20 RC Structure
Plan Configuration	27mx21m
Floor to Floor Height	3.0m
Building Height	60 m
Thickness of wall	230mm

Material Properties	Specifications
Grade of Concrete	M25
Grade of Steel	FE-500
Size of Columns	0.5mx0.5m
Size of Beams	0.35mx0.5m
IS-Code referred	IS-456 (2000)

Load Properties	Specifications
Wall Dead Load	10.925 KN/m^2
Wall Dead Load on Roof	2.508 KN/m^2
Live load	4 KN/m^2
Live load on Roof	1.5 KN/m^2
IS-Code referred	• IS-875 Part-1 for Dead Load Considerations • IS-875 Part-2 for Live Load Considerations

Seismic Properties	Specifications
Soil Type	Medium-II
Zone considered	Zone 3
Zone Factor	0.16
Importance Factor	1.5
Response Reduction Factor	5
Damping	5%
Rock & Soil Site Factor	Medium
IS-Code referred	IS-1893 Part-1 (2016)

B. Analysis Report

COMPARISON OF DISPLACEMENT VALUES

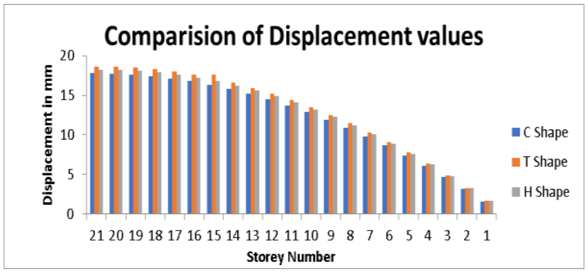

Figure 3.1 Visual depiction of displacement values

COMPARISON OF TIME-PERIOD VALUES

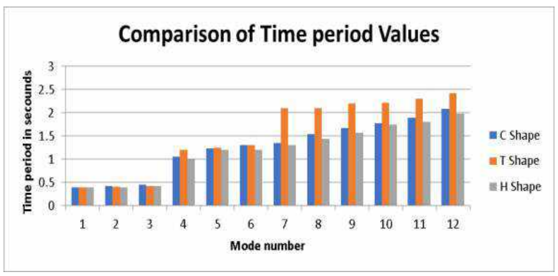

Figure 3.2 Visual depiction of Time Period values

COMPARISON OF SHEAR FORCE VX VALUES

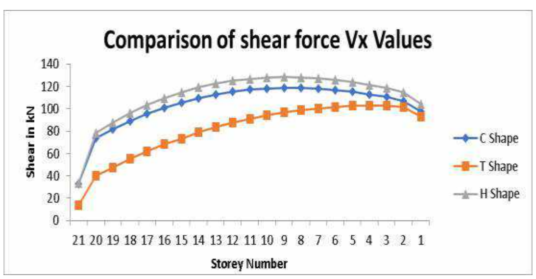

Figure 3.3 Visual depiction of shear force values in the X direction

- COMPARISON OF FREQUENCY VALUES

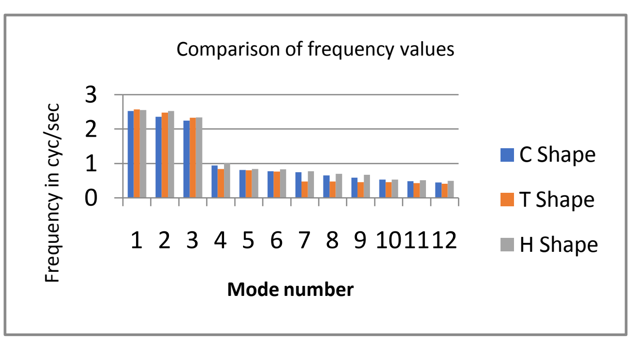

Figure 3.7 Visual depiction of frequency values

COMPARISON OF SHEAR FORCE VY VALUES

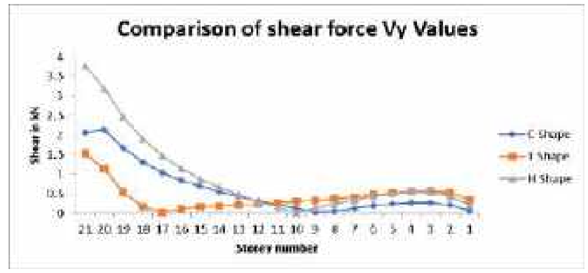

Figure 3.4 Visual depiction of shear force values in the Y direction

COMPARISON OF BENDING MOMENT MX VALUES

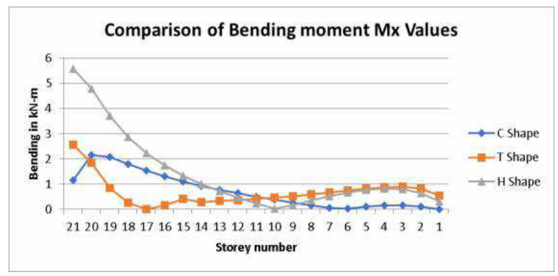

Figure 3.5 Visual depiction of bending moment in the X direction

COMPARISON OF BENDING MOMENT MY VALUES

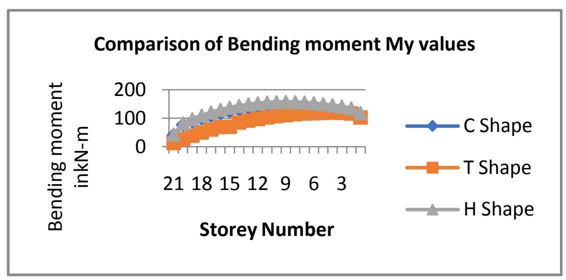

Figure 3.6 Visual depiction of bending moment in the Y direction

- COMPARISON OF STOREY SHEAR VALUES

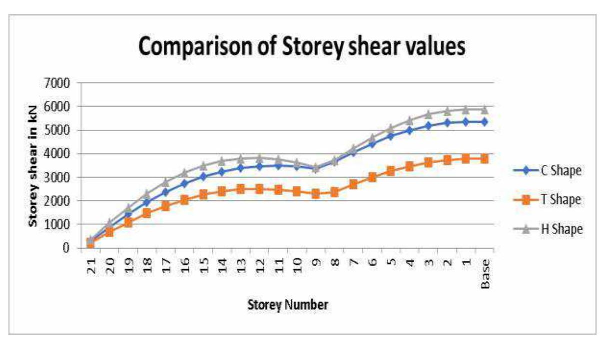

Figure.3.8 Visual depiction of storey shear values

DISCUSSIONS

Engineers strive to counteract the forces of a potential earthquake and reinforce the structure in order to design a building that is earthquake-resistant. The plan is to have the building push in the opposite direction from the direction that earthquakes release energy in. These are a few techniques for making buildings more earthquake-resistant.

- Base isolation is a technique that allows a building to be "lifted" above the ground in order to withstand ground forces. During an earthquake, the isolators vibrate when the base moves, but the structure stays stable. Seismic waves are effectively absorbed by doing this.
- The structures should have the least amount of mass possible. Avoid placing a lot of heavy mass at the top of the structure. ”Reinforced Hollow Concrete Blocks” masonry system can be adapted as it reduces the dead load on the structure and may attract lesser seismic forces.
- Generally, anyone type of foundation system should be adopted and all of the foundations should be at the same level. Footings should be interconnected either by tie beams at the foundation level or by mat/raft to avoid the uneven settlement of the structure due to ground motion during an earthquake.
- A material needs high ductility—the capacity to withstand significant deformations and tension—in order to withstand stress and vibration. Structural steel is a material that can take on many different forms and is frequently used in the construction of modern buildings. It allows buildings to bend without breaking. In addition to structural steel, materials that offer additional resistance to the structure include bamboo, memory alloy, and fiber-reinforced plastic wrap composed of different types of polymers.
- Moreover, diaphragms, cross braces, and shear walls can help a structure maintain its shape when the ground moves.
- Pendulum power is another popular damping technique that is mostly utilized in skyscrapers. This is implemented by suspending a sizable ball from steel cables that are connected to a hydraulic system at the top of the structure. As a result, the ball functions as a pendulum and moves in the opposite direction to stabilize the building when it starts to sway.
- Good quality control, good workmanship, good supervision and, good construction methods are necessary for earthquake resistant structures.

CONCLUSIONS

This paper is an attempt to bring forward the information which is critical at different stages of the design process from a structural designer and architect’s perspective. It is crucial that adequate attention is given to earthquake considerations at the planning and designing stage. Even if analysis of structural response to earthquakes, structural design, and corresponding detailing is considered as the subject matter of the structural designer, it does not minimize the responsibility of the architect. He should be aware of the tools that are available for analysis. Understanding the dynamic behavior of the structure is crucial to getting the most out of even the most basic method of analysis. The following conclusions are made in light of the findings of the analytical study that was done on the building models:

- Simple geometry buildings perform well during high magnitude earthquakes rather than the buildings having U, H, and V and cross shapes. The bad effects of their interior corners can be avoided by making the building into two parts. Large cornices, vertical and horizontal cantilevers, facia-stones etc should be avoided.
- Structures with fewer walls or columns in a given story are not ideal during an earthquake. The location and size of windows and door openings should be as symmetrical as feasible. If the building is large, it should be divided into multiple blocks, each maintaining its own symmetry and regularity.
- In reinforced concrete building design, the beams must be the weakest links and not the columns. The concept of the strong column and weak beams must be followed.
- The joints between columns and beams and between columns and foundation should be strong enough so that they do not fail during an earthquake. Columns should have a minimum width of 300mm and the lap length should be provided at the middle half of the column and not near the top and bottom ends.
- In the design of the RCC beams, the shear failure should be avoided by using closed -spaced stirrups. 8mm dia stirrups should be used and the ends of the stirrups must be bent at 135 degrees to avoid opening of the stirrups during an earthquake.

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ELECTRICAL ENGINEERING DIVISION

EL_IEC 2023 TV 022

An Overview on Methods of Dynamic Programming based Optimized Controller for Charging of Electric Vehicle Batteries Utilizing Sustainable Power

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***Abstract**: The utilization of environmental friendly power and electric vehicles (EVs) can lessen the energy costs and limit radiation to significant degree. The discontinuous idea of sustainable power sources and its inconsistent use, coordinating sustainable power sources into the electric network is a difficult cycle. In the event that the stock of sustainable power isn't satisfactory to satisfy the necessity, pulling additional energy from the power grid is costly. This may likewise lessen the energy proficiency of the charging system. Focal point of this study is to introduce techniques for streamlining a regulator for the charging of electric vehicle batteries utilizing environmentally friendly power hotspots for energy the board. Zap of transportation, specifically, is seen as one of the critical roads to accomplishing significant CO_2 outflow decreases. EVs have acquired prevalence lately, and more than 180 000 have been conveyed overall excessively far. Despite the fact that this number addresses simply 0.02 percent of all vehicles out and about, the Global Energy Organization has defined an elevated objective of having north of 10 million electric transports and light obligation vehicles (EV) out and about by 2030. The result of the Powerful Programming streamlining and various different methodologies utilized in energy improving programming are contrasted with figure out which one would precisely limit the expense of energy expected for charging but satisfy the total battery charge keeping up with models. In light of this study it is obvious that the Powerful Programming based streamlining procedure gives the most elevated level of precision while keeping a reliably elevated degree of fuel reserve funds in EVs.*

***Keywords**: Electric Cars, Battery, Electric Vehicles, Dynamic Programming, Renewable Energy Sources*

INTRODUCTION

At the financial, natural, modern, and social levels, the absence of oil stockpiling and the ascent in gas discharges (CO_2, SO_2, and NO_x) have become worldwide issues. Using sustainable power sources to create power can possibly extraordinarily diminish gas discharges and save the climate from future calamity[1]. One more feasible choice to save climate harm is to change to EVs from customary Gas powered Motor (ICE) vehicles. To keep away from issues like high pinnacles and power misfortunes for the lattice and to lessen EV proprietors' charging costs, composed charging is vital[2]. As sustainable power sources become more pervasive, conventional petroleum product based power-creating offices are being transitioned away from as the worldwide energy scene changes[3]. Module crossover electric vehicles (PHEV) and Battery Electric Vehicles (BEV), which are turning out to be more pervasive, both contain sizable, provided battery capacity limit that could be connected to the matrix while left for expanded periods, making additional opportunities for the mix of Environmentally friendly power sources (RES)[4]. Energy framework improvements are remembered to affect the various techno-financial examinations about electric vehicle-to-matrix incorporation since they unveil the best design, qualities, and the executives of an evaluated, coordinated energy framework [5]. EVs might give a few benefits over.

Customary vehicles, as less expensive working expenses, decreased gas outflows, and so on. EVs, then again, give an exceptional energy stockpiling ability to help the creation of sustainable power and the electrical network [6]. EVs could be worked such that upholds a roof Photovoltaic (PV) framework, which can accommodate the family's electrical requirements while bringing down costs [7]. Furthermore, involving environmentally friendly power to charge EVs would acquire prevalence as a green and successful energy-use system [8]. As indicated by a review, accusing 50,000 electric vehicles of sustainable power might cut yearly gas discharges by 4x×105 tons [9].

Be that as it may, giving EV charging environmentally friendly power has its own arrangement of issues. The discontinuous idea of environmentally friendly power age, which is significantly affected by climate, makes it hard to plan and timetable the activity of force frameworks[10]. To bring down the expense of acquiring extra energy and to further develop power capability, it is critical to painstakingly examine the stochastic elements and the unique help between sustainable power creation and limit prerequisite[11]. This study inspects the best charging strategies in view of dynamic programming to bring down the general expense of charging EVs. **Figure 1** shows the schematic chart of Electric Vehicle [12].

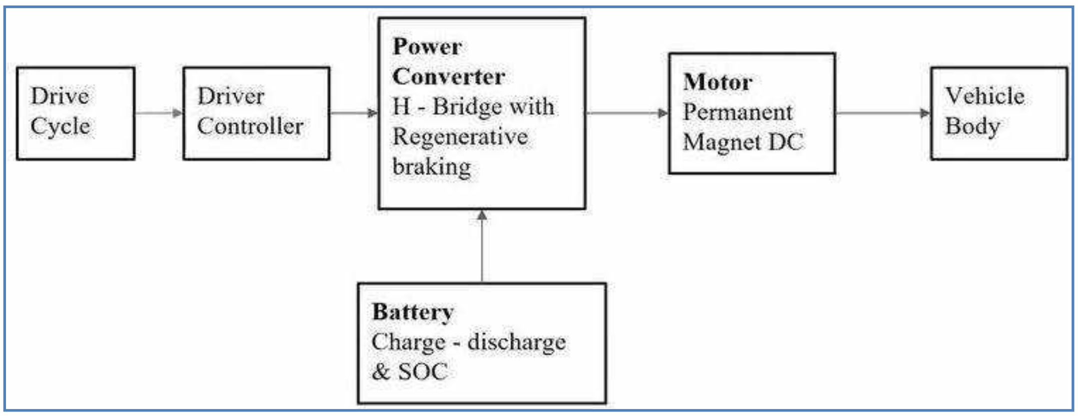

Figure 1 Schematic diagram of electric vehicle modeling

EV (Electric Vehicles)

An electric vehicle is a vehicle, truck, or another engine vehicle that is pushed exclusively or for the most part by at least one Electric Vehicles (EVs) [13]. It very well may be controlled by a battery, a gathering framework, or energy from extravehicular sources [14]. Nonetheless, these strategies can't be used at the same time. An EV is moved by an electric engine rather than a gas powered motor, which produces power by consuming a blend of fuel and gases [15]. A couple of instances of electric vehicles are electric watercraft for both the surface and the profundities of the ocean, electric planes, and electric spaceships EVs [16]. Three essential classes of electric vehicles are module crossover electric vehicles (PHEV), half and half electric vehicles (HEV), and Battery Electronic Vehicle (BEV) [17].

HEV (Hybrid Electric Vehicles)

Hybid Electric Vehicles (HEV) consolidates a Internal combustion Engine (ICE) with a battery pack and electric engine to decrease fuel utilization [18]. HEVs do this by applying an electric engine to push the vehicle when ICE would be especially inefficient, for example, while advancing from a stop [19]. Half breeds could favor the gas powered motor (ICE) regardless of whether it would be more proficient for them not to do as such in specific circumstances, for example, while driving at roadway speeds [20]. **Figure 2(a)** shows the schematic chart of a Series Hybid Electric Vehicles & **Figure 2(a)** shows the schematic chart of a Parallel Hybid Electric Vehicles [19].

PHEV (Plug-in Hybrid Electric Vehicles)

Plug in Electric Vehicles (PHEV) are a double fuel innovation that expects to supplant non-sustainable, high-carbon powers in the transportation energy foundation with additional harmless to the ecosystem choices [21]. Power is one of the fills utilized in PHEVs. PHEVs can give execution comparable to that of the present state of the art vehicles [22]. Benefits are the result of changing from customary transportation energizes to power, which is more huge, as well as an effective fuel-energy conveyance from the tank to the wheels [23]. **Figure 3** shows the schematic chart of Plug in Hybrid Electric Vehicle [19].

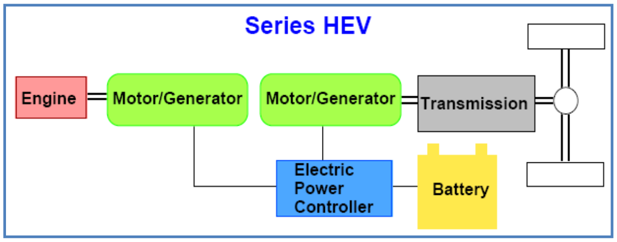

Figure 2 (a) Series Hybrid Electric Vehicle

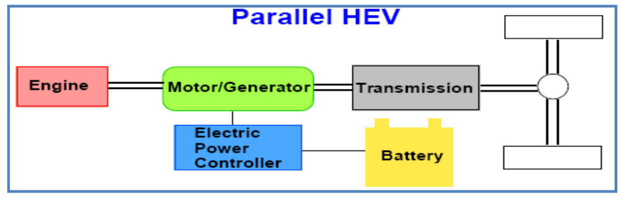

Figure 2 (b) Parallel Hybrid Electric Vehicle

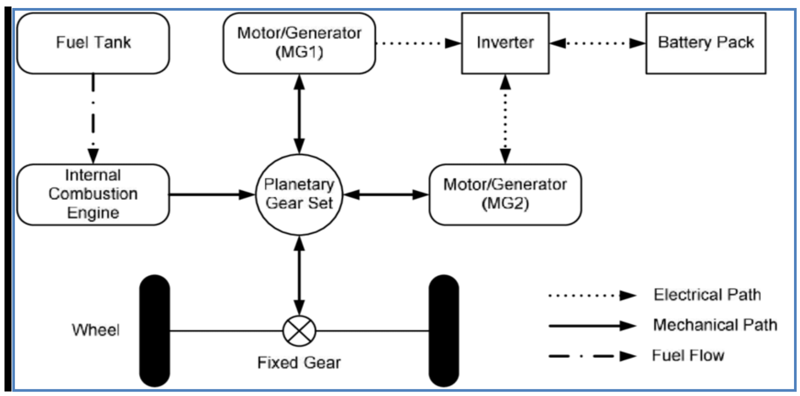

Figure 3 Schematic diagram of a PHEV

BEV (Battery Electric Vehicles)

Battery Electric Vehicles are known as unadulterated electric vehicle, just electric vehicle, or completely electric vehicle alludes to an EV that exclusively depends on substance force aggregated in battery-powered battery sets and uses no extra wellsprings of force [24]. An "all-electric" or "full-electric" vehicle is alluded to as a BEV [25]. BEVs just use power, with locally available battery packs filling in as a wellspring of flow for the electric engines in every vehicle [26]. BEVs miss the mark on ICE parts. Because of their selective reliance on power, BEVs frequently have batteries with a lot higher limits and kilowatt-hour (kWh) yields than identical half and half and module electric cars [27]. The PHEV has a cheaper punishment than a BEV with comparable execution since it utilizes less batteries than a total BEV [30]. **Figure 4** shows the schematic chart of Battery Electric Vehicle [31].

DYNAMIC PROGRAMMING METHOD

To successfully settle a class of issues with covering sub issues and an ideal base property, dynamic programming consolidates numerical streamlining methods with PC programming strategies [32]. Dynamic writing computer programs is a numerical methodology that might be utilized to settle any issue that calls for evaluations to be done successively to find a choice course that causes minimal measure of punishment [33]. With regards to this conversation, a "punishment" is a mathematical portrayal of the unwanted outcomes that are brought about by a choice [34]. The calculation propels from the finish of one obligation cycle to the start of the following while it at the same time computing the punishment brought about by various control settings at each time step [35]. The powerful programming approach can't be utilized in useful control strategies since it expects earlier information on the obligation cycle [36]. Notwithstanding, genuine regulators might be planned and tuned utilizing the powerful writing computer programs calculation's results [37]. The advantages of DP improvement approaches are as per the following:

- A decline of around 40% in the expense of charging energy for the situation when there is a low entrance of Environmentally friendly power sources (RES) and a two-levy electrical energy estimating design [38].

- More prominent utilization of RES capacity and, would it be a good idea for it happen, a proportionately diminished cost of lattice power for charging when RES share surpasses nearby energy interest without EVs [39].

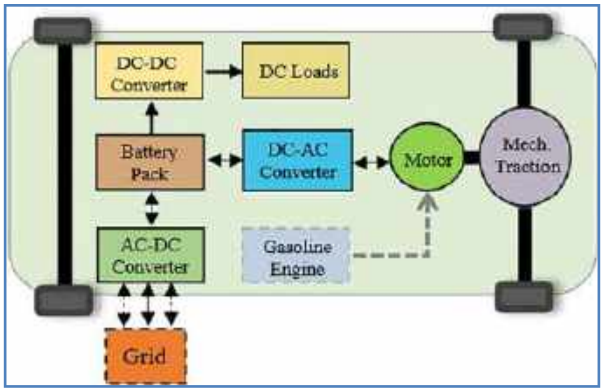

Figure 4 Schematic diagram of the battery electric vehicle

The punishment capability that was utilized in this exploration relegated a punishment for the utilization of fuel, for neglecting to satisfy the obligation cycle speed-time follow that was given, and for neglecting to keep an end condition of charge that was fair [40]. Just a little part of the entire plan space is explored by the powerful programming approach in its ongoing structure, which was utilized for this study [41]. Along these lines, the creator couldn't say that the control is ideal, but instead that it is close ideal [42]. A kind of worldwide improvement approach known as powerful programming, or just DP, accomplishes its motivation by separating an issue into a few stage based cuddled sub issues, combining the outcomes found at each level, and moving backward from the latest stage to the one preceding it [43]. Following the optimality standard, the ideal not entirely settled at each stage by figuring them in light of the ideal results of the stage that preceded [44]. The expense of charging clients is the essential accentuation of enhancement, with thought given to evaluating changes [45]. Figure 5 portrays the flowchart of Dynamic Programming approach [46].

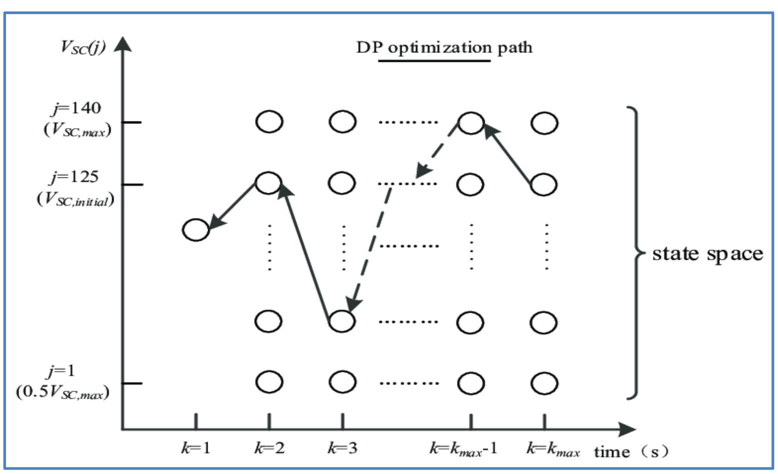

Figure 5 Dynamic programming (DP) approach flowchart

Renewable Energy

Quite possibly of the most possibly game-changing impact that EVs could have on the electrical framework is their ability to work with the joining of inexhaustible power supplies into the flow energy system [47]. Planning EV accusing of other network interest and inexhaustible creation turns out to be extremely troublesome because of RESs' irregular and indispatchable nature [48]. The EV's flighty appearance, irregular sustainable power, and fluctuating framework power costs are undeniably thought of and described as independent Markov processes [49]. The energy expected to charge every EV, in the interim, differs arbitrarily [50]. Module electric vehicle reception and the inescapable utilization of environmentally friendly power (RE) may both add to the decarburization of the transportation and power areas [51]. The station contains sustainable creating (wind and sun oriented) and a capacity framework to build the quick charging stations' productivity and lower the high energy interest from the network [52]. The change to a low-carbon, profoundly incorporated inexhaustible society requests drives from various areas and levels [53]. **Figure 6** shows the fundamental schematic diagram of Sunlight based-electric-vehicle.

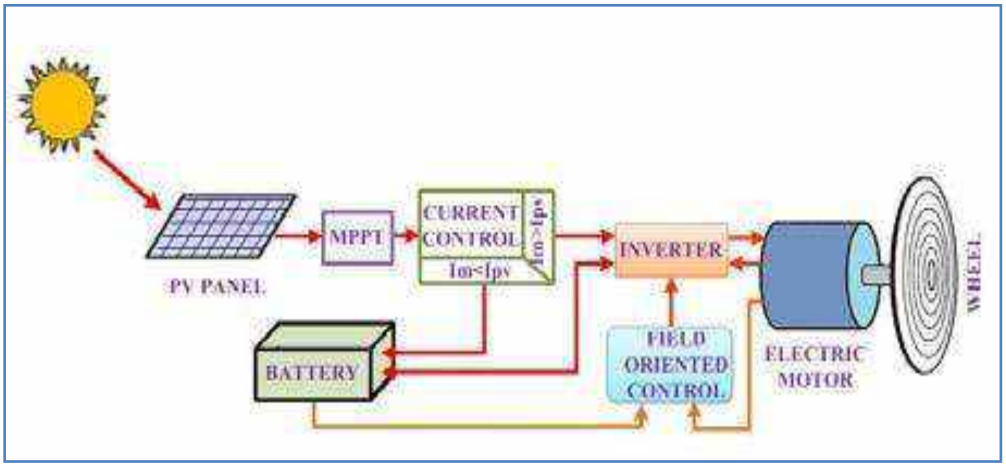

Figure 6 Block Diagram of Solar Electric vehicle

Wind Energy

A sixteen-crease extension in northeastern breeze power capacity was anticipated while demonstrating the Brazilian electrical area from 2010 to 2030 [62]. The quantity of PHEVs (module cross breed electric vehicles) whose batteries may be renewed by the overabundance wind power yield is then determined [63]. The abundance creation shifts occasionally and happens all the more frequently among January and June; thus the creators acknowledge that the vehicles work on neighboring produced ethanol during different months of the year [64]

Solar Energy

Consolidating prompt battery re-energizing from sun powered photograph voltaic with the parking area chargers that were examined before is one method for utilizing the advantages presented by this sort of charging [65]. Sunlight based vehicles are not intended to be used for business reasons; be that as it may, the Vehicle-incorporated Photovoltaics (VIPV) may be utilized to build the mileage of mixture and electric vehicles which are now out and about [66]. It is guessed that this would bring about a 10-20% expansion in the mileage of the vehicle [67].

LITERATURE REVIEW

This part underlines different deals with the subject of Dynamic programming based ideal regulator for charging electric vehicle batteries utilizing sustainable power. **Table 1** shows the summed up investigation of the different scientists participated in the field.

Table 1 Summarized study of the various researchers engaged in the field

Author	Technique	Outcome
Yang et al., (2021) [71]	Dynamic Programming (DP)	Compares the GA-centered charging program to the DP-centered charging program and the baseline charging plan, the overall charging cost is lowered by 41.5% and 46.3%, using the two alternative charging schedules.
Salazar et al., (2020) [73]	Stochastic optimization (stochastic DP formulation), time-variant Markov model.	The simulation results are provided to demonstrate how effective the suggested DP-based technique is in comparison to an algorithm that is based on rules.
Yu et al., (2019) [75]	Dynamic Programming	The findings demonstrate that owing to the nature of EV use, the mid-morning EV mandate for commercial fleets cannot be moved to another period.
Chen et al., (2014) [79]	Dynamic Programming	The suggested technique may need less computing time in exchange for improved management of battery and fuel efficiency performance.
O'Keefe et al., (2006) [4]	A dynamic programming optimization approach	Under optimal conditions, the quantity of gasoline used by a strategy that utilizes mixed control and one that emphasizes the use of electric vehicles is same for a given set of objective distances.

RELATIVE EXAMINATION

Foreseeing a Powerful programming-based upgraded regulator for charging EV batteries in sustainable power sources has been a drawn out objective of this review, which would investigate past examinations done in this field. In contrast with different strategies, the Unique Programming Enhancement (DPO) approach has found to have the most noteworthy exactness (91%). AI (ML) calculations with 90.3 percent of exactness and stochastic DP definition (SDPF) with 88.52 percent precision come a while later. Remote Charging Geographies (WCT) performs with 88% precision and Lyapunov Streamlining (LO) Technique with 72.31 percent exactness.

Table 2 shows the near investigation of different creators in light of exactness and utilized procedures.

Table 2 Relative Examination

Author	Technique	Accuracy
Yang et al., (2021) [71]	Dynamic programming Optimization (DPO) Approach	91.0%
Shibl., et al (2020) [74]	Machine Learning (ML) algorithms	90.3%
Salazar et al., (2020) [73]	Stochastic Dynamic programming formulation (SDPF)	88.5%
Joseph et al., (2018) [77]	Wireless Charging Topologies (WCT)	88.0%
Jin et al., (2014) [1]	Lyapunov Optimization (LO) Method	72.3%

Figure 7 shows the examination diagram for the different strategy's (Dynamic programming Advancement Approach, AI calculation, Stochastic DP plan, Remote Charging Geographies, Lyapunov Enhancement Technique) precision in the current writing.

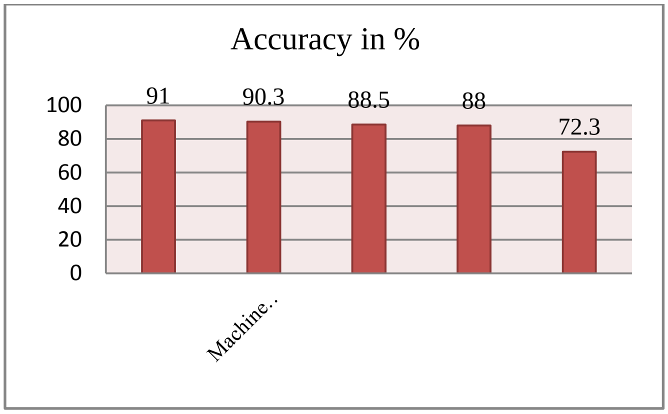

Figure 7 Comparison graph for the classifier's accuracy.

CONCLUSION

This examination procedure for streamlining the optimizing the controller of charging the electric vehicle batteries utilizing sustainable power sources is proposed in this audit concentrate on that was directed with the objective of boost the utilization of sustainable power. The Unique Programming Advancement (DPO) strategy offers the best exactness of 91% when contrasted with different ways to deal with improving the charging of electric vehicle batteries utilizing sustainable power. Furthermore, there is a conversation of the notable techniques that are accessible and these can be used to work on the most common way of charging the batteries of electric vehicles utilizing environmentally friendly power sources. This study's essential goal is to gather the entirety of the appropriate data, like past exploration on Unique Programming, electric vehicle batteries, sustainable power batteries, and existing methodologies, and give the subtleties in most thorough way.

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AI based Approach for Forecasting of Solar Power Generation based at Solar Power Unit of Tamil Nadu

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Abstract: *Renewable energy plays a crucial role in mitigating global warming by reducing reliance on fossil fuels, which release large amounts of greenhouse gases. Harnessing power from sources like solar and wind helps curb carbon emissions, contributing to a more sustainable and climate-friendly energy mix. Embracing renewable is pivotal for achieving global climate goals and fostering a greener, low-carbon future. Through machine learning algorithms, ML contributes to smarter decision-making, fostering a more resilient and adaptive renewable energy infrastructure. ML can analyse patterns in historical energy usage data, along with other factors like weather forecasts (temperature, sunlight hours, etc.), time of day, day of the week, and special events or holidays. Using data related to weather patterns, irradiation, and other relevant factors ML model trained and learning from these patterns, ML can predict future energy demand with a high degree of accuracy. This paper demonstrates the effectiveness of machine learning /artificial intelligence in predicting the solar power generation on a particular day at Thopplakarai village in Tamilnadu, India helping the producer to better planning and act accordingly.*

Keywords: *Artificial Intelligence, Solar Power, Radiation intensity, Random Forest algorithm, Forecasting, Regression, Support Vector Machine*

INTRODUCTION

Climate change concerns such as heat waves and rising sea levels present a great macroeconomic challenge that requires a drastic reduction in carbon emissions to fully mitigate it. As the electricity sector is the one of the largest carbon emitter worldwide, energy transitions to less-carbon intense technologies within the sector are crucial to realizing climate change goals. Renewable resources, however, are waste and pollution free, and durable [1].

Solar and wind energy will constitute a significant part of the world's energy supply in the future and will bring new challenges to power system works [2]. Solar energy is inexhaustible and is considered one of the most promising sou rces for large

scale electricity generation. Due to its clean and green features, solar energy is one of the fastest growing energy sou rces in the world. Photovoltaic (PV) cells are a technology that converts solar energy into electricity. Since photovolt aic energy production is directly related to solar irradiance on the ground, solar irradiance forecasting is also importa nt for smart solar grid management. In fact, there are many factors that affect solar energy production, such as solar radiation, cloud cover, temperature, humidity, atmospheric pressure and wind speed.

Due to the complexity of Earth's atmosphere, environmental conditions can change at any time, making it unreliable and accurate solar forecasting is difficult. In addition, power exports and export losses also affect the performance of these solar power units resources [3]. As weather-driven resources, solar energy production often presents some inconsistencies, inefficiencies and fluctuations, threatening the economy and the stability of energy and power. The randomness of solar energy directly aggravates the impact of the energy system, which must urgently maintain a balance between energy production and consumption, increasing capacity and production costs. By using machine learning tools for prediction, the gap between production and availability can be better controlled in a better way.

One of the widely used forecasting methods in business is the physical model, which is based on the physical nature of the weather, such as weather number [4] (NWP), satellite images, and terrestrial skies, whether phone data or graphic images. These models depend on the weather and its characteristics such as air cover, irradiance changes, temperature changes and other weather parameters that help predict future weather.

Examples of these methods are Autoregressive Moving Average (ARMA) and Autoregressive Integrated Moving Average (ARIMA)[5]. Cognitive models are another type of predictive modelling that can be used for control and optimization efficiency of solar power plants due to their learning capabilities. Examples of these models include support vector machines (SVMs), regression, and neural networks.

LITERATURE REVIEW

In one of the studies, Mohammad Rasouli et al. [6] have developed a neural network (NN) based numerical weather prediction (NWP) model to predict the generated power in residential smart micro grid. To check the effectiveness of the neural network model for accurate solar power forecast, two other methods including multi-variable regression and support vector machines were utilized for solar power forecast based on the same data. Mean Absolute Percentage Error and Mean Squared Error values were computed to compare the accuracy of NN with two other models. The application of these methods and the utilization of the forecast values by power generation companies for predicting solar power for balancing the power generation and demand in order to perform a long-term optimization and expansion planning for a residential smart microgrid. Zechun Hu et al. [7] have discussed about the growth in renewable energy generation including solar power and high penetration level of photovoltaic (PV) generation arises in smart grid. To balance the smart grid accurate forecasting of weather (parameter- cloud cover variability, atmospheric aerosol level and other atmospheric parameter) is required for assessing its effect on the solar generation. For forecasting PV and solar power generation- statistical models, ML-based models, physical models and hybrid models, benefits and disadvantages of all models were explained briefly. Huaizhi Wangaet et al.[8] has categorise the various method for solar power forecasting. various method used for solar power forecasting includes ML-based solar power prediction methods, network optimizers and ML algorithms include Machine learning, deep learning and fuzzy logic.

STRATEGIC FRAMEWORK

An ML model has been developed using the past data to for prediction of irradiance and consequently solar power generation on a specified day in future. This paper focuses on application of machine learning tools in forecasting of renewable power generation. The research leverages a rich dataset of weather information, including solar irradiance, and other relevant meteorological parameters, to develop accurate and reliable prediction models.

A case study has been taken from one solar plant from Tamil Nadu. The research explores the integration of weather data, historical generation patterns, and cutting-edge predictive models to provide a comprehensive and forward looking framework for anticipating renewable power outputs. The performance of 100 MW grid connected solar photovoltaic power plant is carried out in this work with the following framework.

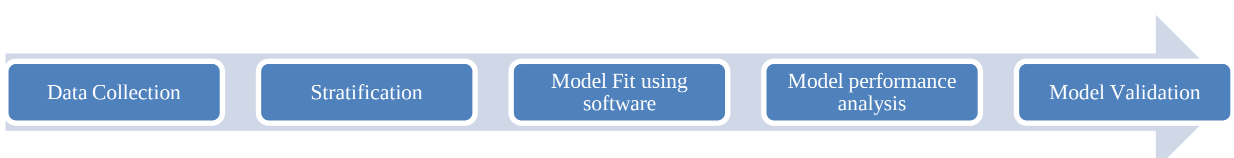

Figure 1 Framework

A CASE STUDY

A case study has been taken for the performance analysis of 100MW solar power plant installed at Thoppalakarai Dist: Virudhunagar, Tamilnadu, India Thoppalakari is located at latitude of 9°24'43.8768" N and 78°21'59.8968" E.

Objective of the Case Study

(1) To study present variation of solar power generation for dependent & independent parameter available at database for Thopplakarai, Tamilnadu, India.
(2) To develop a power output model that will relate solar power output with the meteorological variables.

METHODOLOGY

Figure 2 indicates the stratified sample data set developed using the Python based software.

A. Data Collection:

Data has been collected for the past two years from SCADA of Thoppalakarai. The data is gathered from the aforementioned source.

B. Data Stratification

The input data are all sorted before being used.

C. Variables:

Meteorological data variables, viz. Solar irradiation, Ambient temperature, Module temperature, are used for analysis and model fit. On the basis of these variables and their interaction patterns, solar power generation variation with different variables is drawn in **Figures 3** to **6**.

Figure 2 depicts the data description about the sample size.

Sample Dataset

	Day GHI (KWHr/m2)	Amp. Temp	Mod. Temp	Rain Fall	Total gross generation(KWHr)
0	4.066	29.180	36.120	0.0	369000.0
1	3.106	26.380	34.380	3.0	267000.0
2	3.562	26.180	36.180	1.0	317000.0
3	3.696	27.640	34.270	0.0	348000.0
4	3.092	27.058	33.098	0.0	265000.0

Figure 2 Stratified sample data

Data Description

	Day GHI (KWHr/m2)	Amp. Temp	Mod. Temp	Rain Fall	Total gross generation(KWHr)
count	730.000000	730.000000	730.000000	730.000000	730.000000
mean	4.557764	29.060607	36.655825	1.422192	390065.200411
std	1.029377	3.524105	4.587788	5.573856	85203.140761
min	0.838000	22.280000	25.307000	0.000000	75000.000000
25%	3.987750	26.680000	33.522500	0.000000	351000.000000
50%	4.709500	28.920000	36.420000	0.000000	415000.000000
75%	5.298000	30.767500	39.097500	0.000000	458000.000000
max	6.727000	45.320000	49.620000	66.800000	565000.000000

Figure 2 Data result after ML tool testing

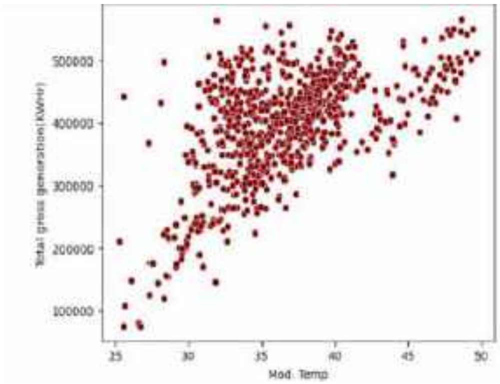

Figure 3 Power generation variation with Mod. Temp

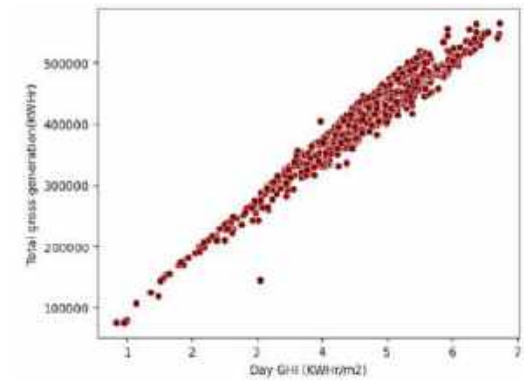

Figure 4 Power generation variation with GHI

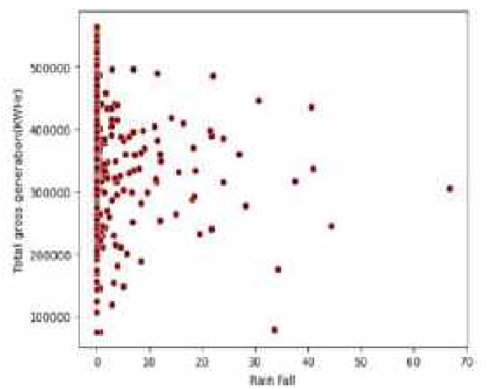

Figure 5 Power generation variation with Rainfall

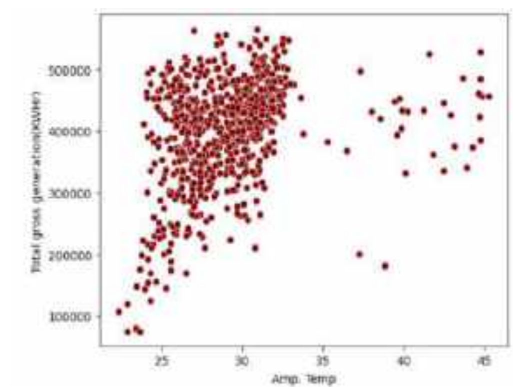

Figure 6 Power generation variation with ambient Temp

Figure 7 shows the co-relation between every parameter. It shows that total gross generation has positive relation with day GHI, ambient temperature and Module temperature whereas it has a negative correlation with the rain fall. Day GHI has positive relation with ambient and module temperature and negative correlation with rain fall. Module temperature has positive related with ambient temperature and has negative relation with the rain fall.

	Day GHI (KWHr/m2)	Amp. Temp	Mod. Temp	Rain Fall	Total gross generation(KWHr)
Day GHI (KWHr/m2)	1.000000	0.420417	0.670838	-0.211249	0.975919
Amp. Temp	0.420417	1.000000	0.531633	-0.108502	0.331864
Mod. Temp	0.670838	0.531633	1.000000	-0.104599	0.573675
Rain Fall	-0.211249	-0.108502	-0.104599	1.000000	-0.225534
Total gross generation(KWHr)	0.975919	0.331864	0.573675	-0.225534	1.000000

Figure 7 Co-relation matrix between parameters

D. **Model Fit using Software**

The relations between weather parameters and solar power generation are established using the Machine learning tools. The training data set is used to obtain the prediction model and random sample test data set is used for model evaluation.

Random forest: Ensemble learning method is used for regression. It combines predictions from multiple machine learning Algorithms to make a more accurate prediction than from a single model. Average of all predictions is RF algorithm. Here, tree runs in parallel and no interactions among trees. This method involves randomly selecting K data points from the data and building a decision tree using these data points. Similarly N number of trees have to be built. In Random Forest, each tree predicted the value of "y" for the data point in the tree and assign new data point to the average across all of the predicted y values. In this algorithm dependent variable (Y) is solar power generation and the independent variables are the Day GHI (KWHr/m2), Amp. Temp, Mod. Temp, and Rain Fall.

SVM: Support vector machine (SVM) is classified as a machine learning algorithm that can be used in pattern recognition, classification and regression problems. In the SVM method, data is processed in an n-dimensional space; where n represents the number of variables to be considered in the analysis. Hyper planes in n-space are used to define multiple groups as they fit the data.

Multi-variable regression: The regression method obtains a linear, multi-variable, or polynomial equation that best fits the data depending on the correlation between the dependent variable and various samples of independent variables.

Assumed that no correlation between the independent variables.

Y= Output/Response variable

b1, b2, .., bm= Coefficients of the model.

x1, x2... xm= Various Independent/feature variable

C- Intercept

Y=∑_i^m 〖b_i*X_i 〗 +C (1)

In this study there are four independent features set with one target variable. The final equation is shown in Equation (5) and (6).

$Y=C+b1*X_1+b2*X_2+b3*X_3+b4*X_4$ (2)

X_1 - Day GHI (KWHr/m2)

X_2- Amp. Temp

X_3- Mod. Temp

X_4- Rain Fall

Model Performance Analysis

An essential step in obtaining forecast models is to have two sets of data: the training and the test data sets. The analysis and predictions are performed using SVM, random forest and regression. As mentioned earlier, the solar energy generation forecast, utilized in this work, is done in three phases.

MODEL

Overall error prediction comparison for solar power generation data based on MLP, RF and SVM

In this section, Researcher has explained about the performance assessment for analysing the effectiveness of the models. These models analyse solar power generation and forecasting, which is a regression problem. To evaluate the effectiveness of models, parameters have been selected.

Residual error= (y - ẏ)

y= actual valueẏ =Predicted value.

Performance metrics used for evaluation are defined and details are as follows.

Mean Square Error (MSE)

MSE is calculated as (i) First Square of the residual error for each data point is calculated and then(ii) average of the entire is calculated. Formula may be seen at Equation.

$$\mathrm{MSE}=\frac{1}{n}\sum_{i=1}^{n}(y_i - \dot{y}_i)^2 \tag{3}$$

Where y_i is the actual value and $\dot{y}_i$ is the predicted value. Here "i" indicates the number of data points.MSE values can vary from 0 to ∞ where smaller values are preferable.

Root mean squared error (RMSE) is represented as square root of mean square error. Formula for RMSE is indicated at Equation (9).

$$\mathrm{RMSE}=\sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \dot{y}_i)^2} \tag{4}$$

Root mean squared error (RMSE) takes the values from 0 to ∞, and the smaller Root Mean square error values are preferred.

Mean squared log error in mean squared log error (MSLE), the residual error is calculated with the logarithm of the original value and logarithmic value of predicated values. Used when predictions have large deviations. The formula for Mean absolute log error is represented in Equation (10).

$$\mathrm{MSLE}=\frac{1}{n}\sum_{i=1}^{n}\log(y_i) - \log(\dot{y}_i))^2 \tag{5}$$

Mean absolute error (MAE) is sum of the absolute residual error. Irrespective of positive error or negative error, value will be considered in this metric. The formula for MAE is shown at Equation (11).

$$\mathrm{MAE}=\frac{\sum_{i=1}^{n}|(\dot{y}_i - y)|}{n} \tag{6}$$

Mean Absolute Percentage error (MAPE)is expressed as addition of percentage to MAE. Good model can be identified with smaller MAPE values. Formula is represented in Equation (12).

$$\mathrm{MAPE}=\frac{100\%}{n}\sum_{i=1}^{n}\left|\frac{y_i - \dot{y}_i}{y_i}\right| \tag{7}$$

If the MAPE value is less than 10%, prediction accuracy is called" high". If the MAPE value ranges between 10 to 20%, prediction is classified as "good". If the MAPE value is between 20 to 50%, predictions are classified as "Reasonable". If the MAPE value is greater than 50%, predictions are classified as "inaccurate prediction".

Median Absolute Error (MAE) formula is at Equation (13).

MedAE $(y, \dot{y})$= median $(|y_1 - \dot{y}_1| \dots \dots \dots |y_n - \dot{y}_n|)$ (8)

This method is a robust measure of the variability of a univariate sample of quantitative data. Value can be anything. The lesser the value, higher the accuracy.

Max Errorcalculates the maximum residual error. The formula used for the calculation of Max error is placed at Equation (14).

Max Error= $\text{Max}|y_i - \dot{y}_i|$ (9)

R^2 score error is the error that has the significance in measuring the effectiveness of model. R^2 model equation is at Equation(15).

$R^2 = 1 - \frac{\sum_{1=1}^{n}(y\hat{}_i - y_i)^2}{\sum_{1=1}^{n}(y_i - \bar{y}_i)^2}$ (10)

This R^2 score error is called as determination coefficient. It ranges from 0 to 1. It gives a clue on how well the trends of the model results is able to track the trends of actual data.

Explained variance score error (EVS)is calculated to measure the proportion of the variability of the predictions of the applied machine learning models. Variance measures the difference between observed values from the average of predicted values. Higher the EVS value the best fit, it is. Formula is at Equation (16)

Formula: $\text{EVS}(Y, \bar{Y}) = 1 - \frac{\text{var}\,(Y - \dot{Y})}{\text{var}\,(y)}$ (11)

After utilizing SVM, random forest and regression model for forecasting the irradiance and its respective power generation, the error of each model is measured by comparing with the original few random samples and the forecasted data. Depending on the level of accuracy required in showing the dependency, various correlation functions could be considered. The straight forward function would be a linear relationship in a particular range.

RESULTS & INTERPRETATION

The analysis has been done based on available two year day wise dataset for Thoppalakarai 100 MW Solar power Plant. The dataset has been divided into training and testing dataset. Training dataset is used to train the model and testing dataset is used to calculate the accuracy of our model with the actual.

The obtained model is as follows,

Regression Model Output:

Solar Power Generation = Coefficients:

Day GHI (kWh/m^2): 88531.27345152

Ambient Temp: - 1599.90699117

ModuleTemp :-2032.6093531

Rain Fall: -144.63720066

REGRESSION MODEL

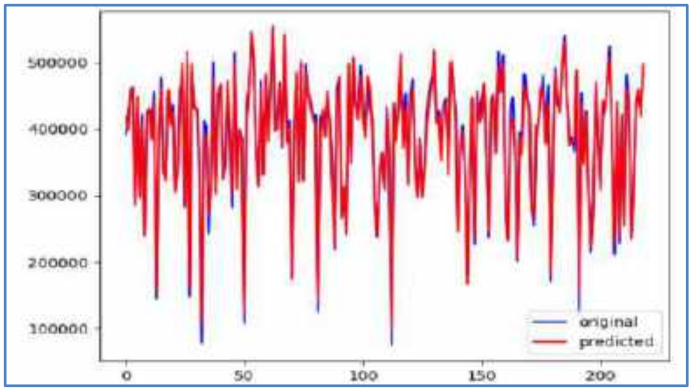

Figure 8 The daily forecast of generated power by solar cells using the multi-variable regression method. The blue curve shows the target values and the orange curve illustrates the forecast values.

RANDOM FOREST

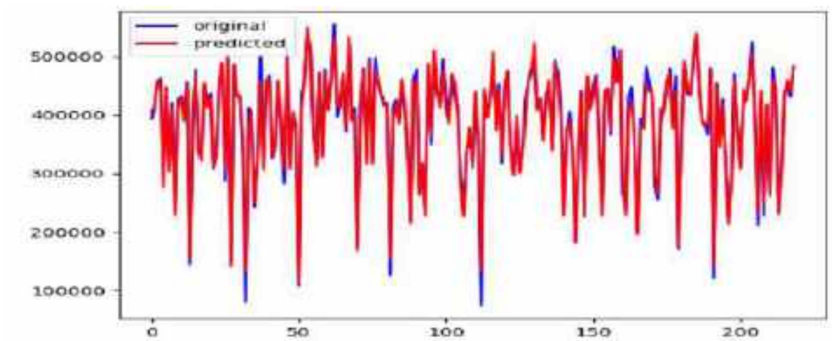

Figure 9 The daily forecast of generated power using the Random forest method. The blue curve shows the target values and the orange curve illustrates the forecast values.

SVM

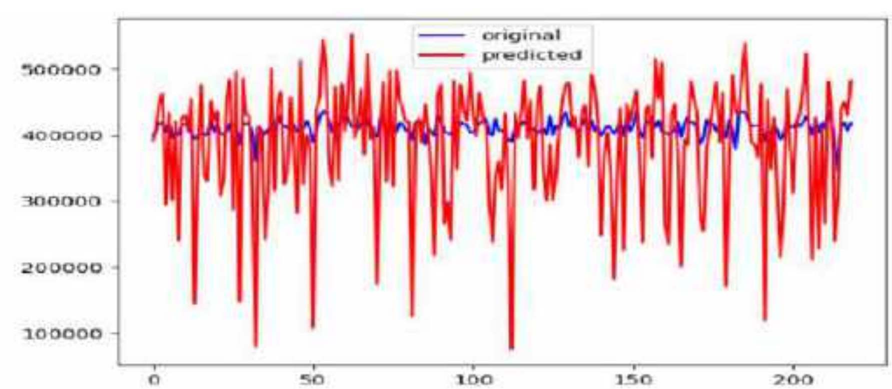

Figure 10 The daily forecast of generated power using the support vector machines method. The blue curve shows the target values and the orange curve illustrates the forecast values.

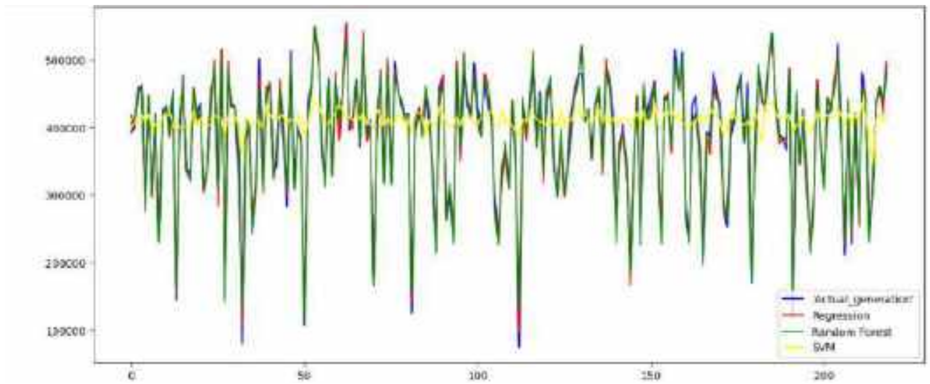

Figure 11 Comparing actual with predicted solar power of regression, random forest and SVM.

Table 3 Performance matrix of MLP RF & SVM

	MSE	RSME	MSLE	MAE	MAPE	MeadianAE	MAXAE	R2	EVS
MLP	1.976983e+08	14060.523845	0.002601	11284.619058	0.034286	10138.726330	39496.024717	0.977604	0.977882
RF	2.111464e+08	14530.875891	0.004375	11007.228904	0.038255	8364.500000	59170.000000	0.976080	0.976180
SVM	8.097092e+09	89983.840498	0.102149	66392.470120	0.262628	50321.353785	315713.499247	0.082713	0.144536

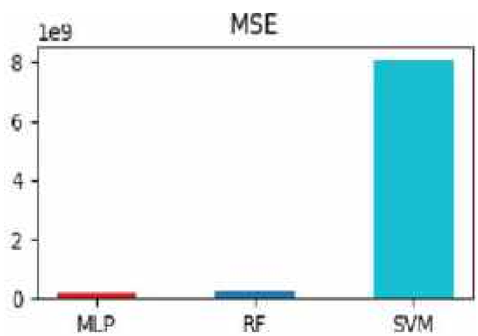

Figure 12 Mean Square Error for RF, MLP & SVM

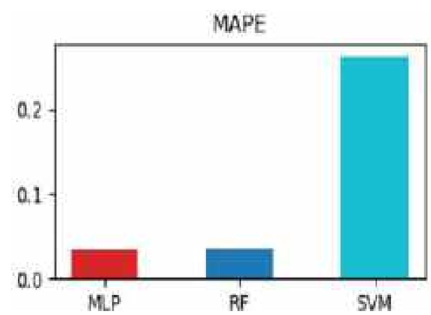

Figure 13 Mean Absolute Percentage Error for RF, MLP & SVM

RESULT & CONCLUSION

In this work, a ML-based numerical weather prediction model was developed based on the actual values of all dominant weather parameters for a 100MW Solar Plant at Thopplakari village of Tamilnadu, India owned by NLC India Limited (A NavRatna , GOI).

From the analysis of data with ML model, it is observed that there is positive correlation between GHI, Ambient temp, and module temperature for power generation. However, there is negative relation with Rainfall. The machine learning based algorithms have been generated based on the actual solar power generated data. Models used in this analysis is very popular Multiple linear regression, Random forest (RF) and support vector machine(SVM). The outcomes of this work could shed light on more efficient methods for essential need of solar power forecasting. The forecast models are used on testing dataset and the obtained forecasted result were compared with the actual to get the error values. Different performance matrix has been compared within all three models and it is found that MLP and Random forest are efficient and accurate compared with support vector machine algorithm. Both MLP and RF are relative same efficient in our test dataset. So, MLP and RF could be used for forecasting of solar generation.

Furthermore, this work can be utilized by utility companies for predicting solar power and balancing the power generation and demand through thermal or other power units.

FUTURE STUDY

Further, more number of metrological parameter shall be drawn for higher accurate analysis and forecasting of power generation in given circumstances.

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Smart Energy Grids-Harnessing Disruptive Technologies for ensuring Quality and Reliable Power for All

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***Abstract**: Electrical power grids, considered to be the largest machines in the world for generating, transmitting and distributing energy spanning over very large areas are now expanding due to a significant rise in the generation of renewable power and an increase in per capita energy demand. This necessitated adoption of the latest technologies to make the grid smart and self reliant.This paper presents a concept notes and components of such smart grids that not only share the responsibility of balancing the increasing share of intermittent generation and the more variable system demand, but also mitigates the risks to system reliability. A case study of dynamic load shedding scheme that is being employed during unintentional islanding of a power distribution grid with a captive generation is also presented. Alternately, Energy storage technologies, such as Pumped storage hydel plants, CAES, electrolysers for generation of green hydrogen and BESS are to become more elastic and less vulnerable to the active power generation and demand scenario. Smart Energy Grids have an inherent potential to improve the power grid resilience, energy independence and reliability, thereby serving reliable and quality power to one and all.*

***Keywords**: Supervisory Control and Data Acquisition (SCADA), Advanced Metering Infrastructure (AMI), Information and Communication Technologies (ICTs), Compressed-Air Energy Storage (CAES), Battery Energy Storage System (BESS)*

INTRODUCTION

The power sector is presently undergoing a significant change that has redefined the outlook for the domestic as well as industrial sectors. Sustained economic growth continues to drive electricity demand throughout the world. As far as India is concerned the GoI's focus on attaining 'Power for all' has accelerated capacity addition in the power distribution of the country[1].

Power outages or black out in power system grids effect, millions of people and cause several economic losses in terms of business and production, resulting in a poor life standard

Modern power system technologies offer integration of renewable energy to grid smart metering by bi-directional energy flow, preventing power outages, sustainability of clean and safe energy as well as energy efficiency. It is imperative that, controllability, measurability and cyber security of the energy at each point of the grid are unavoidable to make the modern power grid system, robust enough against any power, failure, voltage sag, power losses, including illegal usage and voltage frequency, fluctuations, over voltage and over current.

The paper is categorically flowsthroughthe following sections ultimately leading to the methods that can enhance the reliability of the power system in the grid:

Section A deals with the need of a smart grid in the present scenario, wherein, the contrast with the traditional power grid is discussed. While section B details the operating domains of a Smart Grid, section C throw light on the need of energy storage and the dynamic balancing of power generation with the load followed by the challenges in Energy storage. Several disruptive technologies are also discussed in this section.

Section D deals with a case study of an Islanding condition of a micro grid and the dynamic load shedding scheme adopted in the scheme to stabilise the power supply to the loads.

Need of a Smart Grid

The electricity grid in present form or the traditional is unreliable, has high transmission losses, poorpower quality, prone to brownouts and blackouts, supplying inadequate electricity and is discouraging the integration of distributed energy sources.The traditional infrastructure of a power grid for transmission of power generated from the power station to the end users include several power devices such as power, generators, transformers, power, switches, breakers, transmission and distribution lines, utility metres, release, fuses etc. These devices sans communication facilities and provided a unidirectional power flow from the producers to the consumer. If this network is intelligent with automated control and monitoring system to make the system reliable and sustainable, then it might be known as smart grid.

With a significant rise in the generation of renewable power and an increase in per capita energy demand, the power grids have been strengthened, augmented and are ever expanding over the last decade. This necessitated adoption of the latest technologies including SCADA, WAMS, PMUs, Advanced Metering Infrastructure(AMI) managed by GPS and ICTs which made the grid Smart and self-reliant.

Therefore, a multi-dimensionalsetup including energy production with a directional power flow calls for smarter equipment. Integration of the new energy to power grid and so on or the interest of the policymakers in order to balance between energy, production and demand. To understand the design and concept of smart grid, one has to understand the difference with the traditional power grid. A comparison of the traditional grid with that of the smart grid along with other various advancements in the smart grid is illustrated in **Table 1**.

Table 1 Comparison of traditional grid and smart grid

Sl. No.	Comparison		
		Traditional grid	**Smart grid**
1	Information flow	One way communication	2 way communication
2	Power generation	Centralised power generation	Distributed power generation
3	Grid topology	Radial	Network
4	Monitoring	Manual	Self monitoring
5	Metering	Monthly basis	Hourly basis
6	Testing	Manual	Remote
7	Ability to control	Limited	Pervasive
8	Efficiency	Low	High
9.	Outage recovery	Manual restoration	Self-reconfiguration
10	Fault identification/ isolation	Depends on the nature of the fault	Instantaneous monitoring and rectification.

It is also observed that the transmission and distribution losses in the world vary between 5% and 20% depending on the infrastructure of the power grid.[2]

Domains in a Smart Grid

Smart grid may be defined is an intelligent network of electricity that integrates the actions of all stakeholders that are generators consumers and one who does both in order to supply electricity with efficiency, sustainability, economically and securely. Therefore, it can be best understood by the means of dividing the entire network in terms of domains or zones of power distribution. These domains include all the stakeholders that are technical and commercial in nature. The commercial domains namely the power market and its operators, the service providers and the power trading is not elaborated in this paper. The technical domains include the following:

1. Generation domain: the power generation domains form the root of the power system tree. this includes bulk and non-bulk generators, which generate power in various forms, including that from fossil fuels, hydro, wind, solar, etc. while the bulk power generation was handled by the traditional grids in an efficient way, the distributed energy resources have allowed the operators to pump power into the grid as and when it is generated. There for smart grids allow the end users to operate as producers of electric energy for premise, use storage and for resale[4].
2. Transmission domain: The transmission domain is responsible for the transfer of power from the bulk producers to the Distribution system. It typically consists of transmission lines, substations dealing with the EHV network spanning over cross country corridors. This domain is generally monitored and controlled over SCADA and WAMS.
3. Distribution domain: It is the medium that connects transmission domain with the end consumers. This domain may also include the DERs located at customer or at grid operator. In a smart grid, the distribution domain communicates with the market domain due to the market domains potential to affect local power consumption and generation.
4. Consumer domain: The end user who consumes the energy may be private, commercial or industrial in nature. In many cases the consumers install DERs that are exporting the power to the grid, such consumers are called prosumers.

The following illustration explains the domains of the smart grid and their interfacing with the various domains using several type of communication interfaces.

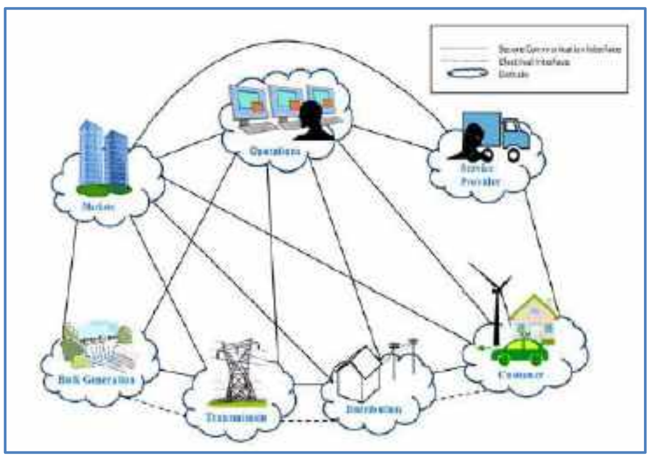

Figure 1 Domains of the smart grid and the communication interface

Smart grid system brings producers network operators and prosumers as well as energy policy makers on the same platform and Information exchange is of utmost importance for the smart grid to provide reliable power generation and distribution to the respective consumers[5].

An essential feature of the smart grid is the information flow over high speed, reliable and secure data communication networks, which also manage the complex power systems effectively and intelligently. This includes communication requirements, physical layer, technologies, network architecture, and the inbuilt installation challenges[6-9].

It has created a need for both international as well as national organisations to develop roadmaps at the same time, define standards and definitions to make the power grid Smart[10-15].

Need of Energy Storage and Disruptive Technologies

The intensive use of fossil fuels and other limited resources has led to several negative impacts, especially on the impact that it is creating on the climate change. This has resulted in the need for a more sustainable energy supply and has become one of the biggest challenges facing humankind. **Figure 2** depicts the electricity generation mix and the targets taken by several nations in order to meet the net-zero emissions[16].

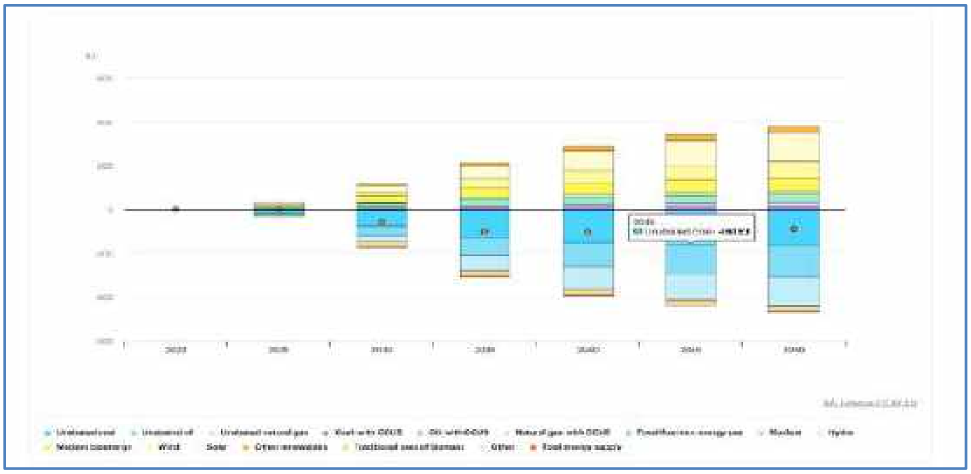

Figure 2 Energy mix for the net zero targets by 2050

Renewable energy supply is an important step in reducing the carbon footprint and mitigating climate change and the consequences caused by the phenomenon. Renewable energy production is just one side of the coin with the other side being that ithas to be transmitted over long distances from/to remote areas for utility.

The other challenge posed by renewable energy sources is their intermittency-not available around the clock. Moreover, renewable electricity generation does not always align with peak demand hours, causing grid stress due to fluctuations and power peaks. Unpredictable weather events can disrupt these technologies.

Renewable energy sources, such as solar and wind power, can be unpredictable and generate surplus energy. Efficient storage systems are needed to store excess energy during low demand and release it when demand is high. Sustainability is a crucial factor for economic growth, and it will continue to be an important consideration in the future.

Demand for clean energy drives sustainable technology development that will impact future energy and the environment.Stationary energy storage is essential in transitioning to a sustainable energy paradigm with greater participation of renewable energy.

The above information and figures put forward the importance of implementation of smart grid applications in the ever-increasing power system grids so that the different sources of renewable energies that are being put for the production of electricity maybe integrated seamlessly.

Several challengesare to be addressed for integrating renewable energy into the power system grid which include the power quality, i.e., the voltage and frequency, deviations that occur due to their intermittency, the instability of energy generation, the variation of power generation, including the speed of the variation.

An umpteen number of researchers have been publishing their research work in order to integrate the renewables into this market system. This includes novel intelligent approach for your position forecasting in wind energy systems[17], floating solar power in industrial reservoirs[18], Photovoltaic maximum power point tracking under quick varying of solar radiation[19] and a survey on the critical issues in smart technologies[20].Increasing amount of distributed renewable energy sources and energy storage systems require new ways of managing and controlling the power grid, distributing the power in a more efficient, effective, environmentally, sustainable and economical manner.

Disruptive Technologies

Energy storage systems shall not only be efficient but also optimised to ensure grid stability and on-demand availability, preventing blackouts. Energy storage provides flexibility and opportunities for multi-desciplinary technologies, including electro-mechanical, chemical, thermal, and electrochemical (batteries). A few of the disruptive technologies is discussed here.

a. Green hydrogen- “Green Hydrogen” is defined as “Hydrogen made by splitting up of water(H_2O) using renewable electricity”[21]. Green hydrogen is a fast-growing economy sector and is one of best choice for the future energy market, both as energy storage media, energy vector and fuel for transportation, industry and other applications.
b. Pumped storage hydel plants: Hydro power is not only a renewable and sustainable energy source, but its flexibility and the potential to store the energy also make it possible to improve grid stability and complement the major intermittent renewable energy sources such as wind and solar. Therefore, itbecomes an advantageous asset to introduce pumped storage in the vicinity of large solar or wind farms so that they can be operated in a coordinated manner [22-26]. For these reasons, energy storage systems which are able to recover the rejected wind energy under economically effective terms are widely applied, achieving maximum exploitation of wind energy at both national and community levelapplications.
c. Compressed Air Energy storage: On a utility scale, compressed air energy storage (CAES) is one of the technologies with the highest economic feasibility which may contribute to creating a flexible energy system with a better utilization of fluctuating renewable energy sources [27]. CAES can be considered as the gas version of the the pumped storage plants discussed above. Here,the greenpower is used for storing compressed air in an underground cavern. The air is then heated and expanded in a gas turbine in order to produce electricity during peak demand hours. As it derives from GT technology, CAES is readily available and reliable[28]. Two plants have been constructed in the world so far; one in Germany and one in the USA of 390 MW and 110 MW turbine capacities, respectively.
d. Battery Energy storage system (BESS): Inline with the growing focus on renewable energy sources, BESS technologies were the obvious and rescuing avenues of energy storage. They not only complement the intermittent generation but can also serve the smart grids in their sustenance. It is not abstract to consider the Electric vehicles(EVs)connected to the grid with smart chargers can boost the voltage stability of the grid exponentially. Improved energy density, cycle life, and safety have made batteries more efficient and reliable, while lower costs have made them more accessible[29].

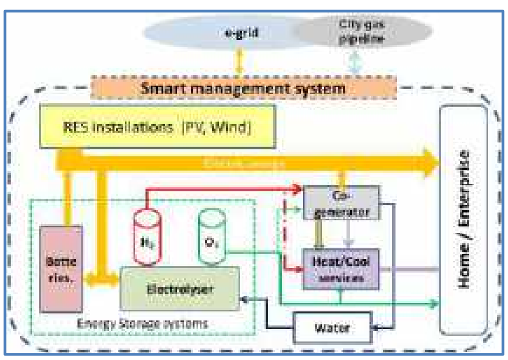

Figure 3 Amalgamation of several disruptive technologies for energy storage

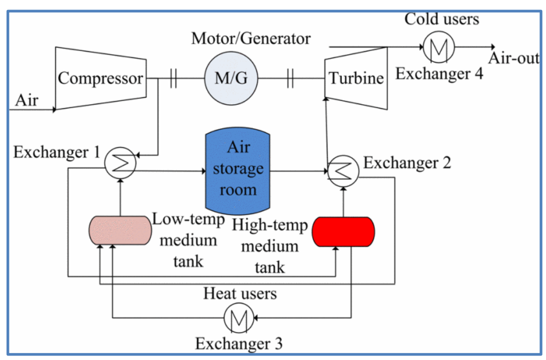

Figure 4 A typical scheme of CAES

Case Study of Dynamic Load Shedding Scheme

The paper presents a dynamic load shedding scheme implemented in an Industry with captive generation. In case of a system disturbance in the grid, Islanding of the power plant system from the Grid along with its connected loads is generally done by an Islanding panel based on the contingency detected by protective relays(Table II) and the power generation in the power plant. These settings are generally dependent on the grid stability and the quality of power supplied by the utility. However, the same may be fine-tuned for initialising the load shedding scheme based on the priority table programmed in the load shedding panel.

Table 2 Typical Grid Disturbance Conditions

Sl no.	Parameter	Settings
1	Under Frequency with time delay	48.5Hz + 0.3 sec
2	Negative rate of change of frequency(ROCOF) (-df/dt)	49 Hz + 1Hz/sec
3	Over Frequency with time delay	51.5Hz + 0.3 sec
4	POCOF (+df/dt)	51 Hz + 1Hz/sec
5	Directional Over current(DOC) +Under-voltage + time delay	10%(DOC)+85%(u/v)+ 100ms Td
6	DOC+Under-voltage + Negative rate of change of voltage (-dv/dt)	10%(DOC)+85%(u/v)+ 1.1kV/s (dv/dt)

Depending on the power distribution network and the available power at the instant of the islanding, the selection of the islanding breakers can be done from the Islanding panel. In any case of islanding, on restoration of grid supply, the same breaker that was used for islanding shall be used for synchronising the respective sections.

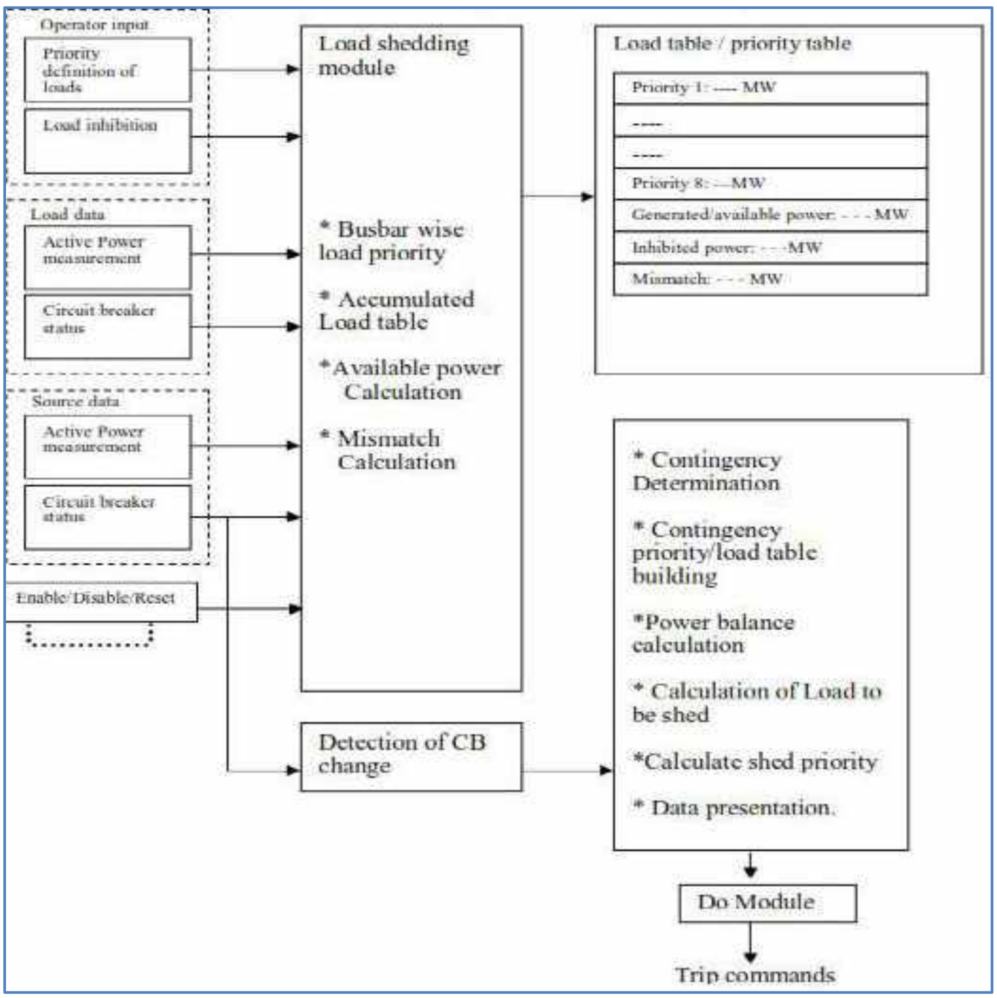

Figure 4 Block diagram of dynamic load shedding scheme

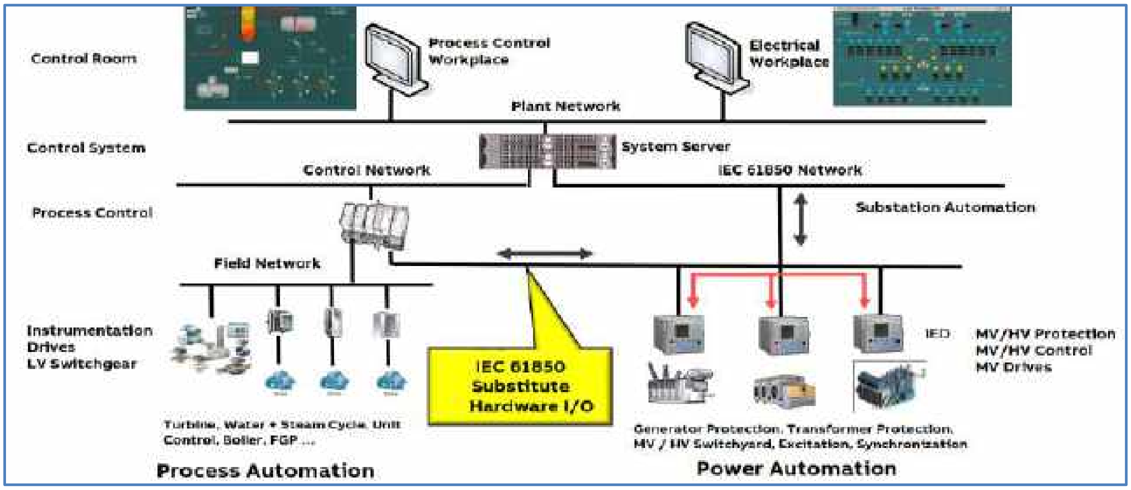

Figure 5 A typical Electrical SCADA architecture

The load shedding shall takeplace in such a way that the system voltage and frequency remain within limits throughout the process.The dynamic load shedding application shall determine all possible islands which may arise dueto breaker trips and shall try to save the island from collapsing due to power deficiency or generationdeficiency by shedding appropriate amount of load while taking into account the machine dynamics.Fast Load shedding scheme is triggered by opening up of any of the critical breaker, which cause the Loadshedding scheme to carry out Power

Balance calculation [**Figure 5**]. In order to implement the scheme, the interplant electrical SCADA architecture [**Figure 6**] is employed as a backbone for communication of the load shedding system. Formulating a load shedding scheme includes several steps:

Step1. Maximizing the Anticipated Overload

Although the selection of the maximum anticipated overloadvalue is completely arbitrary for the stability analysis ofindustrial customers, it is the most important factor in thedecision of the load-shedding scheme, since all the other stepswill be affected greatly with this overload value determination.A well-planned load-shedding scheme should be capable ofhandling the frequency decline for the maximum anticipatedoverload, to avoid a power system blackout. Of course, thescheme should also be able to keep the isolated system instable operation for any load-flow condition, after the tie line has been tripped.

Step 2. Preparing the load priority table

Automation based load shedding scheme ensures that the load to be tripped should be large enoughto compensate for the maximum anticipated overload at oneload-shedding step. Nevertheless, more load than necessarymay be disconnected for less severe overload by this strategy.On the other hand, it may result in a coordination problemamong protective relays if too many load-shedding steps areinvolved. For this reason, a typical priority table is prepared in order to achieve the fast and dynamic load shedding scheme.

Step 3. Stability analysis post load shedding

The system stability is judged by the ability ofthe generators to maintain synchronism during and / or after afaulted condition on the system [30]. The loss ofsynchronism is an undesirable outcome owing to threats thatcome with out-of-step operation.The generation and load mismatch during the faultcondition initiate transients that cause the rotor to swing,because of the acceleration or braking torque applied on therotor [31]. In the perturbations, the breaker trippingoperations clear faults and isolate the faulted section of thesystem.

It is quintessential that the parameters like active and reactive power of the generators, excitation voltage, rotor angle of the generator, speed and phase currents are to be studied post-islanding[32].

A floating based solar power generation in the in the industrial reservoir shall augment to the power generation during the daytime[33].

The Power in the case study is primarily received from the utility at 220kV and stepped down to 33 kV at a Main receiving Substation. Power to the above shops is distributed at 33kV to each of the Load Block Distribution Station (LBDS).The 33kV Double bus system at the Power plantfacilitates to distribute the generated power to the various connected loads of the LBDS PP with minimum Power import/ export through the Tielines and serves to easily island the Power plant from the Grid with minimum disturbances to the connected load and thereby making it a self-sustainablemicro-grid.

CONCLUSION

It is to be understood that implementation of smart grid over the large power distribution network is an evolutionary process and it has begun with a noticeable recognition. The paper not only focused on the present status of the implementation of smart grid power distribution networks, but also have highlighted the challenges posed by connecting the DERs to the grid. In order to overcome the intermittency of renewable power generation, it is recommended that energy be stored various techno-economically feasible disruptive technologies like Electrolysers, CAES, BESS, PHES, etc.With such energy storage facilities coupled with the dynamic load shedding scheme, the smartgrids can function reliably and efficiently, thereby ensuring quality Power for all.

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Thermal Management of Lithium-ion Battery for Electric Vehicles

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Abstract: Most electric vehicles use lithium-ion batteries as their main form of energy storage. For these batteries to be safe, function at their best, and last a long time, effective temperature control is necessary in EVs. Lithium-ion batteries are sensitive to temperature changes, and if these changes are not properly handled, they can cause problems including overheating, decreased efficiency, and even safety threats. The objective of this study is to determine whether a cooling technique for lithium-ion batteries used in electric vehicles is effective. It underlines how important it is to keep the battery's temperature within a particular range, usually between 15°C and 35°C, in order to minimize capacity loss and lengthen the battery's lifespan. This literature finds something for cooling a battery with a minichannel cold plate. The minichannel design provides efficient heat dissipation from the battery cells and it allows for precise thermal control. Minichannel cold plates possess a compact design with multiple small channels, usually at a millimetre scale. Their small dimensions and increased surface area facilitate efficient heat exchange between the cooling fluid and battery surface. It efficiently absorbs heat generated during battery operation and releases it, preventing the battery from reaching undesirable temperature levels. The research also emphasizes the significance of maximizing the coolant-battery stack contact area for the best liquid cooling system performance. Greater flow rates are needed to ensure effective cooling at larger battery discharge rates, although there are certain restrictions because of how effectively the cooling system works. Overall, the study emphasizes the benefits of using a liquid cooling system to effectively regulate temperature and dissipate heat in battery stacks for electric vehicles.

Keywords: Thermal management, liquid cooling, heat transfer, Minichannel cold plate.

INTRODUCTION

Electric vehicles (EVs) have rapidly developed in response to energy shortages and environmental concerns [1]. The lithium-ion battery has become quite well-liked in the EV industry because of its great energy efficiency and environmental friendliness [2]. However, temperature changes have a big impact on how well lithium-ion batteries work. When there are quick cycles of charging and draining, heat is generated through chemical reactions, and the confined space within the battery can lead to heat buildup, potentially causing overheating, combustion, and even explosions [3]. Temperature also significantly affects battery lifespan, efficiency, and safety. Because of this, EVs must have a reliable Thermal Management System.

The operational temperature range for EV battery systems typically spans from -40°C to 60°C [5]. However, to achieve optimal performance, EV batteries are ideally operated within the range of 15°C to 35°C [4,5]. Outside of the ideally operated range, Battery thermal performance suffers, leading to significant capacity reduction and life span reduction. According to estimates, Battery's life span is reduced by 2 months for every degree that the temperature increases. Additionally, a battery pack's internal temperature difference shouldn't go over 5°C [5].

In order to be effective, thermal management of batteries for EVs must satisfy a number of key requirements, including the following: (1) great chilling efficiency; (2) a consistent thermal spread; and (3) a small, lightweight design. Heat production inside the battery becomes a major problem as EV battery capacity rises to boost driving ranges. This is particularly true during quick charging cycles, in which the heat production rates sharply rise as the charging or discharging currents [6]. Consequently, high cooling performance is essential for enabling fast charging of large-capacity EVs. Temperature uniformity is equally crucial as non-uniform temperatures lead to inefficient energy utilization, and uneven battery degradation includes the possibility of a heated overrun [7]. Furthermore, the size and weight of the Thermal Management Systems must be considered, as bulky and heavy battery packs negatively impact overall battery capacity and driving range. As a result, Thermal Management System architectures that are small and light are crucial for EV applications.

Air cooling is a simple way to cool battery packs, however, due to air's poor thermal capacity and conductivity, it is not suited for big-capacity battery packs. In contrast, the liquid cooling system, which offers a small design and increased capacity to cool, is widely recognized as a promising and useful cooling method [8]. Thermal management systems for liquid cooling are seen in commercial cars such as the Toyota iQ, BMW i3, Jaguar Pace, Tesla Model S, and Model X.

It is incredible how well this cooling method keeps the battery operating within the crucial temperature ranges needed for both safety and optimum performance. Furthermore, it significantly lengthens the battery's working life by minimizing temperature changes that may lead to a reduction in capacity. The usage of a U-type minichannel within a cold plate is a very efficient way for temperature control in the battery thermal management system, notably in electric vehicles and other applications where lithium-ion batteries are frequently utilized [29].

HEAT GENERATION

Among the main events that happen inside the battery pack while it is operating is, encompassing processes like charge transport, chemical reactions, and discharge, is the generation of heat. This heat generation stems from chemical reactions and can be categorized into two types: reversible and irreversible [9]. Higher charging or discharging rates lead to elevated current flow, resulting in increased power dissipation and raising the temperature. The initial battery modeling to comprehend its thermal behaviour was conducted by Bernardi and his team [11]. Mathematically, the heat produced by a battery is represented by the mix of heat components that are both irreversible and reversible [12,13].

$$\begin{gathered} Q_{tot} = Q_{irr} + Q_{rev} \\ Q_{tot} = I^2R + I\left(T\frac{\partial U}{\partial T}\right) \# \end{gathered} \tag{1}$$

These equations' T, I, U, and V values respectively, stand for the cell's temperature current open-circuit voltage and terminal voltage. The rate of irreversible heat production caused by the potentiated cell's deviance from their state of equilibrium is expressed by the initial part. The cell's shifting entropy as an outcome of the intercalation and deintercalation of lithium is represented by the second part, which indicates the rate of reversible heat production [14]. This part also contains the entropic heat factor.

Thermal Runaway

The thermal management system's main purpose is to guarantee a battery's secure operation in a variety of working circumstances. A variety of factors, including the composition of the cell [17,18], operational parameters, initial states [15,16], and overloading situations influence the battery's safety. Lithium-ion batteries perform under demanding circumstances, they trigger multiple internal chemical reactions, generating a significant amount of heat rapidly, thus leading to a thermal runaway [19]. This sudden release of excessive heat and gases culminates in the ignition and detonation of the battery [20]. The temperature at the battery cell's core is frequently the highest because heat there is concentrated in a compact area and might bring up an inner short circuit. When the current density is high, the battery's dual electrodes come into touch via another one, which is the main cause for this phenomenon.

The current temperatures and density rise fast in a short area, which might cause exothermic processes on their own. As a result, the electrolyte deteriorates and the conditions for thermal runaway are established [21].

When its temperature rises over the normal operating range, several complex electrochemical reaction events occur at once**. Figure 1** serves to explain this. gives a general summary of the systems' thermal runaway process. Beyond an 80°C threshold, the process begins with the dissolution of the solid-electrolyte interphase (SEI), which is followed by exothermic interactions between the anode and electrolyte as well as between the anode components and the binder. Along with it, the separator melts, the electrolyte disintegrates, and interactions between the electrolyte and cathode material take place [10].

Figure 1 Thermal runaway process.

Liquid Cooling System

Direct cooling and Indirect cooling techniques are two categories for liquid cooling. Indirect cooling circulates the fluid within the vicinity of the battery packs or cold plates, as opposed to direct cooling, which entails submerging the battery pack in flowing dielectric coolants such as oil [23,24]. Through the use of a radiator fan, this liquid distributes the heat it collects from the battery into the surroundings. As it operates indirectly, this cooling method relies on the principle of conduction. Various liquid cooling mediums include glycol, water, or other dielectric coolant forms. These liquid fluids function as a form of cooling effectively through to their excellent thermal conductivity & absorption. [25]. In Reference [22], a liquid-based cooling model utilizing small-sized channels was employed, showcasing consistent temperature maintenance below 40°C.

When contrasting the efficiency of direct and indirect cooling for cooling, it becomes evident that direct cooling exhibits a greater heat transfer rate because it has a propensity to absorb heat through direct contact between the battery pack and the coolant. However, it's worth noting that when high-viscosity coolants like oil are utilized, direct cooling demands more power, especially if an elevated force velocity is used.

Liquid-cooled technologies are more often employed in real-life situations due to their better performance and simplicity [26]. Because of its exceptional capacity for heat and transfer of heat coefficients, liquid is an excellent choice for Thermal Management Systems for batteries in electric vehicles [27].

To track temperature changes in simulations run at various flow rates, Bhattacharjee et al. [21] created a thermal simulation for batteries. The indirect water-cooling system's coolant passes via tubes between the battery cells. A 2C output steady rate was taken into consideration, and fluid velocities varied from 0 to 1 m/s. As the velocity of flow increases, more coolant flows at once, improving heat dissipation and reduced temperature.

Different modified pack designs were introduced by Yoong et al. [6] with the goal of improving cooling performance. These include four distinct pack designs: the reference design (A) in **Figure 2(a)**, the thicker cooling fin design (B), the sandwich-type cooling plate design (C) in Figure 2(b), and the interleaved cooling plate design (D) in Figure 2(c). Using thicker metal fins, as shown in Type B, is a simple method to increase cooling performance. While Type B's cooling fins are twice as thick, its geometric layout nearly approaches that of the reference model. As shown in **Figure 2(c)** in Type C, a battery pack with a sandwich-like structure, and cooling plates can also be added to the top and bottom edges of the battery stack.

(a) (b) (c)

Figure 2 (a) reference battery pack design (b) type-C battery pack and (c) type-D battery pack [6].

However, Type C has drawbacks, such as greater system pressure loss, weight, and potential leak vulnerability because of the coolant channel's upper placement. Type D, the interleaved design, was created to lessen these problems. The battery stack is split in half and positioned vertically in this arrangement. Vertically cooling plates along with small battery packs are alternately positioned such that heat is transferred to the coolant channels from the opposite sides of the cooling plates. Overall, this configuration employs fewer cooling plates. After comparison testing, type D displays the most effective cooling capability in terms of the battery pack's dimensions and weight. It displays a 38% increase in the equivalent heat conductance to volume ratio and a decrease in the maximum temperature differential compared to the reference model.

The U-type minichannel incorporated into the cold plate is another liquid cooling technique. It functions by enabling a liquid coolant with thermal conductivity to travel through this U-shaped tube. Through this tube, the coolant circulates, absorbing and efficiently distributing the battery's heat production. In order to properly prevent overheating and keep the battery's temperature between the appropriate ranges, this method is crucial. According to Shen et al. [28], the design with eight channels that are all on the same side offers optimal cooling efficiency. At a discharge rate of 2 C and an initial coolant temperature of 30°C, the cell with this minichannel cold plate has a maximum temperature & temperature difference of 33.9°C and 3.4°C, respectively.

CONCLUSION

Different cooling strategies were looked at in this study to improve how well lithium-ion batteries performed at high temperatures. With its enhanced heat capacity and superior thermal conductivity, liquid cooling proves to be an extremely effective cooling technique. In this procedure, a liquid act as a coolant to remove heat from the battery. These systems offer effective heat dissipation, increasing battery performance, lifespan, and safety.

In this liquid cooling method, it has displayed promising outcomes, liquid cooling exhibits notably superior performance. The most effective method in order to maintain battery temperatures within the acceptable range is liquid cooling. It may be carried out in an indirect manner by circulating a water-based solution through pipes or cold plates.

The battery's lifespan might be greatly increased using this method for long-term use. It enhances the long-term life of Li-ion batteries and efficiently distributes heat. Liquid cooling is a vital technology for the future of energy storage and transportation as the need for high-capacity Li-ion batteries in uses like electric cars increases the need for effective thermal control.

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A Study and Simulation of Fault Detection & Classification in Power System Model using Artificial Neural Network Based BP Algorithm

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Abstract: *The reliable and efficient operation of power systems is of paramount importance for ensuring the stability and continuity of electrical supply. Power system faults can lead to widespread disruptions, economic losses, and even compromise public safety. This study presents a comprehensive investigation into fault detection and classification in power systems using an Artificial Neural Network (ANN) based on the Back propagation (BP) algorithm. The research begins with a thorough analysis of power system faults, encompassing various fault types, including short-circuits, line faults, and equipment failures. Real-world data is used to simulate these faults in a digital power system model, creating a robust testing environment for the ANN-based fault detection and classification system.*

The core of this study is the development and implementation of an ANN, trained using the BP algorithm, for fault detection and classification. The ANN is trained on a diverse dataset of fault scenarios, with an emphasis on generalization and adaptability to different power system configurations. The model aims to identify the presence of a fault and, if detected, classify the fault type accurately. Simulation results are presented, demonstrating the efficacy of the developed ANN-based system in accurately detecting and classifying power system faults. The performance metrics such as accuracy, sensitivity, specificity, and F1-score are reported, showcasing the reliability and precision of the proposed method. Additionally, the study explores the impact of various network architectures and training parameters on the system's performance.

Keywords: *Power system faults; Fault detection; Fault classification; Artificial Neural Network; Back propagation algorithm Simulation; Resilient power systems*

INTRODUCTION

Power systems, often referred to as electrical grids, are intricate networks responsible for generating, transmitting, and distributing electrical energy to meet the demands of our modern society. These systems are designed to operate with high efficiency and reliability, but they are not immune to disruptions and anomalies. Among the various challenges power systems face, faults are a significant concern.

Causes of Power System Faults

The causes of faults are numerous, e.g.

- Equipment Failures
- Lightning
- Environmental Factors
- Weather-Related Faults
- Vegetation

- Human Error
- Operational Errors
- Unauthorized Access
- Aging Infrastructure
- Overloads
- Switching and Transients
- Interconnected Systems
- Animal Interference
- Corrosion and Contamination
- Generator and Motor Faults
- Frequency Deviations

Common Power System Faults

According to their frequency of occurrence, the four types of power system problems are as follows,

- Single line to ground fault
- Line to line fault
- Double line to ground fault
- Balanced three phase fault

The first three types are known as unsymmetrical faults because they involve only one or two phases and have severe imbalanced operating circumstances. The fourth type is known as a symmetrical (balanced) defect because it involves all three phases when it occurs.

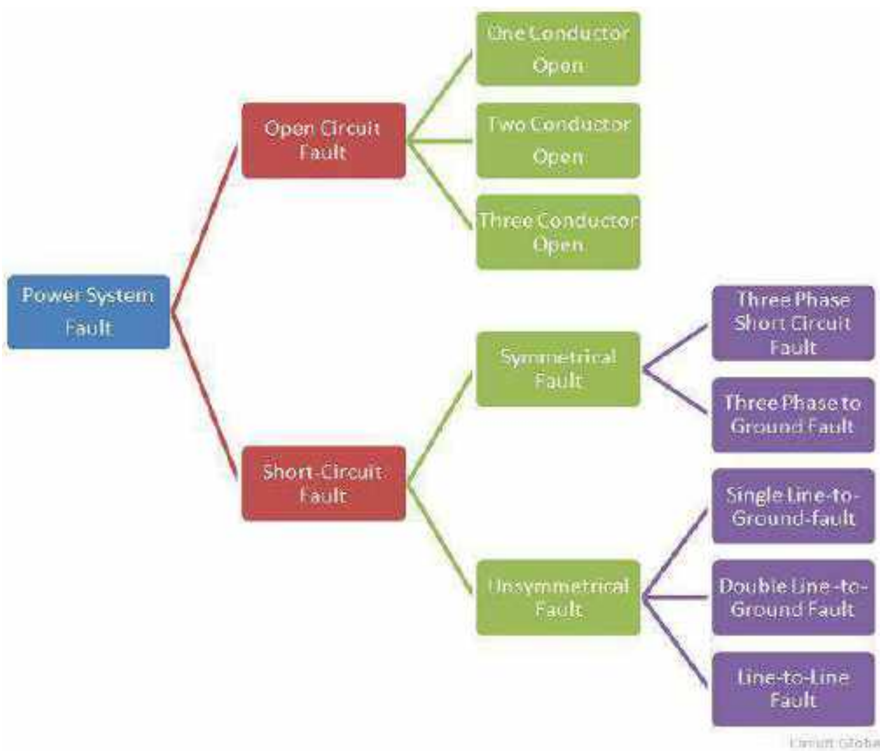

Figure 1 Power system faults classification

Effects of Electrical Faults

Electrical faults can result from a variety of causes and have diverse effects, ranging from minor inconveniences to severe damage and safety hazards. Understanding the causes and effects of electrical faults is essential for maintaining safe and reliable electrical systems. Here are some of the common effects of electrical faults:

Power Interruptions

Electrical faults can cause momentary or prolonged power interruptions, leading to inconvenience and potential financial losses for homes, businesses, and industries.

Equipment Damage

Faults, especially short circuits and arcing faults, can damage electrical equipment, including transformers, circuit breakers, motors, and electronic devices.

Safety Hazards

Electrical faults, particularly ground faults and arcing faults, can pose significant safety hazards, leading to electrical shocks and fire risks.

Voltage and Current Fluctuations

Electrical faults, including transient faults and harmonics, can lead to voltage sags, swells, and fluctuations that may disrupt sensitive electronic equipment.

Energy Inefficiencies

Faults like phase imbalances and harmonics can lead to energy inefficiencies, causing equipment to operate less effectively and increasing energy costs.

Environmental Impact

Electrical faults can result in equipment failures and oil leaks from transformers, potentially harming the environment.

Loss of Data

Electrical faults can disrupt data centers and communication systems, leading to data loss and network interruptions.

MACHINE LEARNING BASED FAULT DETECTION AND CLASSIFICATION

In today's complex and technologically driven world, machinery and industrial systems play a vital role in various sectors, from manufacturing to energy production. Ensuring the reliable and uninterrupted operation of these systems is of utmost importance, as any faults or malfunctions can lead to costly downtime, equipment damage, and even safety hazards. In response to this challenge, the integration of machine learning techniques for fault detection and classification has emerged as a powerful and transformative solution.

Machine learning, a subset of artificial intelligence, has revolutionized the way we handle data and automation. It allows systems to learn patterns and make intelligent decisions based on data, all without explicit programming. When applied to the field of fault detection and classification, machine learning offers a data-driven, adaptive approach to identify and categorize anomalies in machinery and industrial processes.

The primary objective of machine learning-based fault detection and classification is to develop algorithms and models that can autonomously identify deviations from normal system behavior, characterize the nature of these deviations, and initiate appropriate responses, such as alerting maintenance personnel or triggering automatic corrective actions. This approach provides a significant advantage over traditional rule-based systems, as machine learning can handle complex, nonlinear relationships and adapt to evolving operating conditions.

The process typically involves the following key steps:

Data Acquisition:

Collecting data from sensors, monitoring systems, or other sources to create a dataset that includes both normal and fault conditions.

Data Preprocessing:

Cleaning, filtering, and preparing the data to ensure it is suitable for machine learning algorithms.

Feature Extraction:

Identifying relevant features or attributes from the data that are indicative of system behavior.

Model Training:

Using historical data, machine learning algorithms are trained to recognize patterns and anomalies. Common algorithms include neural networks, decision trees, support vector machines, and more.

Fault Detection:

Once trained, the model can be applied to real-time data streams to detect deviations from the norm. It can identify the presence of faults or anomalies.

Fault Classification:

Beyond detection, machine learning models can also classify the type or category of the detected fault, providing insights into the root cause.

Decision-Making:

Based on the identified fault and its severity, appropriate actions or alerts can be initiated, such as scheduling maintenance, adjusting operating parameters, or shutting down the system to prevent further damage.

Machine learning-based fault detection and classification have found applications in various domains, including manufacturing, predictive maintenance, energy distribution, and transportation systems. These techniques not only enhance the reliability and efficiency of industrial processes but also contribute to cost savings and safety improvements.

This approach represents a synergy between advanced data analytics and industrial automation, promising a future where machinery and systems can self-diagnose and respond to faults in real time. As machine learning algorithms continue to evolve and mature, they will play an increasingly pivotal role in ensuring the continued and seamless operation of critical infrastructure and industrial processes.

Statistical Techniques

Statistical techniques are a fundamental component of machine learning-based fault detection and classification. These techniques play a crucial role in data analysis, feature extraction, model training, and result interpretation.

- Descriptive Statistics
- Feature Engineering
- Probability Distributions
- Hypothesis Testing
- Statistical Process Control (SPC)
- Bayesian Statistics
- Regression Analysis
- Clustering Analysis
- Time Series Analysis
- Outlier Detection
- Confidence Intervals

These statistical techniques are integrated into the machine learning process, from data preprocessing and feature engineering to model training, validation, and interpretation of results. Combining statistical rigor with machine learning algorithms enables the development of robust fault detection and classification systems that can operate effectively in diverse industrial contexts

Categories of Machine Learning

Machine learning, a subset of artificial intelligence, encompasses various approaches and techniques for teaching machines to learn from data and make predictions or decisions. Machine learning can be broadly categorized into three main types, each with its own set of techniques and applications

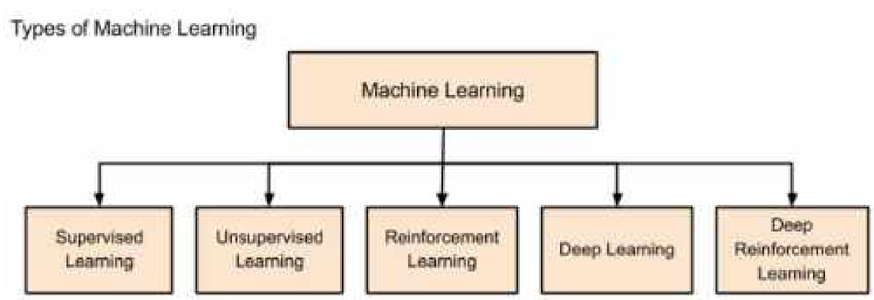

Figure 2 Types of Machine Learning

Supervised Learning

In supervised learning, the model is trained on a labeled dataset, where each data point is associated with a target or outcome variable. The model learns to make predictions or classifications based on input features by finding patterns in the labeled data.

Examples: Classification (e.g., email spam detection, image recognition) and regression (e.g., predicting house prices, stock market trends) are common applications of supervised learning.

Algorithms: Common supervised learning algorithms include linear regression, logistic regression, decision trees, random forests, support vector machines, and various types of neural networks.

Unsupervised Learning

Unsupervised learning deals with unlabeled data, where the algorithm's task is to discover patterns, structures, or relationships in the data without guidance from labeled outcomes. It is often used for data exploration and dimensionality reduction.

Examples: Clustering (e.g., customer segmentation, document grouping) and dimensionality reduction (e.g., principal component analysis, t-distributed stochastic neighbor embedding) are common applications of unsupervised learning.

Algorithms: Unsupervised learning algorithms include k-means clustering, hierarchical clustering, and various probabilistic models.

Reinforcement Learning

Reinforcement learning involves training an agent to interact with an environment, learn from the consequences of its actions, and make decisions to maximize a cumulative reward. It's particularly well-suited for tasks that involve sequential decision-making.

Examples: Reinforcement learning is applied in robotics, game playing (e.g., AlphaGo), autonomous vehicles, and recommendation systems.

Algorithms: Reinforcement learning algorithms include Q-learning, deep Q-networks (DQN), policy gradients, and actor-critic methods.

These categories of machine learning are not mutually exclusive, and many real-world applications involve a combination of these techniques. Additionally, there are specialized areas and techniques that fall under the umbrella of machine learning, including:

Deep Learning

Deep learning is a subset of machine learning that focuses on neural networks with multiple layers (deep neural networks). It has achieved remarkable success in various domains, including image recognition, natural language processing, and speech recognition.

Machine learning is a dynamic field with ongoing research and development, continually expanding the boundaries of what can be achieved with data-driven models. The choice of which type of machine learning to apply depends on the specific problem and the nature of the available data.

ARTIFICIAL NEURAL NETWORKS

Artificial Neural Networks (ANNs), often referred to simply as neural networks, are a subset of machine learning models inspired by the structure and function of the human brain. They are a powerful class of algorithms used for a wide range of tasks, including pattern recognition, classification, regression, and decision-making. ANNs consist of interconnected processing units called neurons or nodes, organized into layers. Here's an overview of artificial neural networks. In the diagram below, one such typical architecture is displayed here.

1. Neurons and Layers:

ANNs are composed of interconnected artificial neurons. These neurons are organized into layers, typically consisting of an input layer, one or more hidden layers, and an output layer. Input neurons receive data or features, hidden neurons process the data, and output neurons produce the final results.

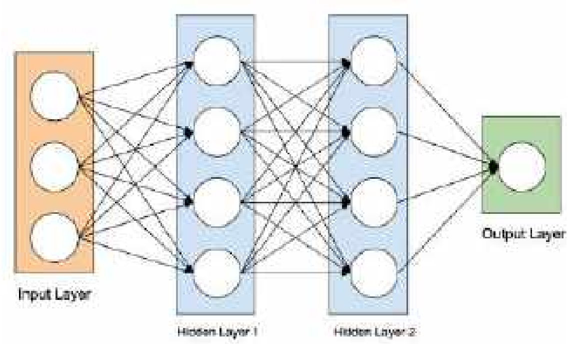

Figure 3 Structure diagram of ANN

2. Neuron Activation:

Each neuron in an ANN applies an activation function to the weighted sum of its inputs. Common activation functions include sigmoid, ReLU (Rectified Linear Unit), and hyperbolic tangent (tanh).The activation function introduces non-linearity, enabling ANNs to model complex relationships in data.

3. Feed forward Propagation:

During feed forward propagation, data or input features are passed through the network, layer by layer, from the input layer to the output layer. Neurons in each layer perform their computations and pass the results to the next layer.

4. Weights and Biases:

The connections between neurons have associated weights and biases. These weights are adjusted during training to allow the network to learn patterns and relationships in the data. The biases shift the activation function's output, enabling neurons to capture variations in data.

5. Learning and Training:

Training an ANN involves adjusting the weights and biases to minimize the difference between the model's predictions and the actual target values (labels) in a labeled dataset.

Common training algorithms include gradient descent and back propagation, which update the model parameters iteratively based on the gradient of the loss function.

Various types of neural networks have been developed for specific tasks, including:

- Feed forward Neural Networks (FNNs): Basic feed forward networks for regression and classification.
- Convolutional Neural Networks (CNNs): Suited for image and spatial data.
- Recurrent Neural Networks (RNNs): Designed for sequential data, such as time series and natural language.
- Long Short-Term Memory (LSTM) networks: A type of RNN for handling long-range dependencies.
- Gated Recurrent Unit (GRU) networks: Another variant of RNNs.
- Radial Basis Function (RBF) networks: Used for function approximation and clustering.
- Self-Organizing Maps (SOMs): Unsupervised learning for dimensionality reduction and clustering.

EXISTING AND PROPOSED SYSTEM

Existing method drawback

- Overall system stability is less when compare to proposed system.
- More noise.
- More Power consumption
- Less Learning Efficiency
- Slow convergence rate
- Reliability is less when compared to proposed system

Existing system blockdiagram and description

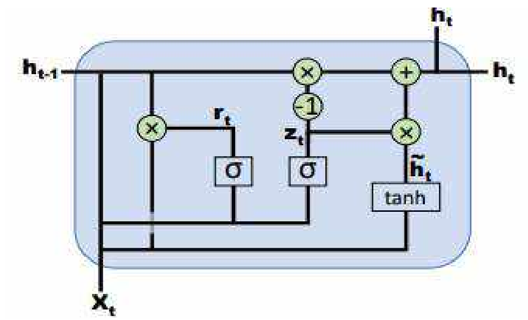

Figure 4 Block Diagram of GRU

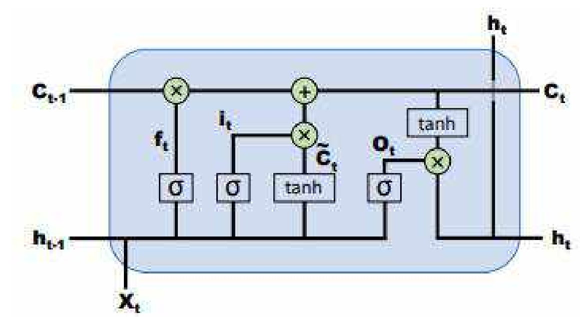

Figure 5 Block Diagram of LSTM

- The input for LSTM and GRU based Algorithm is more complicated because it needs to take time-series data into account. The input vector for the LSTM and GRU models is a 3-D vector with 24 layers, where the number of layers corresponds to the number of variables (in this case, 8 busbars 3 phases), and the no of rows and columns corresponds to the time-step (in this case, 5). There are 450,000 samples total in the LSTM and GRU models. A time-series is created with relation to each row of the input vector by the values of the line voltages at the current sample-step plus four prior samples.
- As a result, the input vector's size is 450,000×5×24. It's important to remember that 80% of the data is used for training and 20% is used for testing. Input vector size for LSTM/GRU model training is 360,000×5×24.
- The network is generated by four RNN layers, each of which has 50 LSTM/GRU units. The possibility of vanishing gradient in RNN algorithms was previously mentioned. In order to accomplish this, the dropout method is used to over fitting, and some nodes are eliminated at random along with all of their connections to inputs and outputs. Each layer takes into account a 20% dropout rate. The output layer, which converts the LSTM/GRU output into a 1-D readable vector for users, is a dense layer with 10 units and the softmax activation function.

PROPOSED METHOD

Proposed Method – Block Diagram

Description

- In proposed model, the real time data is collected from the simulink power system model, for detecting and classifying the faults by using ANN based technique
- The obtained data from the real time is being processed before given as input to the neural block. The preprocessing step going to use in this project is finding the missing values in the dataset. The real-world data often has a lot of missing values. The cause of missing values can be data corruption or failure to record data.

The handling of missing data is very important during the preprocessing of the dataset as many machine learning algorithms do not support missing values.

- The next step would need to define the independent (X) and dependent (Y) variables in this process. We will divide the data into a training set and a testing set using the given variables, which will then be utilized for modelling and evaluation.
- In proposed system, the input node contains (8X6528) matrix, which is representing static data; 6528 samples of 8 elements and the target is (4X6526) matrix, representing static data; 6528 samples out of 4 elements
- These 6528 samples are randomly divided as Training, validation and testing samples. Then selecting the algorithm which is used to perform these samples(Levenberg - Marquardt Back Propagation Algorithm)
- Then the simulated model is combined with the neural model to run the specific functions.

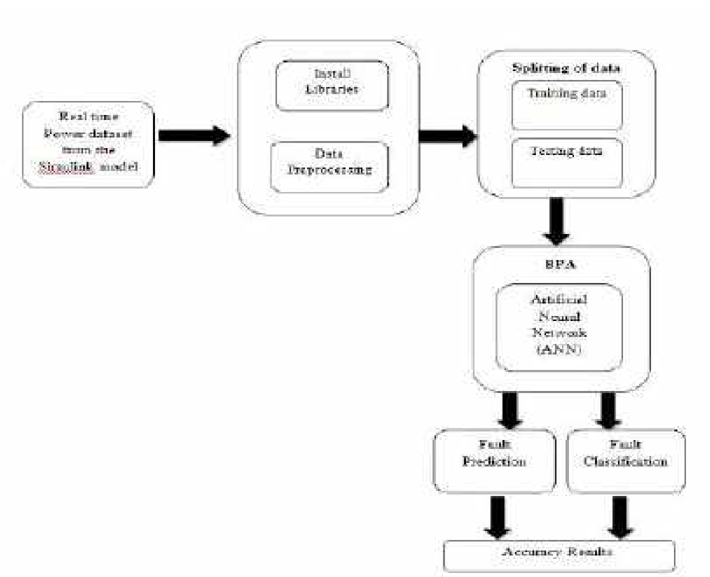

Figure 6 Block Diagram of Proposed System

Proposed Method Advantage

- High efficiency with improved reliability, compactness and cost-effectiveness.
- The method is flexible, and it does not require prior knowledge about the network
- Less trained samples are needed
- Fault detection is easily done
- Accuracy of fault detection is high

SIMULATION AND RESULTS

Tools Used

- MATLAB – SIMULINK (Version 2018a)

Simulation Block Diagram and Results

- While power quality terminology is applicable to transmission and distribution systems, their approaches to power quality differ.

- A transmission system engineer is responsible for controlling active and reactive power flow in order to maximize the transmission system's loading capabilities and stability limitations.
- A strategy to overcome an existing disadvantage - a proposed model is built and explored in this research. The approach is fundamentally simple and is based on adding one integrator to the system (or three in a three-phase example). The fault created by the dc component is thus totally rejected. Furthermore, an estimate of the dc component is provided.

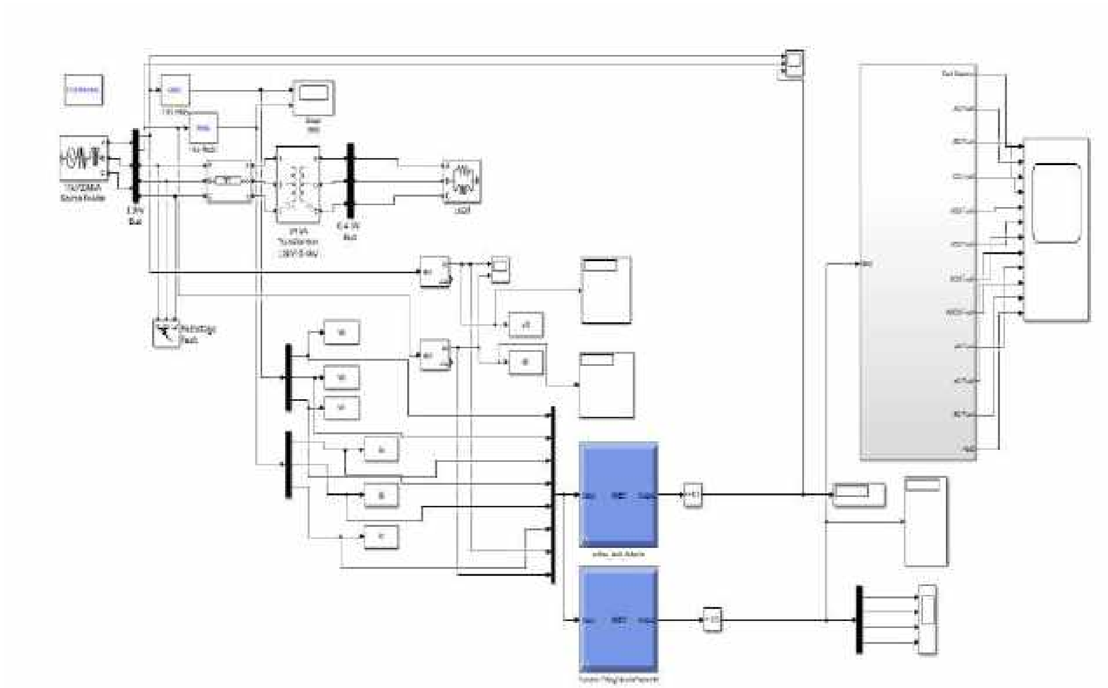

Figure 7 Simulation Diagram of fault detection and classification using ANN

RESULTS

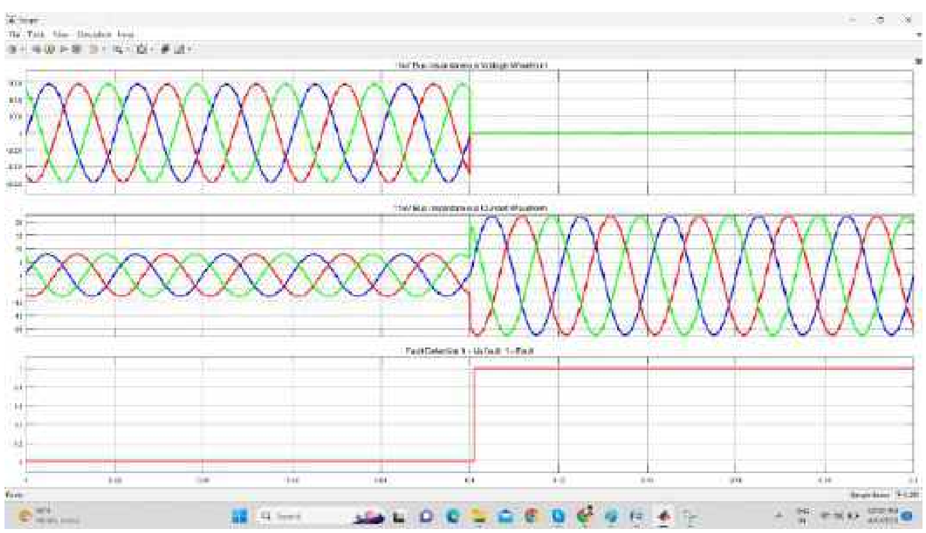

Figure 8 Output Waveform

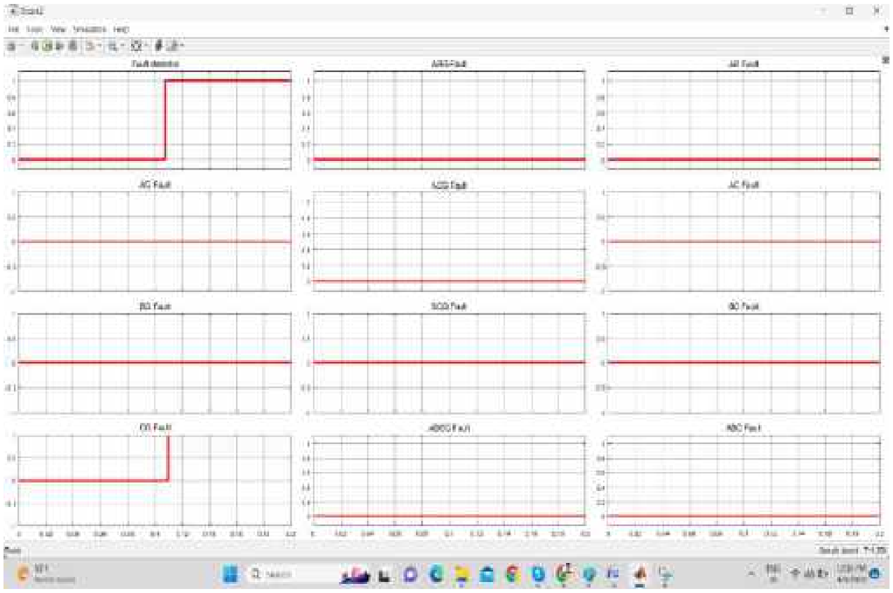

Figure 9 Output waveform of one line to ground fault

Figure 8 shows the Fault occurs at 0.1 sec and neural network output is change from 0 to 1. 0 means no fault and 1 means fault in the system and also that Fault detector is change from 0 to 1 for fault indication CG fault is change from 0 to 1 for fault classification. Remaining results are maintained at 0 for no fault classification.

CONCLUSION

In conclusion, the study and simulation of fault detection and classification in power systems using an Artificial Neural Network-based Back propagation (BP) algorithm represents a significant advancement in ensuring the reliability and efficiency of electrical grids. This research venture has delved into the fusion of advanced machine learning techniques with the intricacies of power system fault analysis. The study has shed light on the critical importance of swift and accurate fault detection and classification within power systems. Power system faults can have far-reaching consequences, impacting not only the reliability of electrical supply but also public safety, the economy, and critical infrastructure. By harnessing the power of Artificial Neural Networks and the Back propagation algorithm, this study has demonstrated that a data-driven approach can enhance fault management in these complex environments.

As the energy sector continues to evolve, the findings from this study will likely play a pivotal role in shaping the future of power system fault management. The integration of artificial intelligence with power systems engineering offers the promise of a more reliable, adaptive, and responsive electrical grid. With further research and implementation, we are poised to usher in a new era of fault detection and classification in power systems, ensuring a resilient and dependable energy supply for the modern world.

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Renewable Energy and EV Charging – Perfect Synergy for Sustainable Development

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Abstract: *Energy is at the heart of the climate challenge – and key to the solution. Humans have been using fossil fuels for over 150 years with the associated release of the greenhouse gases produced when these fuels are burned. These greenhouse gases trap heat in the atmosphere causing the temperature of the Earth to rise. This global warming is one symptom of climate change. To avoid the worst impacts of climate change, emissions need to be reduced by almost half by 2030 and reach net-zero by 2050. To achieve this, our reliance on fossil fuels need to end and investment in alternative sources of energy that are clean andreliable should increase. Furthermore, widespread adoption of electric vehicles (EVs) can help reduce greenhouse gas emissions while also improving air quality. With the rise in the demand for electric vehicles, the need for a reliable charging infrastructure increases to accommodate the rapid public adoption of this type of transportation. Simultaneously, local electricity grids are being under pressure and require support from naturally abundant and inexpensive alternative energy sources such as wind and solar. This is why the world has recently witnessed the emergence of renewable energy-based charging stations that have received great acclaim.*

Keywords: *Renewable Energy; Electric Vehicles; Energy Storage; Sustainable Development; Smart EV Charging*

INTRODUCTION

Energy is at the heart of the climate challenge – and key to the solution. The industrial revolution era started in the early 1700s, during which many inventions were acquired so that the technology advanced to the level that humans were able to do things much more effectively. Fossil fuels were discovered and used massively as energy sources, to the level that humans became strongly dependent on them. Usable and reliable electricity systems were invented, and electric power plants were massively constructed everywhere [1]. In a nutshell, the industrial revolution significantly improved human life quality and expectancy to the levels we have today. Along with the improving life quality and unprecedented population growth, human energy use drastically increased. The burning of fossil fuels produces greenhouse gas (GHG) emissions, which cause global warming and threaten life on earth. Such GHGs trap the heat in the atmosphere causing the temperature of the Earth to rise. Currently, around 80% of global energy and 66% of electrical generation are supplied from fossil fuels, contributing approximately 60% of the GHG emissions responsible for climate change.

The global warming is one such symptom of climate change that has seen a rise in extreme weather events, shifting wildlife habitats and populations, rising sea levels and other impacts. In order to prevent the worst climate damages, all the country made the consensus that the global net human-caused emissions of carbon dioxide (CO_2) shall be reduced by about 45% from 2010 levels by 2030, reaching net zero around 2050.Many of the proposed plans for confronting the climate crisis stress the imperative of decreasing emissions by transitioning to 100% “clean” or “renewable” sources of energy. This is because the renewable energy sources don’t emit GHGs and so they do not contribute to global warming. Hence, all countries are making sincere efforts to end the dependence on fossil fuels and invest in alternative sources of energy that are clean, accessible, affordable, sustainable and reliable.

The energy sector is undergoing a profound and complex transformation as the shift to renewable energy gathers momentum. Electricity is only one component of the energy transition. Other sectors such as transport, heavy industry etc., are also crucial in the pursuit of lower emissions. The transport sector is one of the main fossil fuel consumer and contributes about 24% of global GHG emissions. The transportation sector consumes about 60% of the world's oil consumption. Today transportation accounts for 24% of direct CO_2 emissions from fuel combustion globally [2]. In this context, deployment of Electric vehicles is fast picking up and replacing, diesel and petrol driven ones. Over the past decade, Electric Vehicles (EVs) are increasingly seen as a low or zero emission transport alternative. From an environmental perspective, EVs are considered as the future of transportation because of their capabilities of converting electrical energy to mechanical energy at high efficiencies and reducing tailpipe emissions significantly, compared to the ICE-powered vehicles. Other advantages such as near-instant torque, reduced noise, less maintenance, and smooth operation benefited from fewer mechanical parts also make EVs an attractive option to replace the conventional ICE-powered vehicles.

The remarkable increase in the use of electric vehicles has resulted in a massive rise in demand for electric energy across the globe. The integration of renewable energy sources with electric vehicle charging is a promising development in sustainable energy systems. They can provide the electricity needed to charge electric vehicles, reducing the carbon footprint of transportation. However, the increased demand for electricity to power these vehicles also presents challenges for the grid and renewable energy infrastructure. In this paper, it is envisaged to explore the opportunities of using renewable energy sources for EV charging to attain synergy for Sustainable Development.

POWERING EVs AND CARBON FOOTPRINT

The main motivation behind EVs is the reduction of greenhouse gas in the environment. This purpose is fulfilled if the electricity powering those vehicles is generated from renewable sources. Although EVs are considered environment-friendly, whether they are 'truly' a green alternative to the ICE-powered vehicles depends on the electricity mix used to power the vehicles. However, at present, most electric vehicles are powered by fossil fuel-based power stations which do not help in reducing the greenhouse effect. Countries heavily reliant on fossil fuels for electricity generation may not be able to enjoy the environmental benefits of EVs. A reduction in Greenhouse Gas emissions from the adoption of EVs depends on the extent to which electricity is generated from renewable sources. Since EVs rely entirely on electricity, the fossil fuels used in the electricity generation mix could lead to negative effects on the environment. This shifts the focus to the electricity generation and the renewable energy target set by the government [3].

Renewable energy integration is necessary to make the purpose of EVs fulfilled in the near future. Moreover, most renewable sources are intermittent as they are dependent on external factors such as sunlight and wind availability. Solar energy generation is affected by factors like cloud cover, time of day, and season. Solar panels produce electricity when exposed to sunlight, but their output decreases or stops during nighttime or cloudy weather. Similarly, wind power generation relies on the presence of sufficient wind speeds to turn wind turbines and produce electricity. Wind patterns can vary throughout the day and are influenced by factors like weather systems and geographical location. Hence many renewable sources are integrated into the grid to improve the reliability and effectively utilise such resources.

EVs do not have tailpipe emissions, which creates a healthier environment for people living close to streets. However, EVs do have well-to-wheel (WtW) emissions, since the power generation and delivery process to charge the EVs produce emissions. It means, the WtW emissions are from a power system (used for charging EV) that primarily uses coal based power generation are similar to those of ICE-powered vehicles. On the other hand, if charged by renewable energy sources, EVs will have far fewer WtW emissions than ICE-powered vehicles. Consequently, pairing the adoption of EVs with the deployment of renewable energy sources is crucial for addressing environmental issues in urban transportation [3]. EVs might be the key to linking the renewable power and low-carbon transport sectors, for the good of everyone.

EVs DEPLOYMENT AND CHARGING INFRASTRUCTURE

EVs represent a paradigm shift for the transport sector, with the potential to advance the decarbonisation. The push for EVs is driven by the global climate agenda established under the Paris Agreement to reduce carbon emissions across the world to address the growing global warming issue. Although the transport sector currently has a very low share of renewable energy, it is undergoing a fundamental change, particularly in the passenger road vehicle segment where EVs are emerging. According to Germany's Centre for Solar Energy and Hydrogen Research (ZSW), 5.6 million EVs were on the world's roads as of the beginning of 2019. China and the United States were the largest markets, with 2.6 million and 1.1 million EVs, respectively[4].Just consider that 2.0 million electric vehicles have been sold globally in the first quarter of 2022, a 75 percent increase from the same period in the previous year. What's more, a total of 65 million EVs are projected to be on the road by 2030 [5].

The rapid growth in EV deployment will have to address two major challenges. The first challenge is ensuring the deployment of adequate charging infrastructure required to serve the needs of the growing number of EVs. The second challenge is the integration of the EVs into the power system in secure and stable manner. However,to accommodate higher EVs penetration with least possible grid upgradation cost implications, smart charging will play a key role not only in managing high share of EVs, but also cater to a range of grid support services[6].

EV charging refers to the process of replenishing the energy in the battery of an electric vehicle. This is done by connecting the EV to a charging station or charger. A charging station, also known as an EV charging station supplies electricity to charge EVs. EV charging can be of two types – conventional (dumb or normalcharging) and smart charging. To charge an EV using the conventional charging method, one would simply plug the EV into a charge point that connects directly to the main electricity grid. The vehicle would charge at maximum power until the point at which the EV battery gets to 100% SoC. At this point, the charging process will automatically cease.

EV charging acts like a variable and unpredictable load to the power system. If a large number of EVs are integrated into the grid and they are not coordinated properly, a significant portion of them may demand power at the same time. This can create severe complications in the power grid. Several studies found that increases in peak load, power loss, voltage deviation, and power quality degradation are common in distribution grids without coordinated charging.Therefore, high peak loading issue is not economically and environmentally viable due to its cost implications, and at the same time conventional generation sources are primarily filling the requirement of providing the additional power. Bringing in additional conventional generators to meet peak demand will negate the very reason (carbon emission reduction). For example, EV charging driven high peak loading issue initiate a new challenge of maintaining generation-demand balance during peak loading time, which necessitates scheduling of expensive generators and the requirement of installation of new generation plants. shifting mobility to electric vehicles.

To address the above mentioned limitations of conventional charging, smart charging can be utilised to optimally and intelligently charge EVs in a coordinated and controlled manner. Smart charging not only mitigates the limitations of dumb charging, but it can also facilitate maximising the utilization of renewable generations, provided ancillary services support and backup storage.

SMART CHARGING

One of the key technologies driving the advancement of EV charging is smart charging. Smart EV charging is the ability to intelligently control, manage and adjust all aspects of electric vehicle charging. It is done based on real-time data communication between the electric vehicle, the charger, the charging operator, and the electricity provider or utility company. In other words, in smart charging, all parties involved constantly communicate and use advanced charging solutions to optimize charging at all times.

Smart EV charging enables adapting the charging cycle of EVs to both the conditions of the power system and the needs of vehicle users. Smart charging therefore is a way of optimising the charging process according to distribution grid constraints, the availability of local renewable energy sources and customers' preferences [4]. With smart charging, EVs could adapt their charging patterns to flatten peak demand, fill load valleys and support real-time balancing of the grids by adjusting their charging levels as shown in **Figure 1**. Smart charging systems may also be integrated with renewable energy sources like solar and wind power, allowing for even cleaner and more sustainable charging.

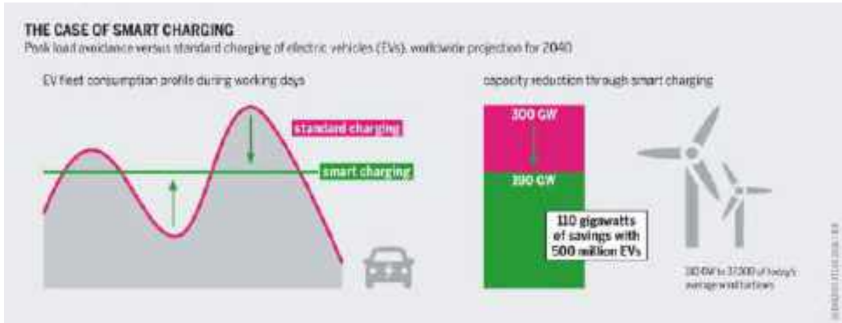

Figure 1 Peak load avoidance by smart charging of electric vehicles

Figure 2 illustrates how smart charging can integrate solar and wind generation in the grid by adjusting the charging profile of the EV to resource availability. As observed, smart charging strategies would differ according to the power system's conditions, including the renewable energy generation mix, load profile and interconnections available [6].

Figure 2 Smart charging for solar and wind generation profiles

KEY STAKEHOLDERS INVOLVED IN SMART CHARGING

In smart charging, EV battery is charged considering all the decision parameters of the system and requirements of EV owner. An external entity or a person controls the charging and decides the schedule of charging complying the interests of EV owner and other stakeholders. As smart charging is externally controlled, it requires observability and communication between the entities. Since it will be practically challenging for a grid operator to monitor, manage and control all the EVs, EV aggregators act as interface between EVs and the grid operator. Roles of key stakeholders in smart charging adoption are as here.

A. Grid Operator

Grid operator represents Distribution System Operator (DSO) or Distribution Company (DISCOM) of a particular network. Grid operators are responsible for maintaining the continuity of electric supply. They control the power grid via communication within and neighbouring utilities. They are also responsible for restoring the supply in case of failure due to any natural disaster or fault conditions. Due to this reason, system operators are interested to maintain secure and stable grid operation.

B. EV Owner

EV owner is a proprietor of EV who is responsible for taking the EV charging decisions. In EV smart charging study

EV driver can also be addressed as EV owner because of having charging decision rights in some situations. The main objective of an EV owner/driver is reduced cost of charging while meeting its commuting needs.

C. Aggregator

EV aggregator is a third party between energy supplier i.e., system operator and energy consumer i.e., EV driver /owner. It establishes an indirect connection by coordinating with EV and system operator by acting as a middle entity between EV owner and system operator. It cooperates with the stakeholders to fulfil their demand (or supply) requirements while respecting the supply (or demand) capability of another stakeholder. It collects information from both (viz, system operator and EV owner) and take suitable decision on EV charging considering the request and constraint from both the parties.

MAIN BENEFITS OF SMART CHARGING FOR EVs

A. Benefit to Electric Grid

Smart charging maintains the system parameters within the permissible limit while ensuring reliable supply to the customer. Some of the benefits of smart charging to the grid operator are

1. System stability and reliability

Smart charging maintains the grid stability by directly or indirectly managing the charging behaviour of EV load. Directly managing charging covers centralised decision taking strategies, whereas indirectly managing charging demand covers decentralised and distributed decision taking strategies. Moreover, hierarchical decision taking strategy also ensure grid stability by managing the charging load with combination of centralised and decentralised decision.

2. Reduce grid upgradation requirement

Smart charging through a coordinated manner can facilitate charging of more EVs compared to dumb/uncontrolled/uncoordinated charging, thereby effectively increasing EV hosting capacity of a distribution feeder. More importantly, at peak load condition, smart charging will not only be able to limit the peak load, but it can also help in peak shaving, hence reducing the need for grid upgradation.

3. Increased RE integration and reduced carbon emission

Grid with high percentage of generation mix from conventional generators are benefited in terms of carbon emission reduction as smart charging reduces the additional generation scheduling and encourages utilisation of renewable energy. Moreover, through smart charging, EVs can provide grid support services and help in accommodating higher RE penetration

4. Reduces overall cost of the system

Since Smart charging reduces the additional generation and infrastructure requirement, and thereby reduces the cost associated with additional expensive generators and establishing new infrastructure.

B. Benefit to EV Owner

EV owners benefit in terms of reduced charging cost and reliable electrical supply as a result of smart charging of EVs. In addition, EV owners indirectly are benefited through clean air and healthy environment because of low demand of additional generation and better utilisation of renewable energy generation.

C. Benefit to Charging Station Operator

Charging station owner/operator earns financial revenue from smart charging by providing the charging management services to EV owners and grid operators. In addition, electricity price hike at peak hour window and peak load duration generates an additional profit for the charging station owner/operator.

The broader landscape of smart charging benefits are shown in **Figure 3**.

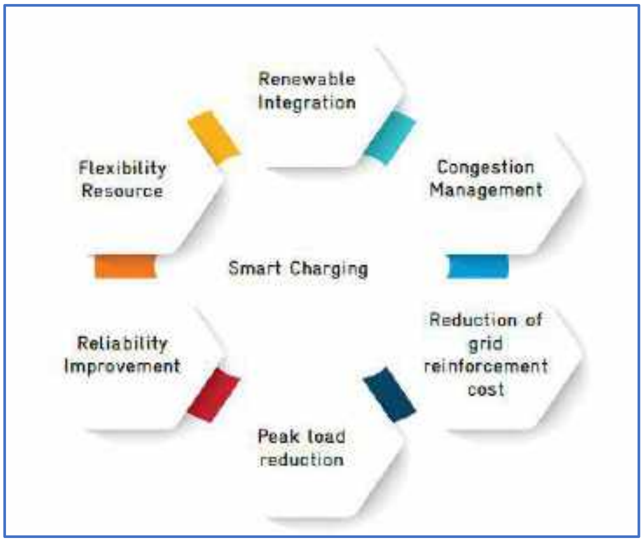

Figure 3 Usefulness of smart charging

CONCLUSION

The EV is becoming popular rapidly due to the increase of the greenhouse effect, the shift of public opinion as well as governmental support. These increasing numbers of EVs require large numbers of charging stations which consumes a huge amount of electric power and puts stress on the power grid. Most of these charging takes place in an uncoordinated manner. This uncoordinated charging causes peak demand of the grid which creates several challenges, such as increased power loss etc., It is seen that smart EV charging is an intelligent and flexible technology able to stabilize networks, reduce costs and exploit renewable energy sources. The transition to renewable energy and smart EV charging is critical for a more sustainable and cleaner future. We can reduce our reliance on fossil fuels, improve air quality, and help mitigate the effects of climate change by investing in renewable energy sources, smart EV charging systems, and smart energy management. Smart EV charging holds the key to unleash synergies between clean transport sector and low-carbon electricity. The synergy between Renewable Energy and smart EV charging help to create a better future for ourselves and future generations.

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ENVIRONMENTAL ENGINEERING DIVISION

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Environmental Management System ISO 14001: 2015 its Importance in Present Scenario

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***Abstract**: The world continues to globalize, discussion on the new standards, their harmonization and the new quality initiatives has increased significantly. Standards are the backbone of our society, ensuring the safety and quality of products and services, facilitating international trade and improving the environment in which we live in. Conformity to new standards and new quality initiatives builds up the customer confidence and at the same time boosts businesses and economies. New standards and quality initiatives are strategic tools to help companies to tackle pragmatically some of the most demanding challenges of modern business. They ensure that business operations are as efficient as possible, increase productivity, help companies access new markets, cut costs through improved systems and processes, increase customer satisfaction through improved safety, quality and processes and reduce their impact on the environment. Further, an effective implementation needs effective reforms in organizational environment and culture which is not possible without effective leadership which assists the workforce to adopt a clear direction of functioning and working. Other contributory factors may include employee satisfaction, training needs, employee cooperation, effective planning etc. It is high time that organizations prepare themselves to face these challenges by motivating employees to adopt new standards and support new quality initiatives by developing a strategic plan. Such organizations will improve the chance for success if they become more aware of and sensitive to obstacles related to their implementation. By understanding the potential severity of the obstacles, companies can anticipate and successfully resolve problems that inhibit implementation of new standards or quality improvement initiatives. The paper deals with the new standards, new quality initiatives and ISO 14001: 2015 Environmental management system and its implementation. In the latter part of the paper Environmental policy, management plan, implementation and procedures are dealt.*

***Key words**: New Standards, New Quality Initiatives, Environmental Management System*

INTRODUCTION

Increasingly stringent environmental regulations, international obligations and agreements, and private sector recognition that potential economic benefits may result from improved environmental performance, have contributed to the development of systematic new tools for dealing with complex environmental problems. These tools are the EMS.

The International Standards Organization (ISO) published the first world-wide standard for EMS, the ISO 14001, in 1996. Both the US Department of Defense and ADF have adopted the industry standard EMS, ISO 14001 as the guiding framework for implementing their environmental policy. The Ministry of Environment and Forests in India is also advocating the adoption of EMS by industry for effective monitoring of compliance and regulation requirements.

The ISO 14001 – 2015 defines an EMS as the part of an overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining an environmental policy. It is a voluntary EMS standard that provides a framework to move from reactive and fragmented responses to environmental issues common to compliance – based environmental programmes. At the same time the framework provides for a proactive approach that facilitates early identification of impacts, liabilities and opportunities. The ISO 14001 – 2015 does not specify absolute requirements for environmental performance but demands a commitment to continuous improvements in environmental performance, efficiency of operations and regulatory compliance, through repeatable and consistent control of its operations. Performance levels are established by environmental law or organizational management.

EMS AND STANDARDS

Thus, instead of focusing on specific environmental activities, the ISO 14001 – 2015 EMS focuses on ‘management’ activities. The emphasis is on the management structure and how management achieves its stated goals. While the framework of an EMS remains constant over time,each individual EMS should be tailored to reflect those aspects and environmental impacts that have been deemed significant by the organization, based on its corporate culture and strategic goals. An EMS is therefore, not a stagnant system, but provides the mechanisms necessary to continually evolve to meet the ever-changing needs of an organization. The management framework of ISO 14001 – 2015 EMS is based on a cyclical process of commitment and policy, planning and implementation, evaluation and review, as shown in Figure 1. The essential elements of ISO 14001 – 2015 are its auditable requirements:

COMMITMENT AND POLICY

An organization should define its environmental policy that ensure its commitment to its EMS and communicates the policy to all employees and public.

PLANNING

An organization should formulate a management plan to fulfil its environmental policy by identifying its environmental aspects and impact and legal requirements, establishing objectives and targets for the significant impacts

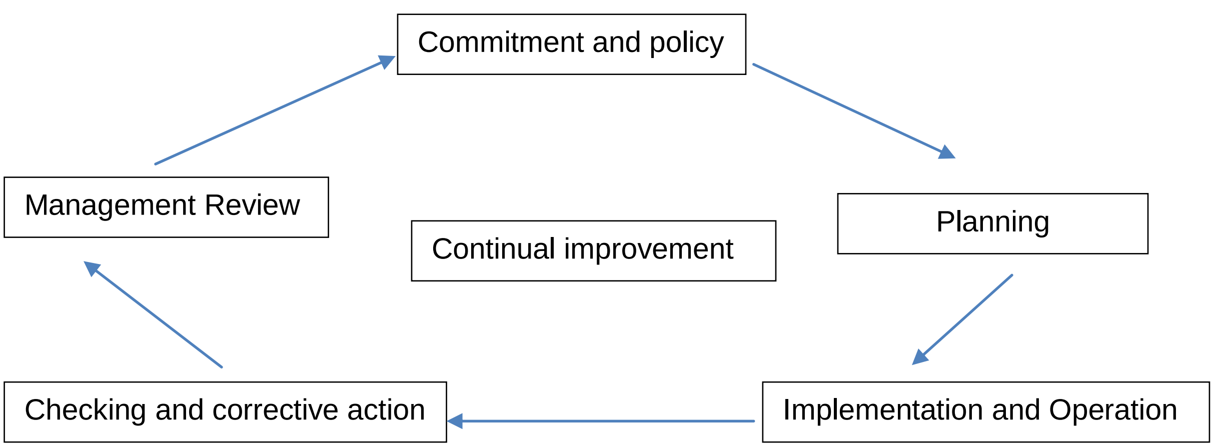

Figure 1 The ISO 14001 – 2015 EMS process.

IMPLEMENTATION

An organization should develop the capabilities and support mechanisms necessary to achieve the environmental policy, objectives and targets, by defining roles and responsibilities, allocating resources, communicating and documenting the procedures, and providing training to its employees.

MEASUREMENT AND EVALUATION

An organization should measure, monitor and evaluate its environmental performance by establishing procedures to control operations and for responding to emergencies.

REVIEW AND IMPROVEMENT

An organization should review and continually improve its environmental management systems, with the objective of improving its overall environmental performance.

Formal certification to ISO 14001 – 2015 can be achieved either by third party audit or self-declaration of conformance with the standard. It is possible to implement ISO 14001 – 2015 without seeking formal certification.

TOWARDS AND ENVIRONMENTAL POLICY

The defence forces in India have installations and carry out operations across many regions in India. Because of rising pressures on land caused by the growing population and from other economic sectors like agriculture industry, tourism, etc., newer suitable training areas are unlikely to be available in the future. Sustainable environmental management of the existing installations and sites is therefore critical for their continued use and ensuring India's would be broadly similar to the corresponding feature of the US. The environmental impacts generated by them will depend on the intensity of the activity and the capacity of the ecosystems, of which they are a part, to absorb the stresses. The stress are on the soil, water, marine, biodiversity, forest and other eco system resources. The ecosystems in India are in many ways more sensitive (than is the case in USA) because of different physiographic, climate and other natural resources, regimes and significantly higher population densities. The more sensitive ecosystems in India have been identified in the Western Ghats, ravines, the Sunderlinedelta with its wetlands and mangroves, the Northeast, the shiraliks, flood plains, forests, Eastern Himalayan region,red and black soil, and coastal areas. In all these areas the defence forces have a strong presence. Some of these locations were chosen because of the natural and location of advantage they provide for training. In each location, the environmental issues and priorities are likely to be different. From the perspective of the military mission, therefore, it is important to manage these installations in a sustainable fashion. Equally significant is the need to sustain the ecosystems for future generations as some of them are unique and possess biodiversity and other resources of immense value to mankind.

The environmental policy and strategy to be adopted need to vary with location, type of installation of nature of ecosystem. A management systems framework need to be established from a corporate or headquarters perspective to guide its implementation and monitor performance at individual installation level. Drawing on the lessons of environmental policy and its implementation in the US army, and the developments in EMS industry, The Long-term defence preparedness. Accordingly, they will need to adopt an environmental policy and strategy that promotes the military mission while ensuring compliance with the environmental laws and promoting environmental stewardship.

The general layout of the military installations in India, the nature and intensity of training, the townships, industrial and maintenance units within them, and field operations the environmental policy and its implementation in US Army and the developments in the EMS in Indian defence forces also need to integrate environmental policy and programmes into the military mission while ensuring compliance with national environmental policy and programmes and promoting environmental stewardship.

It is suggested that the international standards EMS ISO 14001 – 2015 be adopted by the defence forces to design and implement its environmental policy. The documentation and auditable requirements of this EMS (policy statement, environmental management plan, implementation procedures and mechanisms, performance monitoring indicators, review procedures) provide a unified framework within which the environmental management and performance of each installation can be independently articulated, reported and evaluated with respect to its goals. The management plans need to be based on the best science available for the ecosystems and resources in question. This facilitates environmental management on a 'corporate-wide' scale, and also provides for continuous learning, adaptation and improvements in performance at the installation level.

The challenge is for the defence strategists and the military leadership to articulate the relevance and need for an environmental policy for defence to sustain the military mission, and promote its role in environmental stewardship, obtain the resources, and create organizational structures and systems to implement the policy. The ISO 14001 – 2015 EMS provides the basic framework to meet the challenge.

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Sustainable Water-Food Security through Disruptive and Interdisciplinary Technologies

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***Abstract**: Sustainable development of water systems has to deal with both dimensions of optimal allocation and optimal scale. As hydraulic infrastructure (yet to be monetized like transportation infrastructure in India) is a study by disciplines like engineering, agri-economics / business, social sciences , policy and governance.*

The climate change needs to be understood from ago-ecological / agro-climatic perspectives rather than only rainfall and temperature. Sustainable water management, has an integrated perspective taking into account environmental, human and technological factors and in particular their interdependence. And, how to attach amenity value to water resources, agriculture etc., due to climate change impacts needs to be understood. The Geo-spatial (mainly using satellite remote sensing and very few drone surveys) datasets from ISRO and the world organizations which are available for assessing climate change scenarios (not IPCC but actual) are to be detailed dynamically.

The overall sustainable development with 17 SDGs need a framework relating / linking aspects of monitoring, managing and governing not only hydraulic water infrastructure but all other types of infrastructure assets using cyber physical systems in digital India.The food security has to come from rain fed agriculture than by irrigated agriculture in times of climate change. There should be emphasis on green water use than blue water use in integrated water resources management.

The monitoring and management of water-food resources in a continuous mode, can be cheap and sustainable by using small satellites constellations.

***Keywords**: Hydraulic Infrastructures; System of Systems in Sustainability; Rain fed Farming,;Agro-climatic change; Nano/Small Satellites*

IINTRODUCTION

Many developing countries still do depend upon agriculture for economic growth. Processes of economic globalization have connected commodity markets and food security outcomes across geographies and overtime. Much more agricultural production is traded than 30 years ago. Food-price shocks in one country or region have ripple effects elsewhere. In order to assess sustained and equitable access to food security, appropriate research approaches need to be capable of capturing the interlinked relationships that comprise a food system. These include the biophysical resources which make food production possible, the resource use demands of food processors and retailers, and consumer behavior, including food preferences, preparation and intra house hold distribution patterns.A region is secure when it has sufficient, clean and affordable for livelihoods, public health and industry. Various definitions emerged as a concept recently, The definition is broader than the absence of water scarcity. It differs from the concepts of energy and food security. Whereas those concepts cover reliable access to food or energy, water security covers not only the absence of water but also its presence when there is too much of it. A water secure world is one in which there is enough water to support social development, sustainable and inclusive growth, and ecosystems.

The USGS emphasis based on precise estimation of the global agricultural cropland- extents, areas, geographic locations, crop types, cropping intensities, and their watering methods (irrigated or rain fed; type of irrigation) provides a critical scientific basis for the development of water and food security policies. The global food and water security analysis data -GFSAD- is a NASA funded project (2023-2028) to provide highest-resolution global cropland data and their water use that contributes towards global food-and-water security in the twenty-first century. The GFSAD products are derived through multi-sensor remote sensing data (e.g., Landsat-series, Sentinel-series, MODIS, AVHRR), secondary data, and field-plot data and aims at documenting cropland dynamics from 2000 to 2030.

A clear and deep understanding of crop phenologies and intensities will require us to develop a temporal mapping distinct classes within a crop, which in turn will lead to accurate assessments of green water use (rain fed croplands) and blue water use (irrigated croplands). In several regions of the world rain fed agriculture generates among the world highest yields. These are predominantly temperate regions with relatively reliable rainfall and inherently productive soils. Even in tropical regions, particularly in the sub-humid and humid zones, agricultural yields in commercial rain fed agriculture exceed 5-6 t/ha .At the same time, the dry sub-humid and semiarid regions have experienced the lowest yields and the weakest yield improvements per unit of land.

Investing in water management in rain fed agriculture can lead to positive environmental impacts on other ecosystems, as a result of reduced land degradation and relative improvement of water availability (i.e., enabling more food to be produced with relatively less water) and water quality downstream. All these mentioned above are to be looked into in the context of Industry 5.0. The Confederation of Indian Industry should be roped into sustainable development of water sector with the new role assigned to them as CII-Connected Innovation Intelligence management.

Industry 5.0 and Sustainability Context In Advancing Technologies and Digital India

Water resources sector in India is undergoing technological changes with sophisticated ICT systems with SCADA, Cyber Physical Systems, Cloud Computing, sensor networks, embedded systems etc. Investments in SCADA system for monitoring dams, catchment areas/command areas, main system management, canal distributors and management are taking place. India, ranked among the world's top 10 water-rich nations, holds immense potential for savvy investors eyeing Water Resources projects. With a current annual consumption of 750 billion cubic meters, the nation's water requirements are projected to surge to 1.5 trillion cubic meters by 2030. The opportune moment to invest in the Water Resources sector in India is now. Many state governments like Telangana, Maharashtra, Karnataka, Kerala started investing in ICT based hydraulic infrastructure assets.

Digital transformation has the potential to fundamentally alter how businesses function in this enormous market. While the market has a strong design team, there is no competent team for building or operation. Given the fact that these areas are deserted, osculating them will be advantageous. Another critical area within facility management and operations in a technology ecosystem is the collection of digital assets for operations and future development. This includes acquiring as-built models with scans and data in a common format for archiving, making them accessible to facility management and O&M teams, providing a quick start for future projects.

Industry 5.0 is a concept that aims to improve the humanization and sustainability of Industry 4.0. It is an evolution from Industry 4.0, which is primarily driven by the need to emphasize the role of humansin cyber-physical systems. The technologies used to build Industry 4.0 should not impose their choices on people but offer them options.A real option refers to the right to acquire some real world asset without the obligation to exercise that right. Whenever an IT project has flexibility about which applications and functions to implement, and when or how to implement them, real options are present. Planning a thoughtful project, having a methodical plan for promoting company-wide is the need of the hour.

Based on the indicators used by the European Union one can monitor in India too, the level of digitization. It can be concluded from such studies that the biggest challenge for companies is still the integration of digital technology with the digitization of services. There is still a lot to do in the way of transformation of companies to Industry 4.0. The critical elements are high investments and the pace of implementing technological changes in companies from various industries. Industry5.0 means combining the best of the human and machine worlds. It will likely also mean increased productivity.

There is a Industry 5.0 reference model proposed by combined thinking of academia and industry [1].

The various components and sustainability values are as represented by **Figure 1** shows the Industry 5.0 reference model that provides a description of this phenomenon, explaining its underlying technologies, techno-functional principles, smart components, and values. The interpretive structural modeling (ISM) technique was employed to identify the sequential relationships among the functions and construct the Industry 5.0-enabled model of sustainable development. The sustainable development functions like: BPM, business process monitoring; CIP, circular intelligent products; DST, data sharing and transparency; ETA, employee technical assistance; INA, intelligent automation; ORE, operational and resource efficiency; OSI, open sustainable innovation; RIN, renewable integration; RTC, real-time communication; SCA, supply chain adaptability; SCM, supply chain modularity; SII, system integration and interoperability; SOP, service-orientation and personalization; STH, sustainable thinking; UPR, upskilling and reskilling; VUI, value network integration.

These ISM models are to be suitably developed for hydraulic infrastructure assets and their services. The main objective of the study involved developing a road map describing how Industry 5.0 can function to enable sustainable development, especially in terms of resilience, environmental sustainability, and human centrality.

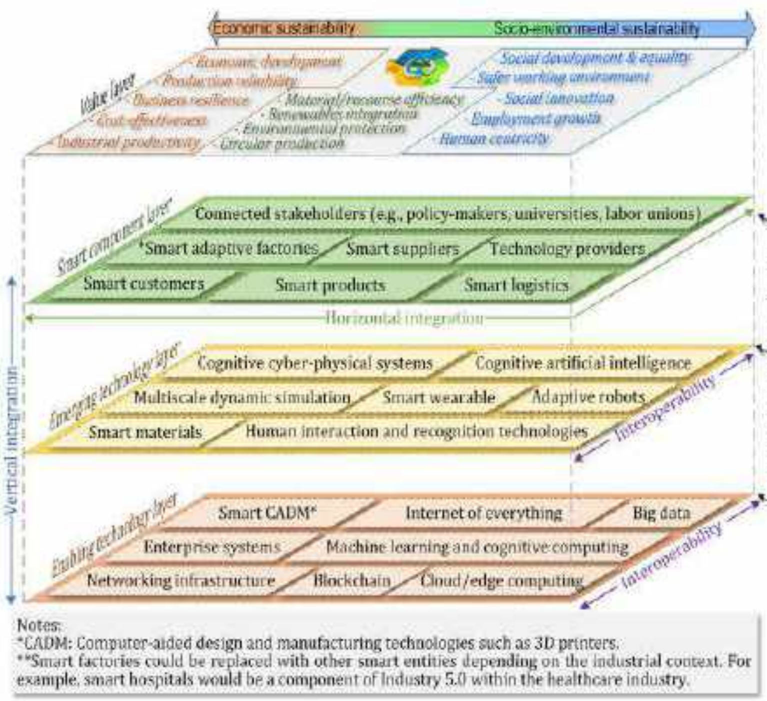

Fig. 1. The reference model of industry 5.0

Assigning Amenity Value for Global Environmental Change / Climate Change

The climate change needs to be understood from ago-ecological / ago-climatic perspectives rather than only rainfall and temperature. The onus of estimating past changes in surface water availability and their sensitivity to climatic variability lies with sustainable water management expertise. Sustainable water management, has an integrated perspective taking into account environmental, human and technological factors and in particular their interdependence. And, how to attach amenity value to water resources, agriculture etc., due to climate change impacts needs to be understood. There are numerous India Government websites for water sector like IndiaWRIS, MOSDAC, NDEM, CGWB, ENVIS, VEDAS, NIC, State departments GIS databases which helps us in assigning amenity value to the climate change scenarios.

The climate change is only one of the pressures facing hydrological system and water resources. Other global changes such as population growth, pollution, land use changes and land management, also have a profound impact on the hydrological cycle.

The remote sensing images can be used in modeling water productivity regions for agriculture. Underpinning this is the assumption that farmers are perfectly informed about the characteristics of different tracts of land across the world regions using geospatial data and the assumption that they are actually able to move. The unit cost function (A) is $A(w, r_a, z) = 1$

Where w is the wage rate, r_a is the price of agricultural land and z is the characteristic of the land (such as climate). The unit price of agricultural output is normalized to unity.

Totally differentiating the unit cost function gives:

$$(\partial A/\partial w)(dw/dz) + (\partial A/\partial r_a)(dr_a/dz) + (\partial A/\partial z) = 0$$

Rearranging the equations and substituting expressions obtained from differentiating the unit cost identity gives

$$-Az = N_a\, dw/dz + L_a\, dr_a/dz$$

Where N_a is the number of agricultural workers and L_a is the amount of agricultural land available. The amenity values for climate seem to be embedded in agriculture land prices. Similarly, the methodology has to be formulated for water resources systems where in we need complex adaptive systems with inclusive growth.

The results /findings of analysis conducted in US, India and Brazil showed that amenity values for climate seem to be embedded in agricultural land prices[2].

The geospatial data obtained from constellation of small satellites is cost effective when we launch these satellites concurrently. The multi spectral, hyper spectral as well as radar payloads can be used on these small satellites which are less than, say, 50 kgs weight. These small satellites can continuously monitor the climate variables-agro-climatic variables and changes because of global change phenomena .

Rain fed Farming -Improvements Needed

The role of green water flow in sustaining rainfall is to be understood. An important but often ignored aspect of the water cycle is that water vapour flows support the formation of rainfall over the landscape, forming an important moisture feedback loop. On a global scale we know that about 40 percent of terrestrial rainfall stems from oceanic moisture that is transported inland by wind. It is, however, not widely known that about 60 percent of rainfall stems from vapour produced from the land surface. This means that the hydrological floodstream that supports the biosphere and the anthroposphere is, to a large extent , generated by the biosphere itself. This leads to the important conclusion that natural or manmade changes in the landscape can have significant impacts on the sustainability and reliability of rainfall.

There are three main ways of increasing production in agriculture. First is expand the cultivated land, second is increasing cropping intensity and the number of harvests over time, third is more food production per unit of soil or water (improve yields of grain or biomass). An increased yield would result in more consumptive green water use, but would involve a much lower shift in water flows compared to a shift from one land use to another, or a shift in cropping intensity. From an ecohydrological perspective the minimum impact on freshwater dependent ecosystems is therefore achieved if food production is attained through yield increases. Increasing cropping intensity is second best, and area expansion is the worst ecohydrological option. Yield increases are to be achieved through sustainable management changes, which do not result in water quality deterioration.

Investing in water management in rain fed agriculture can lead to positive environmental impacts on other ecosystems, as a result of reduced land degradation and relative improvement of water availability (i.e., enabling more food to be produced with relatively less water) and water quality downstream.

The on-farm hydrological cycle is a good indicator of the degree of mismanagement and land degradation in agro-ecosystems. The low crop yields are attributed to a set of management related water deficiencies.The deficiencies are manifested in the inability to cope with dry spells - short periods of water stress during crop growth, poor performance of the crop water balance (high runoff , large evaporation and drainage losses), and poor soil fertility and crop management resulting in low crop water uptake capacity. Research has also shown that there are no hydrological limitations to a doubling or even quadrupling of crop yields in rain-fed semi-arid farming systems, from 0.5 to 1 tonne s per hectare to 2 tonnes per hectare[3] [4].

Sustainability in Water Management using Industry 5.0 Concepts

Building Information Management BIM, is the real tool for smart water networks to do sustainable water management. The smart networks using SCADA and CPS and concurrent processing using BigGeodata Analytics for spatial data can be used in BIM to construct, monitor and manage the required hydraulic infrastructure. BIM is more for operations and management in water resources engineering sector as already any construction is taken care of by National Building Code. The use of ICT, cloud computing, high performance computing, CPS networks using IoT in operating and maintaining hydraulic infrastructure to yield sustainable production there is a need for National Water Code too[5] [6].Sustainability comes from IWRM-Integrated Water Resources Management. There is quite a lot of research done by water engineers (through research in M.Tech and PhD both in India and the world) in assigning priorities among different SDGs in a river basin using system of systems concepts and complex adaptive systems.

The water utopias / dystopia of perspectives and management style suggested worldwide to delve into the water-future are hierarchist, egalitarian and individualist. In hierarchist perspective water scarcity is viewed as a supply problem, potential water supply is seen as total run off ,water demand as a given need. In egalitarian perspective water scarcity is viewed as a demand problem, potential water supply as a stable runoff in inhabited areas, and water demand as a manageable desire. In individualist perspective water scarcity is viewed as a market problem. Potential water supply is seen as a clean fresh water stock (no limits) and water demand is in equilibrium with supply. These perspectives are combined with a suitable management style involving response variables like water pricing (ratio of water price/actual cost), development of water saving technology, public water supply, and sanitation coverage, relative use of the different water sources.

CONCLUSIONS AND DISCUSSIONS

The following conclusions are projected:

1. The multi-disciplinary thinking through ICT technologies in water sector using geospatial data , big data analytics, continuum computing from rainfall to disasters and other normal management of sources of water through IWRM is the need of the hour. National Water Code emerges by doing this system of systems thinking which provides a new set of jobs for those who measures the value of water in the air, biosphere, cryosphere through emerging new technologies.

2. The rain fed water management by using infrastructures provided by Industry 5.0 coupled with appropriate investments is a solution for water-food security for sustainable societies in India and the world.The appropriate policies, economics, environmental law and standards by roping in rural people are essential for Industry 5.0 to survive the societies in Digitally transformed India.

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Transforming Traditional Waste Management in Indian Military Stations: The Impact of Disruptive Technologies, with a Focus on AI

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***Abstract**: In a world increasingly defined by the digitization and modernization of processes, solid waste management is on the brink of a significant transformation. This paper explores the evolution of solid waste management practices in the digital age and the profound impact of emerging technologies such as robotics, the Internet of Things (IoT), cloud computing, Artificial Intelligence (AI), and data analytics. These technologies are poised to revolutionize the efficiency, sustainability, and environmental responsibility of the waste management sector. This paper has taken one of biggest military station as model station giving out how traditional SWM can be transformed with disruptive technologies to give greater impact in present ongoing issues in SWM.*

***Keywords**: Digital Transformation; Solid Waste Management; Robotics; Internet of Things; Artificial Intelligence; Sustainability; Real-Time Monitoring*

INTRODUCTION

This paper investigates the profound influence of disruptive technologies, particularly Artificial Intelligence (AI), on the conventional domain of solid waste management. It explores how innovative technologies, including AI, can revolutionise the approach to waste management, leading to enhanced sustainability, efficiency, and environmental responsibility. The paper gives out the nuances of Traditional Waste Management in Indian Military Stations; Transforming Traditional Waste Management with Impact of Disruptive Technologies; Smart Waste Management System; Impact Assessment; Assessment of Economic, Environmental, and Social Benefit; and Recommendations for Integrating Disruptive Technologies and Circular Economy Practices in Waste Management in Indian Military Stations.

Traditional Waste Management in Indian Military Stations

Analysis of Existing Waste Management Practices

In the past, a multi-pronged action plan was implemented to address solid waste management (SWM) standards in Indian military stations[1]. The salient aspects of this action plan included various initiatives such as raising awareness, improving waste segregation and collection systems, developing waste disposal infrastructure, and ensuring scientific disposal of waste.

Existing Challenges, Inefficiencies, and Environmental Impacts

The traditional waste management practices faced several challenges and inefficiencies. One significant challenge was the need for increased awareness among stakeholders. To address this, awareness lectures conducted by expert teams and Station Waste Management Teams, established by Residents' Welfare Associations (RWA's), were regularly undertaken. These efforts included the use of social media, short film screenings, and the installation and distribution of billboards/posters to enhance the effectiveness of awareness campaigns.

Economic and Social Implications of the Existing System

The economic and social implications of the traditional waste management system were substantial. Efforts were made to improve waste segregation at the source, emphasizing the importance of community participation. Residents were required to segregate their waste into dry and wet categories, with additional specific binsprovided hazardous waste aligning with directives issued in the SWM Rules of 2016[2].

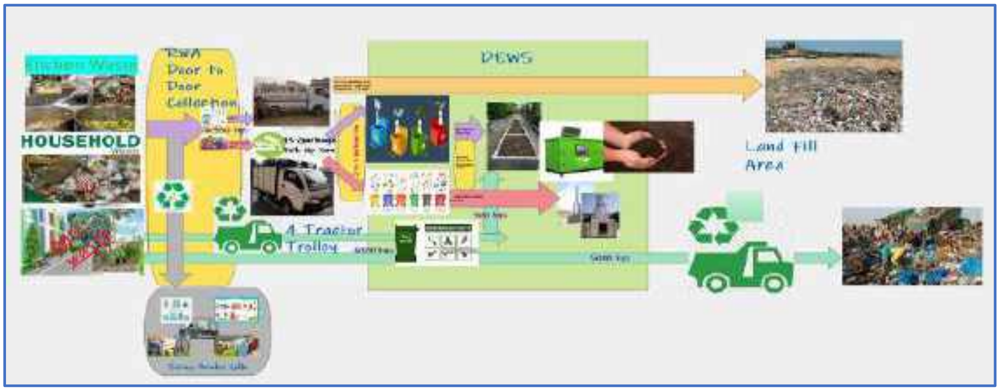

Figure 1 Overview Military Station Solid Waste Management

Furthermore, the improvement in waste collection played a vital role in the waste management process. Door-to-door collection was implemented on a daily basis, with residents, shops, and establishments notified of the collection times. Residents were charged a fee for waste collection, facilitating door-to-door collection of pre-segregated waste. The system aimed at maintaining cleanliness in common areas and included the provision of standardized garbage bags for waste collection.

Efforts were also made to distribute garbage bags to residents and sensitize RWAs for segregation at source, ensuring the door-to-door collection of pre-segregated waste since January 1, 2022. The collection and treatment of specific waste items, such as rinsed and dried milk packets, were managed effectively. Modifications to garbage tractors and lorries, along with the provision of garbage bins, were implemented to enhance segregation mechanisms.

Development of Waste Disposal Infrastructure

Decentralization of treatment and disposal locations within the military station was a key focus. Three separate locations for the treatment and handling of both biodegradable and recyclable waste were established at geographically different locations i.e Garhi, Dhar Road, and Jindra. The development of infrastructure involved activities such as site selection, identification of sheds, and the procurement and installation of heavy-duty machines. Activities were carried out by various units under the aegis of HQ 71 Sub Area, to synergize available budgets. Specific machines, such as the fuel free incinerators, Hydraulic Bale, Wet Waste Shredder, and Garden Waste Shredder, were procured and installed. Output from these machines varied from using residual ash as fertilizer to baling plastic waste (bottles and flexibles) for sale to recyclers thereby generating revenue within the military station.

TRANSFORMING TRADITIONAL WASTE MANAGEMENT WITH IMPACT OF DISRUPTIVE TECHNOLOGY

AI-Powered Waste Sorting Systems[3]

AI-powered waste sorting systems revolutionize waste management through the integration of computer vision, machine learning, and robotics. This advanced technology automates the identification and separation of diverse waste materials. Key components and advantages include: Components of AI-Powered Waste Sorting Systems. Computer Vision - High-resolution cameras capture real-time images of waste items.

Image Processing: Techniques enhance image quality for accurate object identification.

Machine Learning: Trained models classify waste items based on visual characteristics.

Robotic Arms or Pneumatic Diverters: Automated systems physically separate mixed waste into different recycling streams.

Feedback Loop: Continuous learning from the sorting process improves future accuracy.

Advantages of AI-Powered Systems

Increased Accuracy: Higher precision in material identification reduces contamination.

Improved Efficiency: Continuous operation at high speeds enhances processing capacity.

Reduced Labour Costs: Automation minimizes manual labour, decreasing associated expenses.

Enhanced Safety: Elimination of human exposure to waste materials and associated risks.

ML-Based Waste Prediction System[4]

ML-based waste prediction systems offer predictive insights into waste composition, optimizing waste management practices. These systems utilize historical data and various factors to forecast waste types and quantities.

Working of ML-Based Systems

Data Analysis: Historical data, including day, season, events, and weather, is analyzed.

Predictions: ML algorithms forecast incoming waste composition based on analyzed data.

Operational Optimization: Predictions inform efficient collection, sorting, and disposal strategies.

Benefits: Efficient collection scheduling, optimized sorting operations, reduced disposal costs, and improved recycling rates.

Blockchain-Based Waste Management Platform [5]

Blockchain technology transforms waste management by enhancing transparency, accountability, and security. These platforms utilize smart contracts and decentralized ledgers to manage waste shipments and contracts. Core Components are:

Waste Tracking and Monitoring: Blockchain traces waste shipments in real-time, preventing unauthorized diversion.

Contract Management: Smart contracts automate terms and conditions for transparent transactions.

Data Management: Blockchain stores waste-related data for analysis and decision-making.

Permissions and Access Control: Secure sharing of waste-related information among stakeholders.

Subsystems and Integration

- Waste Identification and Tagging: Unique identification of waste items with tamper-proof markers.
- Sensor Integration: Use of sensors for real-time data on waste movement.
- Data Integration: Integration with existing waste management systems.
- Regulatory Compliance: Adherence to environmental regulations and data privacy laws.

Benefits of Blockchain-Based Platforms

- Enhanced Transparency: Immutable ledger ensures a transparent and auditable record, especially for movement of recyclables.
- Reduced Fraud: Decentralization reduces manipulation opportunities.
- Efficiency and Cost Savings: Streamlined processes lead to reduced operational costs.
- Environmental Protection: Accurate tracking prevents illegal dumping, protecting the environment.

Satellite Imagery-Based Waste Monitoring System[6]

Satellite imagery plays a crucial role in identifying and monitoring waste disposal sites, offering comprehensive and up-to-date information. The process involves data acquisition, image processing, analysis, and verification.

Data Acquisition and Processing

- Satellite Image Selection: Choosing appropriate satellite imagery based on resolution and other factors.
- Image Pre-processing: Radiometric correction, geometric correction, and image enhancement.
- Image Mosaicking: Combining multiple images for a broader perspective.
- Image Analysis and Interpretation Change Detection: Identifying areas of significant change to detect new waste disposal sites.
- Spectral Analysis: Analyzing spectral signatures to identify waste disposal sites.
- Object-Based Image Analysis: Segmenting images for accurate waste site identification.
- Machine Learning Classification: Automating waste site identification through machine learning.

Verification and Reporting

- Field Verification: On-site visits to validate remote sensing analysis.
- Waste Site Mapping: Creating detailed maps of waste disposal sites.
- Reporting and Dissemination: Preparing comprehensive reports for stakeholders.

Satellite imagery-based waste monitoring systems provide valuable insights for planning and monitoring waste management strategies, offering a scalable solution for large geographical areas.

Integrating all the explained we get smart waste management system network which provides a high-level overview of the different components and their interactions. The system utilizing a secure and reliable communication infrastructure to ensure seamless data flow between the devices and the central hub. The smart waste management software would aggregate and process the data, providing analytics and facilitating system management. Broad components which plays important role are given in subsequent paras.

Network Diagram for Smart Waste Management **Figure 1**.

Communication Network

The communication network for the smart waste management system would utilize wireless communication protocols like Wi-Fi, LoRa, and Zigbee to connect all sensors and smart devices to the centralized hub. The choice of communication protocol would depend on factors such as the required data transfer rates, range, and power consumption.

For example, Wi-Fi would be a suitable choice for short-range, high-speed communication between devices located within close proximity of the centralized hub. LoRa and Zigbee would be more suitable for long-range, low-power communication between devices located further away from the centralized hub.

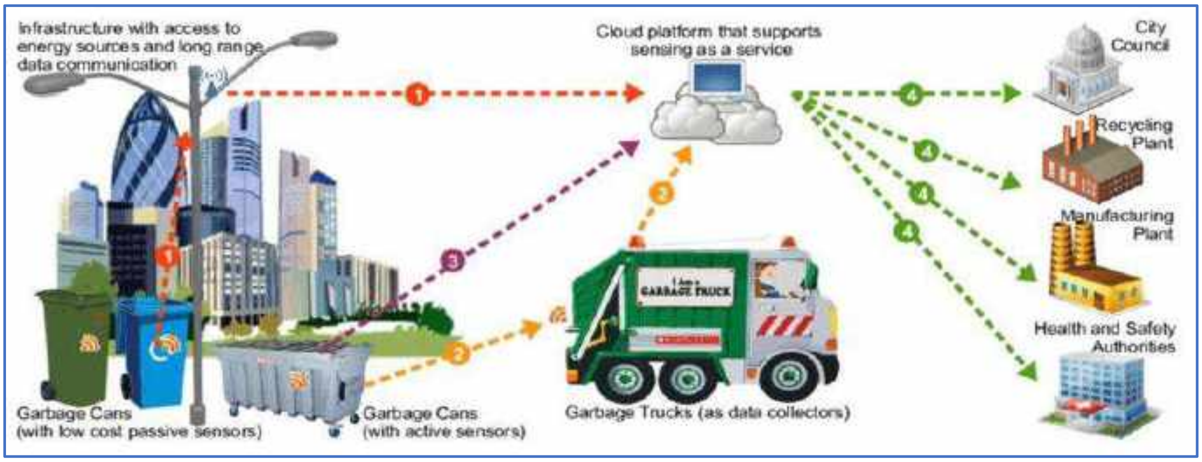

Figure 2 Smart Solid Waste Management[7]

Network Topology

The network topology for the smart waste management system would be a hybrid of star and mesh topologies. The star topology would be used to connect all devices to the centralized hub. The mesh topology would be used to provide redundancy and improve reliability.

Security

Robust security measures would be implemented to protect the integrity and confidentiality of the data exchanged within the system. This would include data encryption, authentication, and authorization mechanisms.

Data Flow

Data would flow from the sensors and smart devices to the centralized hub over the communication network. The smart waste management software would aggregate and process the data, providing analytics and facilitating system management.

For example, the centralized hub could receive data from waste bins indicating that they are full. The smart waste management software could then optimize collection routes to ensure that the bins are emptied efficiently.

The smart waste management system could also be used to monitor and control waste management processes, such as composting and incineration. For example, the centralized hub could receive data from temperature and moisture sensors in compost pits. The smart waste management software could then adjust the composting conditions to ensure optimal decomposition.

The smart waste management system has the potential to significantly improve the efficiency and effectiveness of solid waste management services. By automating tasks, optimizing processes, and providing real-time insights, the system can help to reduce costs, improve environmental outcomes, and enhance public health.

Impact Assessment: Evaluation of the Potential Impact of Implementing Disruptive Technologies and Circular Economy

Disruptive Technologies.

Efficiency Gains: Implementation of AI-powered waste sorting, ML-based prediction systems, and blockchain platforms streamlines processes, reducing operational costs and increasing efficiency [8].

Resource Optimization: Smart waste management systems lead to optimal use of resources, including time, manpower, and materials, fostering a more sustainable approach.

Innovation and Job Creation: Adoption of disruptive technologies stimulates innovation and may create new job opportunities in technology-related sectors.

Circular Economy

Waste Reduction: Circular economy practices contribute to minimizing waste generation by promoting recycling, reuse, and sustainable product design.

Resource Efficiency: Designing products for longevity and recyclability enhances resource efficiency, reducing the environmental footprint.

Economic Resilience: Circular economy models foster economic resilience by reducing dependence on finite resources and promoting a regenerative approach.

Economic, Environmental, and Social Benefits

Cost Savings: Smart waste management systems reduce operational costs through optimized collection routes, resource-efficient processes, and reduced manual labour.

Revenue Generation: Circular economy models may open new revenue streams, such as selling recyclable materials or providing waste management services.

Reduced Environmental Footprint: Circular economy principles contribute to resource conservation, waste reduction, and lower greenhouse gas emissions.

Biodiversity Conservation: Proper waste management and circular practices help protect ecosystems and biodiversity by reducing pollution and environmental degradation.

Health and Well-being: Improved waste management practices contribute to cleaner environments, positively impacting the health and well-being of communities.

Challenges and Risks

Initial Investment: Implementing disruptive technologies requires significant upfront investment in infrastructure, training, and technology adoption.

Technological Barriers: Resistance to change and the need for technological expertise may pose challenges during the transition.

Technological Adoption: Integrating disruptive technologies may face resistance from stakeholders, requiring comprehensive training and change management strategies.

Infrastructure Requirements: Implementing smart waste management systems necessitates additional finance, and robust infrastructure, which may be a challenge in certain regions.

Mindset Shift: Adopting circular economy principles requires a behavioural change at various levels, from consumers to policymakers, which may take time.

Supply Chain Complexity: Implementing circular practices may add complexity to supply chains, requiring adjustments and collaboration among stakeholders

Data Security: The reliance on digital technologies in waste management introduces cybersecurity risks that need to be addressed to ensure data integrity and privacy.

System Downtime: Technical glitches or system failures could disrupt waste management operations, highlighting the need for resilient systems.

SOCIAL AND BEHAVIOURAL RISKS:

Equitable Access: Ensuring that all segments of the population have access to and benefit from improved waste management practices is crucial to avoid disparities.

Recommendations for Integrating Disruptive Technologies and Circular Economy Practices in Waste Management in Indian Military Stations

Policy Framework and Leadership:

Policy Development: Formulate clear policies that support the integration of disruptive technologies and circular economy practices in waste management within Indian military stations.

Leadership Support: Garner leadership support at all levels to drive cultural and organizational shifts necessary for successful adoption.

Incentivization: Implement incentive-based policies to encourage the adoption of circular practices and disruptive technologies.

Regulatory Compliance: Develop and enforce regulations to ensure adherence to waste management standards and circular economy principles.

Technological Interventions

Smart Waste Management Systems: Invest in AI-powered waste sorting systems, ML-based waste prediction tools, and blockchain platforms to optimize waste collection, processing, and tracking[12]. Along with deploying network of IoT devices such as smart bins, sensors, and GPS trackers to enhance real-time monitoring, data collection, and analysis.

Collaboration with Tech Industry: Foster collaboration with technology providers and startups to stay updated on emerging technologies and innovative solutions. By initiating small-scale pilot programs to test the feasibility and effectiveness of new technologies and circular practices.

Continuous Improvement: Establish mechanisms for continuous improvement by regularly evaluating and upgrading the adopted technologies. Conduct comprehensive training programs for military personnel and waste management staff to ensure proficient use of new technologies.

Circular Economy

Educational Campaigns: Launch awareness campaigns to educate military personnel, families, and communities about the principles and benefits of a circular economy.

Product Design Guidelines: Develop guidelines for product design to ensure longevity, reparability, and recyclability of materials.

INFRASTRUCTURE DEVELOPMENT

Composting Facilities: Establish composting facilities with proper infrastructure for efficient conversion of wet waste into compost.

Incineration Units: Introduce advanced incineration units for the safe and environmentally friendly conversion of hazardous waste.

Performance Monitoring

Feedback Mechanism: Establish a feedback mechanism to involve residents in providing insights and suggestions for improvement.

Key Performance Indicators (KPIs): Define and monitor KPIs related to waste reduction, recycling rates, and operational efficiency to gauge the success of implemented measures.

Data Analytics: Leverage data analytics to derive actionable insights and make informed decisions for continuous improvement.

Collaboration with Stakeholders:

Public-Private Partnerships (PPPs): Explore opportunities for PPPs to leverage external expertise and resources for effective waste management[12].

Collaboration with Local Authorities: Engage with local municipalities and environmental agencies to align practices with broader waste management goals.

CONCLUSION

The path to transforming waste management in Indian military stations is illuminated by a commitment to innovation, sustainability, and community engagement. By heeding the call to action and implementing the outlined recommendations, stakeholders and policymakers can spearhead a transition that not only optimizes military waste management practices but also sets a precedent for sustainable living and environmental stewardship. This transformative journey is a shared responsibility, and the time for action is now.

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Save Planet Earth through Circular Economy of Waste-Free World

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Abstract*: Huge quantity of resources obtained daily from the Earth is being wasted. If these wastes can be utilised for useful purposes, the pollution of the earth will be controlled and GDP Growth will improve. There are various types of Wastes, such as House-hold Wastes, Industrial Wastes, Commercial Wastes and Agricultural Wastes.*

We are hereby dealing with household wastes. These wastes can be divided into two groups:

(1) Biodegradable wastes
(2) Non-Biodegradable wastes, mainly Plastics.

Biodegradable wastes can be converted into Biogas and Fertilizer though Composting. Non-Biodegradable wastes i.e. Plastics can be re-cycled, and Re-used , thus reducing Carbon emission. Plastics emit 3.4% of the Global Greenhouse Gas Emission throughout its Life Cycle. Thus Circular Economy of plastic Wastes will contribute to the reduction of Climate Change. With implementation of Circular Economy, the Waste-Free Earth will be cleaner and Pollution-free for better Human Life.

Keywords:
(1) Avoid Wastes and SAVE PLANET EARTH.
(2) A World without Trash.
(3) Circular Economy of Biodegradable Waste.
(4) Circular Economy of Plastic Wastes.
(5) Avoid Plastic Pollution . Reduce Climate Change

WASTE-FREE WORLD

It is a great concern for the society that two-thirds of the resources we are taking daily from the mother earth is wasted in different forms.

Presently the population of earth is approximately 740 crores. By 2050, it is apprehended that the population will increase to 1000 crores. The capacity of the earth at present is to sustain a human population of 500 crores only. So unless we are able to utilise our wastes properly, many have to die in future due to poverty and starvation.

It will be a great achievement for mankind if we can create a waste-free world. The waste generated can be converted to resources for boosting up the world economy.

WASTE GENERATION

Urban India produces 42.0 million tons of Municipal wastes annually. It creates high environmental pollution causing human hazards.

The various sources of wastes are

(a) Domestic Wastes: Plastics or Non-Biodegradable waste.

Biodegradable waste –Food and vegetable waste.

Misc. waste such as paper, glass, metals, textiles, medical waste.

Figure 1 Save Planet Earth for Sustainable Development

(b) Industrial Wastes

(c) Constructional Wastes

(d) Commercial and Institutional Wastes

(e) Agricultural Wastes

The solution to the problem is to adopt a Policy of 5 R's: as follows:

Refuse, Reduce, Re-use, Re-purpose, Re-cycle

PLASTICS FOR CIRCULAR ECONOMY

Plastics generated from Oil Refineries are inevitable for modern life. It is widely used for manufacturing packaging materials, carry bags, toys & various Industrial goods.40% of the total plastics produced is used for packaging. Approximately 500 billion plastic bags are used worldwide annually. Most of the plastic wastes generated are not degradable and chemical effect lasts for more than 1000 years creating pollution for soil and environment. The use of these plastics can not be avoided, since the society has been highly dependent on its use.

PLASTIC WASTE DISPOSAL

The plastic wastes ate disposed of as follows:

(a) Landfill: 79% of the plastic wastes of the world are sent for landfill or to the oceans. A huge quantity from the landfill fly to the cattle-field. The cattle eat the plastics with grass or straw and their milk becomes poisonous, which is consumed by the people and ultimately becomes dangerous for human health.

(b) Recycle: 9% of the plastics are recycled to produce items of different shapes and sizes.

(c) Incineration: 12% gets incinerated for production of gas or for power generation. The smoke generated is filtered so that clean air is passed to the atmosphere.

PLASTIC WASTE IN WATER BODIES

12 million tonnes of plastics find its way to river or to the ocean every year. 8 million pieces of plastics flow to the ocean daily. Micro-plastics in different forms are present in almost all the water-bodies like streams, canals, lakes, rivers and oceans. Fishes eat the microscopic pieces and become poisonous. 100,000 animals die annually due to plastics.

AIR POLLUTION DUE TO PLASTIC WASTE

Plastic contributes to 3.4% of global greenhouse gas emission, throughout its life cycle.

Every ton of plastic wastes in landfills releases about 3 tons of CO_2 equivalent greenhouse gas that contributes to global warming and climate change.

Plastic incineration emits 2.9 kg of CO_2 for every kg of plastic burnt.

Re-use of Plastics for Circular Economy

For Re-use of Plastics, it can be divided into 4 categories.

(1) Environment-friendly packaging

High quality of packaging materials should be used which can be re-processed several times and whose capacity for emission is also less.

(2) Manufacture of bricks

With proper research, bricks are being manufactured in USA for construction school buildings.

(3) Improvement of quality for Re-cycling

By adding some new polymer, plastic wastes can be re-used several times.

(4) Road making

The easiest method for re-use of plastic wastes is to make "Polymer–modified Asphalt Road" which is very strong and has got a long life.

In USA one company has built up a huge Industry by obtaining thousands of tonnes of plastic wastes from the sea. The cost of Raw material is practically NIL and hence the Industry is flourishing. They have got several Associates and established a modern Research Centre for improvement of quality for better use. India also can carry out research or tie-up with the American companies to build-up a similar Industry to protect the environment.

Biodegradable and Non-Biodegradable Waste for Circular Economy

Household Wastes are generally categorised as:

Organic or Bio-degradable Wastes: Vegetables, fruit peels, bones & meat wastes, chicken & fish wastes, paper, wood etc.

Non-Biodegradable Wastes: Plastics, metal, glass, medical waste, Radio-active waste.

Figure 2 Plastic Waste for Sea

Commercial, Industrial and Institutional Waste:

Bio-degradable Waste: Cooked food from Hotels. Huge quantity of Cooked Food are often wasted from Hotels. This can be utilised for the poor people.

Vegetable or perishable items from big or Whole-sale markets.

Wastes from Textile, Jute or Paper Industries.

Non-Biodegradable Waste:

Metals from Industries:

The metal scraps can be melted to form ingots or casted to make different shapes and sizes. With proper research, useful alloys can be formed with scraps of different metals.

Constructional Waste:

New buildings or structures are often constructed by demolishing the old structures, which emits huge quantity of dusts. As per the study of Central Air Pollution Control Board, the generation of Constructional Waste in India is approximately 2.5 crore tons per year. In Kolkata the generation is 1600 tons daily. The daily generation in Chennai or Mumbai is 2500 tons.

It is very essential to re-use these dusts for Circular Economy and also for public health. These wastes are very useful for manufacture of Paving Tiles.

As per the latest Research, 26% of the Air Pollution is caused by the Constructional Waste. The Research also shows that 800 persons die worldwide daily for air pollution. .

The Govt. should enact strict rules to Protect the Environment.

Hazardous Waste:

Medical Wastes from Hospitals are Hazardous and mostly Non-biodegradable Radioactive elements from certain Industries are Non-Biodegradable and Hazardous.

Figure 3 Non-Biodegradable and Hazardous waste in Hills.

Disposal of Bio-degradable Waste:

Bio-degradable wastes can be used for Energy, Fuel or Fertilizer. Organic Wastes can be converted to organic manure through aerobic and anaerobic digestion.

Generation of Energy:

In most of the European Countries, bio-degradable wastes are used for generation of electricity. The MSW Wastes are properly mixed mechanically and then burnt in Incineration for production of Gas. This gas is used as fuel for production of steam to run the Steam Turbine for generation of electricity.

In India the Calorific Value of Municipal Solid Waste is very low, because rag pickers are taking away the wastes of high calorific value like papers, plastics, card boards etc from the Dumping Ground. For this reason a German Company refused to set up a Power Plant at the largest Dumping Ground at Dhapa of Kolkata.

Generation of Fuels:

Bio-fuels are Gaseous Fuels such as Hydrogen, Methane and Liquid Fuels such as Methanol, Ethanol, ,Acetone etc. These fuels can be obtained from plants and animals. Municipal Solid Wastes c(MSW) consists of organic materials which can be effectively used for production of Bio-fuels, which are commercially viable different end-use.

Production of Fertiliser:

Composting is the basic process for production of Fertiliser. In a deep trench bio-waste is spread over to make a layer of 3 inches thick. It is covered by Municipal Bio-mass of 3 inches thick. Thus several set of layers can be made in the trench which is left for 3-4 months. Due to aerobic and anaerobic reaction at different temperature, the fertiliser is formed in the trench. This fertiliser is very useful for plant fertilisation.

Disposal of Non-Biodegradable Waste:

Hospital Waste:

The methods for disposal of Medical equipment, expired or unused medicines from Hospitals are:

Autoclaving with steam sterilization, Chemical disinfection., Incineration, Microwave.

Disposal of Radioactive wastes from Electronic and other Industries:

These are the most Hazardous wastes in the society. Depending on the intensity of Hazards they are categorised as High Level/ Intermediate Level/ Low Level / Nuclear.

There are various Govt. regulations for disposal of the wastes depending on the category of hazard. Nuclear wastes are generally packed in cement container covered by a strong Stainless Steel Container. It is dumped under in a deep sea or buried below rock structure.

This is known as Geological Disposal. and it can not contribute to the Circular Economy but hazards can be avoided. Thus it can be considered as contribution to the Circular Economy by avoiding disasters which can destroy the whole economy of a country..

Intensive Research should be carried out, how to utilise the hazardous and radio-active wastes for Circular Economy.

Global Warming:

The sun-rays consist of UV rays and Infrared rays. The UV rays are absorbed by the Ozone layer surrounding the earth , but the visible Infrared radiations pass through the atmosphere. These infrared radiations of short wave-length is absorbed by the earth, which is converted to heat energy. It is then emitted as long wavelength Infrared radiations. The infrared radiations of long wavelength cannot pass through the layer of Green house gases in the atmosphere. It causes heating up of the atmosphere and the temperature of the earth's atmosphere rises. This is known as "Global Warming."

The temperature increase of the earth's atmosphere was 0.5 degree centigrade during last 100 years. The temperature increase will be 1.5 to 4.5 degree Centigrade by 2030 if the Greenhouse Gases are emitted at the present level.

The Greenhouse gases (GHG) are CO_2, CH_4, CFC, N_2O, O_3, NO_2, Water Vapour, SO_2 etc. – 65% of the gases are CO_2.

The global GHG emission in the year 2020 was 50 GigaTons. China is the largest producer of the gases, followed by USA.

In 2020 China produced 10,668 million tons of CO_2. During this period USA produced 4,713 million tons of CO_2.

The green house gases are produced by vehicles, Industries and Human beings. If the emissions are not controlled, the higher temperature of the earth will have serious effect on health, food scarcity, water management and environment. It can be disastrous for the economy of a country.

Climate Change

Climate change in simple term is the variation of average weather on long term basis. Global Warming is responsible for the Climate Change in different areas. Due to the Global Warming ice is melting from the high mountains, North and South Poles and the water is flowing to the ocean and raising the sea level. So many of the countries near the sea will be immersed in water, while some other of higher altitude will be dry and become deserts. Somewhere there will be heavy rains and the area will be flooded. In some other area there will be no rain and there will be crisis of water. Plants and animals of different varieties will perish from the earth. This will be a great disaster for the world. The economy of some countries will be totally destroyed.

Figure 4 Air Pollution for Global Warming

Figure 5 Ice Melting due to Climate Change

The First Conference of the United Nations on Environment & Sustainable Development was held in 1972 at Stockholm, Sweden. 113 countries participated in the conference. Thereafter, the most important Conference was held at Kyoto at Japan in 1997. 156 countries participated in the Conference and a Protocol was signed. As per the Kyoto Protocol, the Green House Gas emission was to be brought down to 1990 level within 12 years from 2005 i.e. by 2017. America and Australia did not sign the Protocol.

It is necessary for all the countries of the world to realize the importance of impending danger on Environment and implement various measures to utilize the wastes which will Save Planet Earth through Circular Economy of Waste-Free World.

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The Lakes of Jabalpur Precious Heritage: Challenges and Opportunities

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***Abstract**: "Water is important for life". One of the most valuable resources for people is water. Various civilizations, from the very beginning, saw development along the banks of lakes and rivers and established the importance of water as a driving force in the process of development. Due to this judicious management of water and saving water bodies becomes a prime responsibility for everyone. Jabalpur city is endowed with abundant water resources, but due to improper management as well as over-exploitation, most of the water bodies are severely depleted. In times to come, the gap between the demand and supply of water will widen, leading to major imbalances in socioeconomic development and environmental sustainability. Jabalpur once had 52 major and 84 minor water bodies (ponds), out of which about 100 have lost their existence. This research paper covers the geographical conditions of all the existing water bodies/lakes of Jabalpur city, the area, history, ownership, and current status of the lakes along with the causes of their degradation, water quality, water pollution levels and suggestive measures of some of these lakes. Complete statistical information is included and various parameters are studied. [3]*

***Keywords**: Lakes and Rivers, Socioeconomic, Environmental sustainability, Water Bodies, Water pollution*

INTRODUCTION

The city of Jabalpur in M.P. is located in the picturesque Narmada Valley at the confluence of the Vindhya and Satpura ranges. Jabalpur city is located in the eastern part of Madhya Pradesh, about three hundred kilometres from the capital Bhopal. It is located at 23° 10' 32" North, 79° 53' 44" East and Mean Sea Level 402 metres. Jabalpur was the center of Kalchuri and Gond rule. The region has the best of water resources, natural and man-made both, the Narmada River being the important one. According to reports, the area's prior emperors built a great deal of water bodies to suit local demands for agriculture, homes, and recreation while also preserving rainfall. There are currently just 36 lakes in Jabalpur, down from the previous 84 minor water bodies, or "Tallaiya," and 52 large water bodies, or "Taal." Numerous lakes in the city of Jabalpur have entirely vanished as a result of alterations in land use patterns, intrusions, urbanization, and activities focused primarily on humans. [3]

LAKES IN THE OF JABALPUR CITY

Jabalpur is the city with the highest number of lakes in Madhya Pradesh. A systematic study has been conducted by the author on the lakes of Jabalpur in coordination with other departments i.e. District Administration Jabalpur, Jabalpur Municipal Corporation (JMC), Jabalpur Development Authority (JDA), Madhya Pradesh State Electricity Board (MPSEB), Irrigation Department, Agriculture Department. Department, Cantonment Board etc., a complete picture of all the lakes in and around the Municipal Corporation area of Jabalpur has been prepared, and a useful and unique document in the form of a book named "Jabalpur Ke Sarovar - Anmol Dharohar" has been prepared. Complete details of all the lakes studied including their status, current status with current photographs, brief history, lake areas (area), Khasra map, management agency and geographical location with mean sea level (MSL) have been studied. [5]

Table 1 Details of Lakes of Jabalpur City [3]

Sl.No.	Name of Lakes	Location (Gram)	Area (Hect.)	Management (Ownership)
1	Madhotal	Madhotal	16.999	Government and JDA
2	Adhartaal	Adhartaal	16.19	Agriculture Department
3	Kanchanpur	Bhadpura	2.145	Private
4	Gokalpur	Karondi Kachhpura	122.492	Government
5	Khandari	Kota	157.804	Jabalpur Municipal Corpn
6	Hanumantal	Jabalpur	6.33	Nagar Nigam Jabalpur
7	Ranital	Laxmipur, Hinotia,Jabalpur	10.25	Jabalpur Municipal Corpn
8	Guluawa Tal	Chavanpur	2.898	JDA
9	Shahi Tal	Kachhpura	1.55	Jabalpur Municipal Corpn
10	Maharaj Sagar	Garha	1.231	JDA
11	Jindahai Ki Talaiya	Garha	0.151	JDA
12	Bagha Tal	Garha	2.793	JDA
13	Kola Tal	Garha	1.086	JDA and Osho Ashrama
14	Machhhari Bijori	Garha	1.193	Private
15	Phool Sagar	Garha	0.672	Private
16	Madhkai	Purwa	0.91	Jabalpur Municipal Corpn
17	Suraj Tal	Purwa	5.504	Jabalpur Municipal Corpn
18	Imarati	Purwa	1.793	Jabalpur Municipal Corpn
19	Baksera	Purwa	2.939	Jabalpur Municipal Corpn
20	Awasthi Tal	Purwa	0.87	Medical University
21	Bal Sagar	Purwa	23.06	Medical University
22	Gullu KI Talaiya	Purwa	0.65	Medical University
23	Sagda	Sagda	1.574	Private
24	Ramnagra	Ramnagra	8.31	Government
25	Sangram Sagar	Purwa	15.855	Government
26	Thakur Taal	Badnpur	4.371	M.P.Government and Forest Deptt.
27	Devtal	Garha	1.534	JDA
28	Supatal	Garha	9.58	Jabalpur Municipal Corpn
29	Ganga Sagar	Ganga Sagar	18.64	Jabalpur Municipal Corpn
30	Gaurav Taal	Badanpur	1.619	Private
31	Pandutal	Rampur	0.400	MPSEB
32	Jalpari	Rampur	0.350	MPSEB
33	Kakrahi	Gorakhpur	2.855	Private
34	Mahanadda	Mahanadi	5.85	Private
35	Khamb Tal	Cantt Area	2.210	Cantt Area
36	Bheeta Tal	Bheeta	4.035	Private

REASONS OF WATER POLLUTION IN SOME LAKES OF JABALPUR

Adhartal Lake

Adhartal Lake is located on the Jabalpur-Katni National Highway near the Agricultural University in the Adhartal area of Jabalpur city. This water body is named after Diwan Adhar Singh Kayastha of Gond rule in the period of 16th century AD. The lake has religious and historical importance. A very famous and historical Pachamatha temple is situated on the banks of Adhartal Lake. This temple is currently under the control of the Archaeological Department. This lake is situated in village Adhartal and as per government records approximately 16.189 hectares (40 acres) area of Adhartal is being used for fish farming by the Agriculture Department. Presently Adhartal Lake is facing a lot of problems, such as silt, sewage inflow and waste water from nearby residential colonies, which discharge from the drainage channels. The lake is infested by washing clothes, bathing animals; Weed infestation in the lake, surface runoff with organic matter, sediment and decaying matter. An additional issue with this lake is the disposal of sacred relics. One of the main issues with the lake is idol immersion during different celebrations. The conservation measures required on priority basis are desilting; Restrictions and guidelines for idol immersion, weed removal, control over flow of sewage effluent, waste water and solid waste etc. [5]

Hanuman Tal

Situated near the heart of Jabalpur, Hanuman Tal Lake is a significant landmark in the city. It is about rectangular in design, with bathing ghats around the outside and stone masonry for the walls. It is a significant location in the city's history and religion. During the reign of Bhosale, in 1794, Hanuman Tal was built. On the banks of the lake are numerous temples. Urban settlement covers the entire tank's catchment area. Numerous diffuse non-point sources, including organic matter, sediments, decomposing matter, etc., enter this pond during rainfall from drainage channels. Other issues with this lake include the dumping of solid waste and the removal of religious relics. Numerous diffuse non-point sources, including organic matter, sediments, decomposing matter, etc., enter this pond during rainfall from drainage channels. Other issues with this lake include the dumping of solid waste and the removal of religious relics. One of the main issues with this lake is idol immersion during the Durgotsav, Ganeshotsav, and Tajiya festivals. The lake's environmental issues include the following: solid waste disposal, sewage inflow, growth of aquatic weeds, declining water quality, bathing and laundry, etc. [5]

Figure 1 Religious remains dumping in Aadhartal

Figure 2 Idol immersion at Hanuman Tal [6]

Devtal

This tal is located at Gram Gadha at 23° 09' 18" North, 79° 53' 50" E and MSL 412 m, opposite Bajrang Math, near the Osho Ashram Jabalpur. It is built by an soil embankment with stone steps. Many ancient temples are present on the banks of Devtal. The temple has religious importance. Idols Immersion and disposal of religious relics takes place in this lake during festivals. Presently the lake is being used for washing/bathing and other disposal activities which are affecting the water quality of this lake. Apart from this, other problems like extensive growth of aquatic weeds, sewage inflow can also be seen in Devtal lake. Conservation of the lake requires comprehensive action including removal of weeds, control of idol immersion and waste flow and development of the coastal area. [5]

Ganga Sagar Lake

Ganga Sagar Lake is situated on Jabalpur Nagpur National Highway NH-7 at Village Gangasagar at 23° 09' 24"

North, 79° 54' 51" East, and MSL 390 m. Raja Madan Shah, the Gond king, constructed it. With a surface area of roughly 45 acres and a maximum depth of roughly 5 meters, it is one of Jabalpur's larger lakes. Numerous historic temples can be found on the northern shore of this lake because of the religious significance of the temple. The area by this lake's banks is being encroached upon. Lake water is currently utilized for bathing, washing, and other personal hygiene purposes. During festivals, idols are immersed in this lake and religious relics are disposed of there. This lake also exhibits sewage flow. Removal of encroachments and weeding, guidelines for idol immersion, effluent flow restriction and marginal area development are the priorities for the conservation of Ganga Sagar Lake. [5]

Figure 3 Immersion of Idol and bathing at Devtal

Figure 4 Dumping of remains at Ganga Sagar

Ranital

Ranital is situated at 23° 10’ 15” North, 79° 55’ 10” East, and MSL 391 m in the three villages of Laxmipur, Jabalpur, and Hinotia. It is said to have been constructed in the 16th century AD, during the reign of Rani Durgavati. Rani Tal Lake used to be 48 hectares in size, but after improvements and the building of the sports complex, it is now only 10.250 hectares. The area along the banks of the Ranital and the earthen dam are under the control of the slum dwellers from three directions. On one side of the pond is where the town's solid waste is dumped. It is currently utilized for disposal purposes. Ranital's environmental issues include sewage inflow, encroachment, and growth of aquatic weeds, declining water quality, waste dumping, and storage capacity depletion. [5]

Figure 5 Municipal Solid Waste (MSW) dumping at Ranital [6]

Figure 6 Growth of weeds at Ranital [6]

OVERVIEW

Water bodies in urban areas are facing continuous degradation due to development and anthropogenic activities. The area along the banks of urban lakes usually undergoes settlement or encroachment, which affects the catchment area of the lakes and ultimately reduces the water area of the pond. The studies conducted in the present investigation have revealed that one of the most important reasons for water pollution in lakes is our festive occasions like Vinayaka Chaturthi, Durga Puja, Saraswati Puja, Narmada Puja, Chhath Puja, Tajiya etc. It became a tradition to immerse the idols. Unplanned urban development without proper attention to appropriate management of sewage and waste material is another major source of pollution in water bodies such as lakes, ponds, wells, estuaries, and open coastal beaches, among others. After conducting a survey to assess the water quality of a few lakes in Jabalpur, the Lake Conservation Authority of Madhya Pradesh found that nearly all of the lakes in Jabalpur are severely polluted. Due to the pollutants that are carried by the effluents from neighboring drains, Suptal, Balsagar, and Shahital have high TDS levels. The water in the majority of these lakes is exceedingly turbid, with turbidity values exceeding allowable limits. Although it is within allowable bounds, the nitrate percentage is high in Gangasagar, Sagada Pond, and Machhri Bijori Lake. The WHO's recommended guidelines typically accept a pH range of 6.5 to 8.5. [4] The pH range of 7.5 to 8.5 was found in the water samples from several lakes in Jabalpur that were used in this investigation. This demonstrates that all of Jabalpur City's lakes have a pH value that is slightly alkaline by nature. [5]

Table 2 Water Quality in various lakes of Jabalpur [1]

Sl.No.	Lake Name	pH	Turbidity (NTU)	Conductivity (mS/cm)	TDS (Mg/l)	Nitrates (Mg/l)	Orthophosphate (Mg/l)
Standards as per BIS [2]		6.5-8.5	5-10	< 1	500 Max.	20	
1	Madhotal	8.21	26	0.47	287	1.225	0.625
2	Adhartal	8.25	14	0.56	342	1.157	0.854
3	Gokalpur	8.12	26	0.47	287	1.225	0.625
4	Hanuman Tal	8.21	58	0.215	131	1.541	1.025
5	Ranital	8.25	54	0.56	362	1.12	0.954
6	Guluawa Taal	8.55	63	0.57	348	1.381	0.90
7	Shahi Taal	8.55	84	0.96	586	1.268	0.236
8	Maharaj Sagar	8.23	36	0.85	519	0.988	0.581
9	Phool Sagar	8.52	35	0.36	220	1.447	0.362
10	Madhkai	8.25	24	0.41	250	1.432	1.023
11	Bal Sagar	8.54	53	0.65	397	1.698	0.774
12	Sagda	8.63	36	0.25	153	2.015	1.24
13	Sangram Sagar	8.15	54	0.45	275	1.574	0.99
14	Dev Taal	8.55	109	0.36	220	1.575	1.023
15	Supa Tal	8.41	25	0.84	512	1.49	1.65
16	Ganga Sagar	8.45	47	0.58	354	2.224	1.246
17	Machhhari Bijauri	8.14	25	0.54	329	4.126	3.256
18	Baksera	8.25	29	0.69	421	0.849	0.741

SUMMARY

Jabalpur has abundant and large water resources, but these resources are currently degrading and experiencing ecological and environmental issues. Lakes are a natural component of the environment. Lakes have historically provided the population's water needs for drinking, personal hygiene (such as washing clothes), agriculture, fishing, and religious and cultural activities. In addition to providing direct access to lake water, lakes also help by replenishing groundwater, directing water flow to avoid logging, and averting floods. A wide range of flora and fauna, particularly birds, can be found in the lakes. Water resource management must take an integrated and sustainable approach because the world's resources are still in a precarious state. Due to factors like rapid population growth, unsustainable consumption patterns, inadequate management techniques, pollution, low infrastructure investment, and ineffective water demand and supply management, the available water resources are in extremely critical condition. It is now imperative to start taking action to preserve, manage, and restore lakes as important components of the larger ecosystem. Every citizen must take part in the preservation of Jabalpur's priceless lakes.[5]

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Impact of Compostable Plastics in Plastic Recycling: Assessment of the Quality of Plastics Obtained from Recycling of Conventional Plastics Mixed with Compostable Plastics

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***Abstract**: Plastic recycling has been identified as a key factor in attainment of circular economy as well as reducing the effects of plastic in climate change. Due to a number of issues, the plastic recycling industry is not able to thrive and the rate of recycling of plastic waste is very poor. To deal with plastic waste problem and promote recycling of plastic waste the Govt. Of India has made amendments in existing rules which prohibits use of certain SUP having low utility, high littering potential and low recycling value. The SUPs in circulation today will largely be replaced by compostable plastics and other biodegradable materials. While this shall be a good step to reduce impact on environment due to littering and uncontrolled disposal of SUPs, the plastic recycling sector which is expected to get a major boost due to EPR program shall have to deal with the problem of biodegradable plastic contaminating the plastic wastes. This paper is to analyze the effect of compostable and biodegradable plastics on the plastic waste recycling sector and overall plastic waste management.*

INTRODUCTION

Plastic is a versatile and indispensable innovation known for its affordability, lightweight, strength, and durability. However, its excessive production, especially in the form of single-use products, has led to environmental and climate concerns. Annually, over 300 million metric tons of plastic are produced worldwide, with half designed for short-term use, contributing to litter and pollution[1]. The plastic industry currently accounts for 7% of global oil consumption, projected to reach 20% by 2050, exacerbating its environmental impact.

Single-use plastic and packaging are the most littered items on the planet, harming human health, ecosystems, and contributing to climate change through greenhouse gas emissions. Microplastics, a by-product of plastic degradation, also hinder marine organisms' ability to absorb carbon dioxide, exacerbating global warming. In response, the Indian government amended plastic waste management rules in 2021 to phase out low-utility, high-littering single-use plastics. Studies have also shown that plastic waste is also playing a major role in clogging of drains and artificial water logging. It was also seen that 89% plastics in the drain are non-recyclable and11%are recyclableplastics[2]

Compostable plastics have emerged as alternatives to conventional plastics, primarily plant-based and non-toxic, decomposing into benign by products when properly managed. However, they require controlled industrial environments for decomposition. This study assesses whether compostable plastics can effectively address the plastic waste issue, while also identifying potential waste management challenges in a market saturated with these alternatives.

This study focuses on Assam, India, to highlight the challenges that may arise post-single-use plastic ban enforcement, considering factors such as cost, demand, and utility. The transition to compostable plastics will create the need to manage two separate plastic waste streams, raising questions about their long-term viability and environmental implications.

PLASTIC POLLUTION

Plastic pollution is a critical environmental issue that stems from the extensive use of plastic materials, especially single-use plastics and packaging. This widespread pollution poses a significant threat to our planet, contributing to contamination of water, air, and land. Microplastics have been discovered in marine species and even in the water we consume, raising concerns about their impact on human health[7-12]. Moreover, plastic production is deeply intertwined with climate change[3]. Greenhouse gas emissions occur at every stage of the plastic life cycle, from raw material extraction to manufacturing and waste disposal[4]. In 2019, plastic production and conversion were responsible for 1.8 billion tonnes of greenhouse gas emissions, a figure projected to double by 2060, exacerbating global warming[5,6]. To address this complex problem, it is imperative to implement solutions such as utilizing renewable resources for plastic production, adopting cleaner energy sources, reducing single-use plastics, fostering a culture of reuse, and enhancing plastic recyclability. Tackling plastic pollution is vital not only for environmental preservation but also for mitigating the climate crisis.

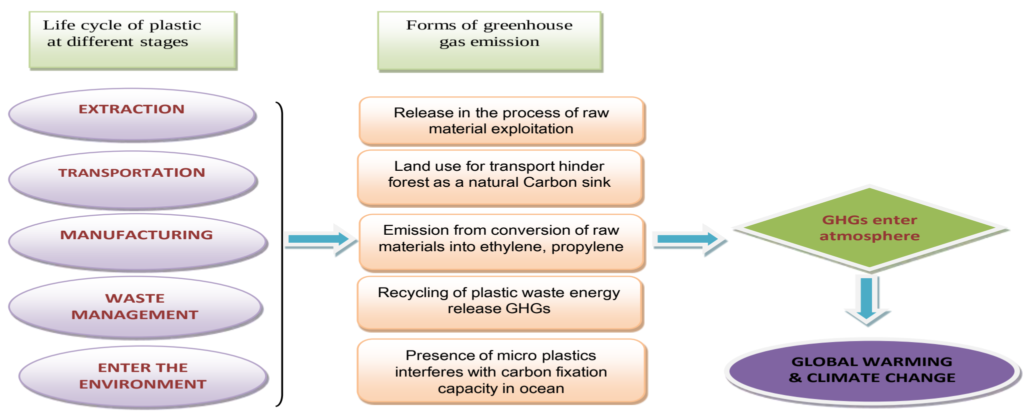


Figure 1 Graphical representation of how plastic contributes to emissions from the beginning to end of its life cycle

PLASTIC WASTE MANAGEMENT

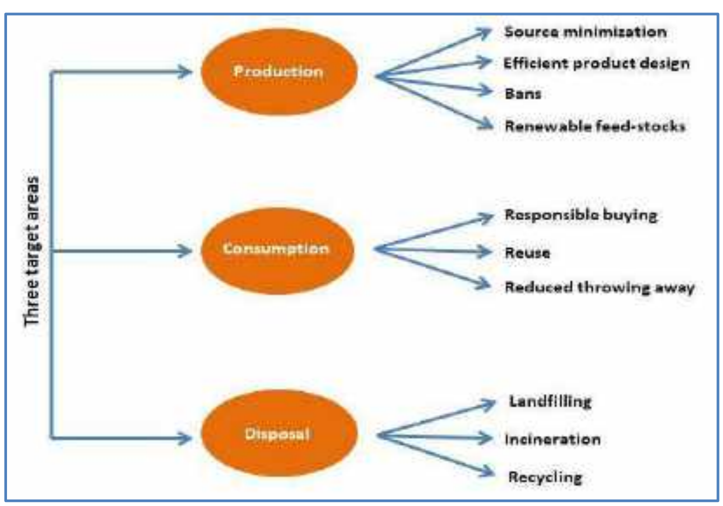


Figure 2 Plastic waste management by targeting plastic production, consumption and disposal

Present-day plastic waste management suffers from various constraints and challenges right from their collection to their disposal –

Low efficiency at collection level ⇒ Improper segregation of source ⇒ Insufficient transportation ⇒ Inefficient Recycling ⇒ Unsecured land filling

Inefficient collection and lack of source segregation

Municipal solid waste (MSW) forms the bulk of total post-consumer waste generated in any urban area. In India, a key role is played by municipalities/local authorities in regulating the daily MSW flow which mainly includes setting-up and managing door-to-door collections. The onus of collection of such waste resides on garbage collectors and municipal workers who are severely underpaid, overworked and not very skilled. This amounts to low or irregular waste collection from such areas. Illegal practices such as open burning of wastes not only degrade the air quality of the area but also lead to loss of valuable plastic material that could be recycled. The situation gets worse when you move away from cities to smaller towns and villages which have no to very little planned waste collection systems.

Lack of proper infrastructure facilities

Although increasing in number, there is a huge lag in plastic waste processing and recycling units as compared to the waste generated in India. For efficient waste management, it is important to have high-end infrastructure for mechanical waste sorting, washing and various other downstream processes so as to reduce dependence on manual labour and make the entire process cost-effective and fool-proof. The setting up of such kind of infrastructure entails huge cost expenses and thus relies highly on government intervention through subsidiaries and incentives. Again, a lot of states entirely lack recycling facilities and their waste is either burnt or land filledor sent to other states for processing. This leads to an additional cost of transportation. The building of waste infrastructure, in line with environmental policy, faces a large variety of social acceptance issues. In order to meet the challenging objectives and strategies of solid waste management system several factors must be taken into consideration. Informed local debate is an essential first step to building high quality national infrastructure that takes public participation beyond the consultation stage. Public perception must be taken on account in the early decision making process along with the role of public communication in the delivery of waste facilities[13].

Boragaon Dumping site- issues due to lack of improper waste management

From 2006, the GMC (Guwahati Municipal Corporation) started to dump waste in West Boragaon, close to the water body of Deepor Beel. It holds more than 70% of the total waste generated and as the site is not an engineered landfill, there are no strategies or tactics in place to ensure the proper and safe disposal of waste. The solid waste management plant has capacity of only 10 tonnes, which is not sufficient for segregation of wastes and hence the land-filled area gradually increased in size due to increase in the amount of waste collected from the city. Hence it is essential to study such issues as open dump sites are also responsible for various environmental and health hazards[14].

Plastic Recycling

Plastic recycling plays a crucial role in mitigating the ecological and environmental impacts of plastic waste. Recycling involves converting plastic waste into raw materials for producing new plastic products. While only a small fraction of plastic waste is currently recycled, it offers several benefits. Recycling reduces the ecological burden caused by chemical leaching in landfills and greenhouse gas emissions from incineration. It also lowers energy consumption and decreases dependence on petroleum as a raw material. Recycling contributes to three key objectives: mitigating climate change, reducing ecosystem damage from plastic litter, and promoting a circular economy that conserves natural resources.

Pre-consumer plastic waste is particularly valuable as it requires minimal processing and is free of extraneous impurities. In contrast, post-consumer plastic waste is often mixed with non-plastic materials, necessitating cleaning and separation, which increases recycling costs[15]. Effective waste management relies on segregating dry and wet solid waste at the source and building recycling infrastructure[16].

However, recycling mixed plastic waste, like multi-layered packaging and barrier coatings, presents challenges. Such materials often end up as waste-to-energy fuel because they can't be processed through regular recycling streams. Additionally, the economics of plastic waste recycling are challenging. Collection and recycling costs often exceed the revenue generated from selling recycled items, posing a dilemma for governments and businesses.

To address these challenges, governments, including the Government of India, have introduced extended producer responsibility (EPR) guidelines to promote post-consumer plastic recycling and set recycling targets for plastic producers and brand owners. These efforts represent steps in the right direction, aligning with the need to reduce single-use plastics to achieve a more sustainable and circular economy[17].

Collection and sorting

The recyclers don’t have their own collection system. All the recyclers receive the materials from informal waste pickers or directly from industries in case of industrial waste. The materials are sorted manually in the plant before recycling. Rigid plastics are comparatively easier to handle as they can be typically grounded and washed. However sorting and cleaning of flexible plastics contaminated with impurities especially organic food waste is a very difficult and expensive task. Cross contamination of various types of plastics will lead to degradation of the recycled plastic. Most of the recyclers do not process post consumer flexible plastic packaging due to difficulties in sorting and cleaning. Few of the recyclers which do process post consumer flexible plastics also need much larger portion of clean pre consumer wastes to maintain the quality of the recycled products.

Marketing of recycled products

The PP granules are mostly marketed to local plastic goods manufacturers. Based on the quality of recycled granules specified by the customers, most recyclers have to mix virgin plastic granules in the plastic waste to maintain the desired quality. Some recyclers also produce plastic items like ropes, plastic sheets etc which are mostly marketed within the state.

Single Use Plastics and its Alternatives

SUPs are defined as plastic products that are used only once before being disposed. Recognising the fact that SUPs create a gap in circular economy, regulatory tools and voluntary actions to reduce SUP usage have been introduced globally. Recently in India, the Union Government has banned the manufacture, import, stocking, distribution, sale and use of nineteen such SUP items, which have low utility and high littering potential. Due to irresponsible handling and technological lag, such plastic waste can lead to disastrous consequences such as persistence in marine and soil environment, percolation to food chains and consequent ingestion by animals, release of harmful chemicals and gases etc. causing drastic ecological and economic loss. To circumvent the challenges posed by SUPs, there has been a growing trend of the use of sustainable alternatives that are derived from bamboo, agricultural waste, wood, paper etc. However, over-reliance on one such alternative can increase the pressure for one particular type of feed-stock, jeopardizing the current agricultural system.

Biodegradable and compostable plastics

Biodegradable plastics can be decomposed by the action of living organisms, usually microorganisms into simpler compounds like water, carbon dioxide and biomass. According to international standard bodies such as ASTM and ISO, compostable plastics are those that degrade biologically at a rate that is consistent with other compostable substances under controlled environmental conditions to yield water, carbon dioxide, biomass and inorganic compounds. Compostable plastics are derived from either renewable or fossil fuel-based sources. Common bio-based or renewable source-based compostable plastic polymers include polylactic acid (PLA), polyhydroxyalkanoates (PHA) and thermoplastic starch (TPS) whereas common fossil fuel-based polymers include poly (butylene succinate) (PBS), poly (butylene adipate terephthalate) (PBAT), poly (ε- caprolactone) (PCL) and poly (vinyl alcohol) (PVA) [18]. PLA is derived from renewable sources such as corn, wheat and rice and have better thermal processability compared to PCL, PHA etc[19]. Biodegradable and compostable plastics are expected to replace a large part of conventional plastic carry bags and SUP.

Compostable Plastic Waste Management and Industrial Composting

An industrial composting facility completely disintegrates organic waste at a high temperature in the presence of oxygen and organic substrate within a period of three months. Microorganisms use the waste material as their substrate breaking it down into carbon dioxide, water and biomass. The temperature in an industrial composting facility goes up to 50-60°C. Industrial composting consists of two distinct phases – active composting (rotting) which is followed by curing (post rotting), at the end of which the waste turns into a mix of humic substances [20]. Industrial composting not only creates value for the circular economy, it also prevents the release of harmful methane gas from organic waste due to land filling. Products made of compostable plastics have to conform to international or national standards such as ASTM 6400, ISO 17088 or EN13432 [21,22]. It is also to be mentioned that although it is important for compostable plastics to check specifications such as complete disintegration and return to nature, the entire duration of the process depends on the thickness or volume of the products.

MATERIALS AND METHODS

Materials used

a) Compostable plastic granules (PLA+PBAT blend) sourced from SKYi Innovations LLP

b) HDPE granules sourced from CIPET

c) LDPE granules (reprocessed) source from M/s Kusum Udyog, Rangia

SAMPLE PREPARATION

Extrusion Process

Equipment name- Single screw extruder

In the extrusion process, the plastic granules are loaded into hopper by means of gravity into the barrel under the action of rotating screw thrust and continue to gradually move forward from the preheat section to the homogenization section. Under the provision of temperature, the plastic from solid state is converted to molten state and is shaped and drawn into an extrudate of desired cross-section.

For the study, four different kinds of blends were prepared. Homogenous mixture was prepared with the help of single screw extruder (extrusion temperature used for HDPE, HDPE 90% + compostable 10% and HDPE 70% + compostable 30% was 170^0C, 165^0C and 160^0C respectively while the temperature used for LDPE, LDPE 90% + compostable 10% and LDPE 70% + compostable 30% was 150^0C, 150^0C and 145^0C respectively).

Sheet Preparation

Equipment name- Compression moulding machine

Sheet preparation of plastic by compression moulding is a forming process in which a plastic material is added to a metal mould and using heat is conformed to the shape of the mould. Thus, using appropriate temperature and pressure, plastic sheets of fixed dimensions are obtained.

3-4 mm sheets were prepared in compression moulding machine (Temperature: HDPE- 170°C, LDPE-150 °C & 40 T force). These sheets were used for further study.

Tests Performed

IzodImpact Resistance

Equipment used- Universal Testing Machine

The impact test is conducted to check the toughness of a material. The IZod impact test specified by ASTM D 256 standard method is used to determine the impact resistance of materials. This method consists of breaking the specimen, designed with the help of a notch cutter, by one blow from a swinging hammer under specific condition. When the striker strikes the specimen, it absorbs energy and initiates fracture until the specimen is broken. This absorbed energy is a measure of a given material's toughness.

TENSILE STRENGTH AND ELONGATION AT BREAK

Equipment used- Universal Testing Machine

Tensile strength refers to the ability of a material to withstand the force that tends to pull it apart and the extent of deformation before breaking. It is usually done to indicate the strength of the polymer. The dumbbell shaped test sample's deformation is used for determining the tensile properties of a material or component as well as to characterize its ductility or brittleness and important characteristics such as yield point, elastic limit, % elongation, elastic modulus and toughness. The test was conducted as per test method prescribed in ASTM D 638.

OIT (OXIDATIVE INDUCTION TIME)

Equipment used- Differential scanning calorimeter (DSC-8000)

This method is used to measure the level of thermal stabilization of the sample. The polymer is oxidised in the atmosphere in the presence of oxygen which has a negative effect on its mechanical strength and electrical property. The oxidation decomposition starts from low temperature followed by thermal decomposition in the inert gas.The sample is placed in a sample pan along with a reference pan without the sample on the DSC cell. It is covered with thermal lid, followed by a metal lid and a glass lid for air tight sealing. Nitrogen gas is introduced and the first isothermal track is done for 5 minutes. A point is marked which is considered as the start point for OIT calculation. After this point, gas is changed from nitrogen to oxygen. The isothermal track is run until exothermic point is reached. Procedure as specified in ASTM D 3895 was followed for the test.

RESULTS AND DISCUSSION

Table 1 The tensile strength of virgin HDPE, virgin LDPE and their blends with compostable granules

Sl. no	**Test specimen**	**Result obtained (MPa)**	**Reduction (in %)**
1.	HDPE virgin	23.51	
2.	HDPE 70% + compostable 30%	13.61	41.85
3.	HDPE 90% + compostable 10%	17.67	24.84
4.	LDPE virgin	8.75	
5.	LDPE 70% + compostable 30%	7.38	15.65
6.	LDPE 90% + compostable 10%	7.71	11.94

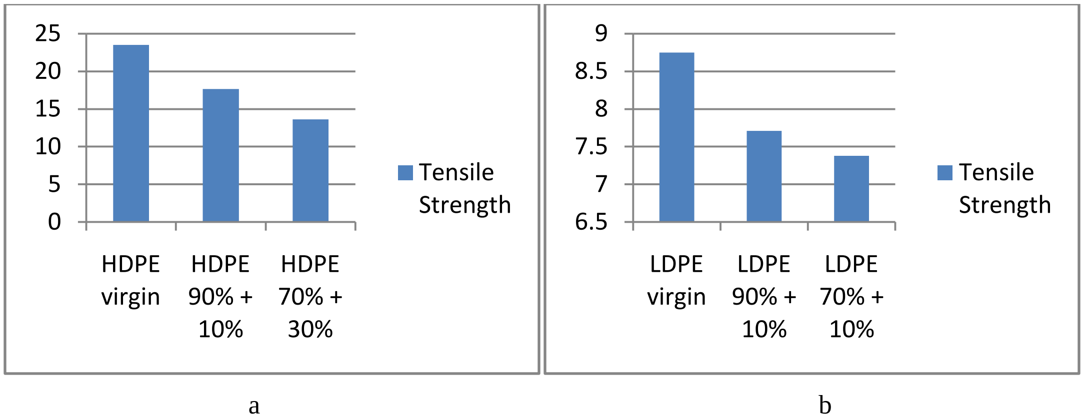


Figure 3 (a) and (b) shows the comparison of the tensile strength for virgin granules of HDPE and LDPE and their blends with compostable plastic.

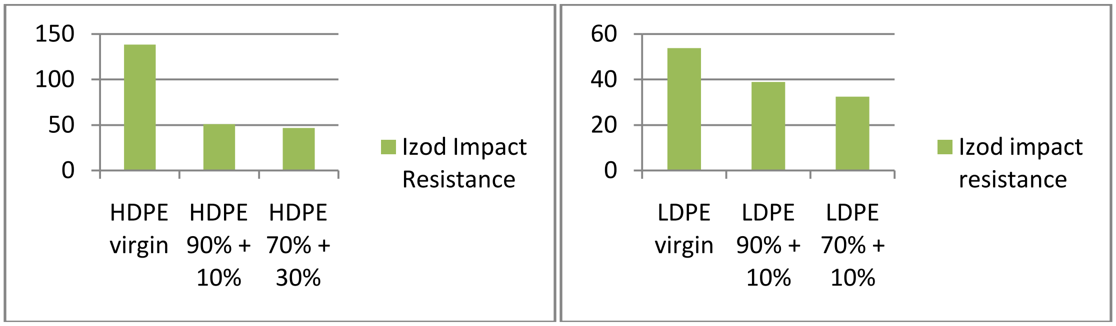
Table 2 The percent elongation at break for virgin HDPE, virgin LDPE and their various blends

Sl. no.	Test specimen	Result obtained (%)	Reduction (in %)
1.	HDPE virgin	100.0	
1.	HDPE 70% + compostable 30%	17.33	82.67
3.	HDPE 90% + compostable 10%	60.0	40
4.	LDPE virgin	226.67	
5.	LDPE 70% + compostable 30%	12.0	214.67
6.	LDPE 90% + compostable 10%	12.0	214.67

Figure 4 (a) and (b) shows the comparison of the percent elongation for virgin granules of HDPE and LDPE and their blends with compostable plastic

Table 3 The impact strength of virgin HDPE, virgin LDPE and their various blends

Sl. no	Test specimen	Result obtained (J/min)	Reduction (in %)
1.	HDPE virgin	138.25	
2.	HDPE 70% + compostable 30%	17.33	66.20
3.	HDPE 90% + compostable 10%	60	63.08
4.	LDPE virgin	226.67	
5.	LDPE 70% + compostable 30%	12	39.64
6.	LDPE 90% + compostable 10%	12	27.69

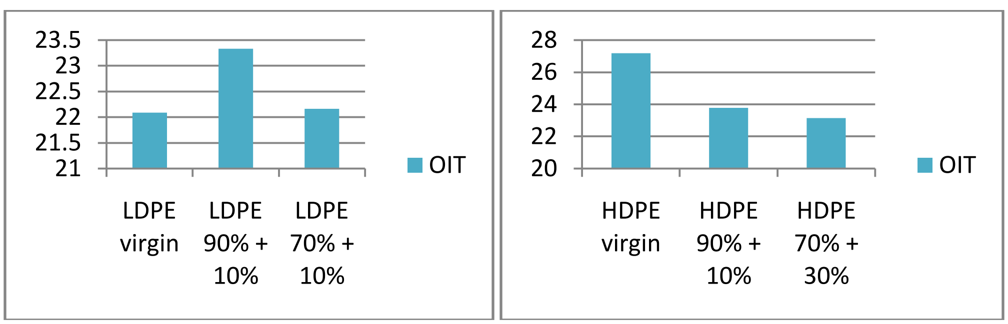


a b

Figure 5 (a) and (b) shows the comparison of impact strength of virgin granules of HDPE and LDPE and their blends with compostable plastic

Table 4 The OIT values for virgin HDPE, virgin LDPE and their various blends

Sl no.	Test specimen	Result obtained (min)	Change (in %)
1.	HDPE virgin	27.18	
2.	HDPE 70% + compostable 30%	23.14	14.86
3.	HDPE 90% + compostable 10%	23.78	11.84
4.	LDPE virgin	22.09	
5.	LDPE 70% + compostable 30%	22.16	0.07
6.	LDPE 90% + compostable 10%	23.33	1.24



a b

Figure 6 (a) and (b) shows the comparison of OIT values of virgin granules of HDPE and LDPE and their blends with compostable plastic

The tensile strength of the blends of the HDPE and LDPE granules was found to have decreased from that of the virgin granules by 41.85 % (7:3 HDPE and compostable), 24.84% (9:1 HDPE and compostable), 15.65% (7:3 LDPE and compostable) and 11.94% (9:1 LDPE and compostable). The decrease in percent elongation on blending with compostable plastic was more in case of LDPE (12.0 % from 226.67 %) as compared to HDPE and was constant for both ratios of blends. This means that the mixing of compostable plastic decreases the strength and ductility of the output product. Hence, the product will be brittle and fracture easily. Also the impact resistance was found to have decreased on blending as well but here, it was more pronounced in case of HDPE granules (a reduction in the range of 60-63 %). The OIT value of HDPE i.e. thermal stability was found to have decreased by around 11-14 % but that of LDPE increased slightly.

Different types of plastic resins are immiscible and have different recycling requirements. The compostable plastic and conventional plastics have different melting point and properties. When equal amount of compostable plastic granules was mixed with LDPE and HDPE granules, a homogeneous extrudate could not be produced in the extruder. After decreasing the temperature of extruder and percentage of compostable plastics to 30% & 10%, it was possible to obtain extrudate of uniform cross section. However the plastic obtained was of much lower quality than the original LDPE and HDPE plastics. The results clearly indicate that presence of small percentage of compostable plastics degrades the quality of recycled plastics. The plastic granules used in the tests were of virgin grade. In case of recycling of post-consumer plastics, the presence of impurities and degradation in quality of the post-consumer waste due to exposure to sunlight, humidity etc. will further degrade the quality of recycled plastic. Therefore if post-consumer plastics are contaminated with compostable plastics, then there is no scope for closed loop recycling which is practiced by almost all the recyclers in the state of Assam. It can be used only for producing less valuable products such as filler materials.

The survey reveals that the rate of recycling of post-consumer packaging materials and carry bags is very low. All the recyclers have to capacity to process low quality post-consumer packaging materials including MLP and carry bags with their current set up or with little modifications. Therefore the issue with recycling is not a technological issue but it’s a management and economic issue. The present scale at which the recyclers are operating, the profit margins from recycling of poor quality post-consumer plastics is too low to make the business economically viable. Due to limited market for recycled plastic in the state of Assam, recyclers are limiting themselves to recycling industrial plastic waste. The large quantity of post-consumer MLPs, carry bags, SUPs and other packaging materials thus remains out of the recycling stream. The recyclers understand that the vast quantities of un-recycled plastic wastes can be a very valuable resource. But for that they need to scale up their operations and access the markets outside of the state which again shall require huge investments and additional risks.

Now that the implementation of EPR is being taken very seriously by the Government, the recyclers sees it as an opportunity to scale up their operation in order to process poor quality post-consumer plastics including MLP. By changing the size of the filters of extruder and upgrading their cleaning and washing system, the existing plant can easily process all kinds of plastic waste to yield products of marketable quality. The funding from plastic producers under EPR will offset additional operating costs and ensure that sufficient flow of plastic waste to the recyclers.

However the recyclers will face a new problem in the form of presence of compostable plastics in the plastic wastes. With the decrease in costs of compostable plastic granules and new legislations restricting usage of conventional plastics for certain products, the market will see a huge rise in compostable plastic items. Production of items like compostable SUPs and carry bags are likely to see huge rise. Apart from economics of recycling, one of the major issues of plastic recycling is availability of segregated plastics. Contamination of a particular plastic waste stream with compostable plastics will create new challenges in recycling of post-consumer plastic packaging. The risk of contamination of plastic waste with compostable plastics will discourage the recyclers from processing post-consumer carry bags, flexible plastic packaging materials and SUP items. Indirectly, compostable plastics have a potential to pose a huge risk to the plastic recycling sector.

FUTURE PERSPECTIVES AND CONCLUSION

Overall compostable plastics can prove to be good alternative to conventional plastic. Throughout its life cycle, compostable plastics will have lower carbon footprint than conventional plastics and its disposal will discharge lesser pollutants into the environment. But compostable plastics alone cannot provide solution to the plastic waste management problem. Unless a proper management system is put in place, compostable plastics have a potential to disrupt the already deficient plastic recycling sector. Distinct marking and labeling of compostable plastics along with intensive mass awareness among plastic users and waste pickers shall be required to ensure that compostable and conventional plastic to not cross contaminate each other. To reduce intermixing, manufacture of plastic packaging should be regulated by designating specific usage for compostable and conventional plastics. plastic packaging that have generally lower probability for contamination and having high rates of recycling can be made of conventional plastics, while the compostable plastics can be used for packaging which is likely to be contaminated with organic waste and difficult to recycle . Waste management agencies shall also have to develop industrial composting facilities of sufficient capacities to process the large quantities compostable plastic waste which is expected to be generated in near future. Sourcing enough quantity of biomass for production of compostable plastics is also a matter of concern, although it will require a separate elaborate research to come to any conclusion. Ultimately down gauging shall be essential for attaining sustainable and circular economy. Even though Compostable plastics and other eco-friendly alternatives to plastic packaging and SUPs are biodegradable, management of these wastes is also an issue. Using less packaging material for a commodity as well as reducing usage of single use plastic items will decrease the volume of waste. Instead of searching for alternatives to single use plastics, getting rid of single use items with very low utility is the most sensible solution.

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ELECTRONICS & TELECOMMUNICATION ENGINEERING DIVISION

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Improved Gain and Directivity in Wireless Microstrip Antenna with Ring Reflector

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Abstract: This paper introduces a groundbreaking compact star-shaped microstrip patch antenna with co-planar waveguide ports fabricated on FR-4 substrate. The proposed antenna exhibits a remarkable fractional bandwidth of 35.735%, covering the frequency range from 3.79 to 5.439 GHz. At the resonant frequency of 4.421 GHz, the highest reflection coefficient (|S11|) is recorded at an impressive -19.306 dB. To further enhance performance, a square-shaped ring array reflector, comprising 9x9 units, is strategically integrated with the antenna design. This addition leads to a substantial improvement in both Gain and directivity. With the loaded reflector, the antenna achieves an exceptional peak gain of 8.375dBi and a peak directivity of 8.838 dBi at 5 GHz, compared to the baseline gain of 2.22 dBi and directivity of 2.5 dBi in the absence of the reflector. Optimal adjustment of the antenna and reflector plane spacing results in the attainment of maximum achievable Gain and Directivity for the proposed design. The physical dimensions of the antenna measure 59×59×10.035 mm³, offering a compact yet powerful solution. Additionally, the antenna demonstrates a bidirectional radiation pattern, showcasing its versatility for various applications. This innovative microstrip antenna configuration holds great promise for a wide range of wireless communication systems, presenting an exciting avenue for further research and development in the field.

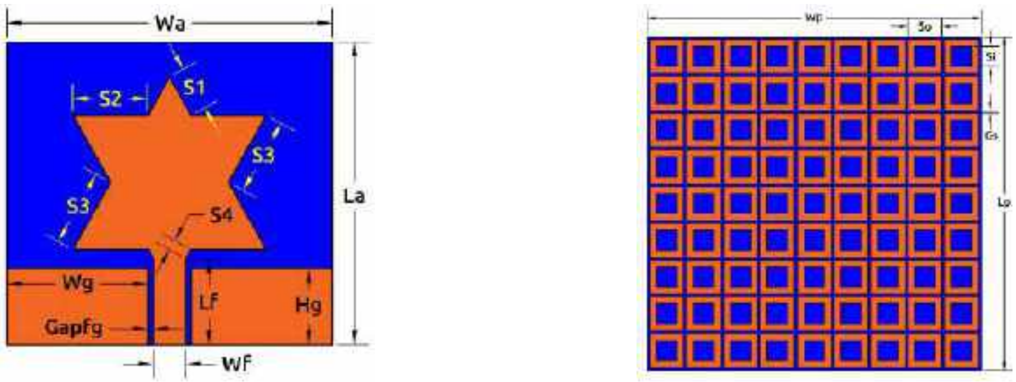
Keywords: Microstrip Antenna (MSA), Gain, Directivity, Reflector Plane.

INTRODUCTION

In addition to the advantages of monopole antennas, the microstrip antenna is compact, low profile, and simple in design, and it can be easily inserted into a circuit board with no effort. Many wireless applications cannot be employed due to difficulties such as insufficient bandwidth, low Gain, and poor directivity, among others. Despite intensive development over the past three decades, microstrip patch antennas have a poor gain compared to other types of antennas. Gain is typically capped at about 5-8 dBi when standard material substrates are used. High-gain planar radiating apertures with a low side lobe level (SLL) have several practical uses [1-4]. Millimeter-wave wireless systems, for instance, have garnered a lot of interest in recent years owing to the persistent need for high data rates. Because of the large propagation loss experienced by short-range wireless communications such as Wi-Fi, printed antennas with high Gain are necessary; as a result, the millimetre wave unlicensed band at 60 GHz is the chosen frequency. Techniques for increasing the Gain of microstrip patch antennas may be classified into many categories: Utilizing low-dielectric-constant substrates like foam or honeycomb, 1) utilizing array design, 2) employing metasurface, 3) employing fractal boundary antenna, and 5) employing reflecting surface patterns are some of the methods for achieving this. Foam and honeycomb substrates are less common than other substrates because of their complexity and high cost. Partially reflective surfaces (PRS) have attracted much attention in recent years [5-8] for their potential use as superstrates in high gain planar antenna construction. Depending on the specifics of their design, these antennas may be referred to as Fabry-Perot cavity antennas or Cavity resonance antennas. These antennas do not need a sophisticated feed network, giving them an edge over conventional microstrip arrays. A significant amount of Gain has been realized using this setup [9-12]. Obtaining good Gain, which enhances the total antenna profile, can only be accomplished by positioning the PRS superstrate at an elevation of about 0.5 above the ground plane. Various studies have looked at methods to minimize profile by employing AMCs and metamaterial on top of AMCs [13-15], and the results have been promising.

ANTENNA DESIGN

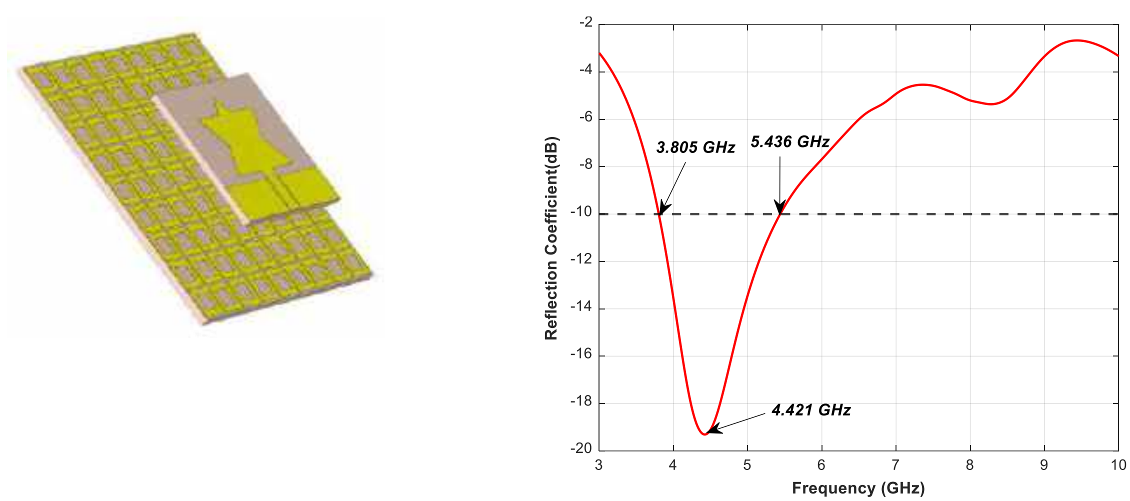
Figures 1(a) and **(b)** depict the optimal suggested antenna construction as well as the characteristics of its reflection coefficient. In order to create the Star-Shaped Microstrip Antenna with Square-Shaped Ring 9x9 Array Reflector, FR-4 material with thickness of 1.6mm, loss tangent of 0.02, and dielectric constant of 4.3 has been used. Patch antenna impedance matching is accomplished by feeding a star-shaped radiating element off of a 50-ohm microstrip feed line, according to the antenna geometry.A coplanar rectangular shape structure has been inserted on both sides of the feed for the ground element. The patch and ground planes of the proposed antenna are coplanar, and a coplanar waveguide feed (CPW) port is used to provide the antenna's power.



(a) (b)

Figure 1 (a) The structure of Star Shaped Microstrip CPW Antenna (b) Square Ring Grid Reflector Plate

The antenna's impedance matching between the radiating patch and the ground was optimised by adjusting the size of the radiating patch, the width of the feed line, and the size of both sides of the ground. This optimisation is crucial for achieving good reflection coefficient characteristics. The total physical dimensions of the planned antenna are 32 x 30 × 1.6 mm^3.



(a) (b)

Figure 2 (a) Composed of a square-shaped 9x9 array reflector and a star-shaped microstrip CPW antenna, (b) Reflection Coefficient characteristics ($|S_{11}|$) of Circular Shaped Microstrip CPW Antenna loaded with reflector

The information regarding each optimised dimension is detailed in Table I. An additional square-shaped 9x9 array reflector was incorporated into the intended antenna in an effort to increase its gain and directivity. The proposed antenna configuration has a total area of 59 × 59 × 11.635 mm^3. The reflection coefficient properties of this antenna are illustrated in Figures 2(a) and (b), correspondingly.

Table 1 Detailed Dimension of the Presented Antenna

Dimension	Value(mm)	Dimension	Value(mm)
W_a	32	W_p	59
L_a	30	L_p	59
S_1	4.35	W_g	13.88
S_2	7.39	S_o	6
S_3	7.61	S_i	3.6
S_4	1.05	G_s	0.5
W_f	3.2	H_g	7.6
L_f	8.53	Gap	10
Gap_{fg}	0.5	h	1.6

RESULT ANALYSIS AND DISCUSSION

In order to achieve a broad frequency range, the antenna design parameters were adjusted to produce favourable characteristics of the reflection coefficient, a reduced cut-off frequency of 3.79 GHz, and an increased cut-off frequency of 5.439 GHz. It has been determined that one of the resonance frequencies (4.421GHz) possesses the greatest maximal reflectivity coefficient ($|S_{11}|$). The constructed antenna is illustrated in Figure 3, while a comparison of the reflection coefficient obtained from experimental evaluation is presented in Figure 4.

Fractional Bandwidth Calculation

The antenna design has yielded a fractional bandwidth of 35.735% within the frequency range of 3.79 to 5.439 GHz, as shown by the simulated results presented in equation (1).

$$\mathrm{FBW} = 2 \times \left(\frac{f_H - F_L}{f_H + F_L}\right) \% \tag{1}$$

$$= 200 \times \left(\frac{5.439 - 3.79}{5.439 + 3.79}\right) \%$$

$$= 200 \times \left(\frac{1.649}{9.229}\right) \%$$

$$\mathrm{FBW} = 35.735\%$$

Reflection Coefficient Characteristics

From 3.68 to 6.06 GHz, the return loss of an antenna without a reflector was studied and observed. f_{r1}=4.631GHz was determined to have a maximum return loss ($|S_{11}|$) of -27.917 dB at these frequencies.

The investigation and observation of the return loss characteristics of the antenna with a reflector have been conducted throughout the frequency range of 3.79 to 5.439 GHz. Resonating frequencies were found to have the highest return losses ($|S_{11}|$) of 19.306 dB at f_{r1}=4.421 GHz.

Antenna 2D E-Field and H-Field Radiation Pattern

The similarity between the antenna's 2-dimensional radiation pattern at frequencies of 4, 4.5, 5, and 5.5GHz and that of the 9x9 array reflector is seen in **Figure 5**. Ten millimetres separate the antenna from the reflector.

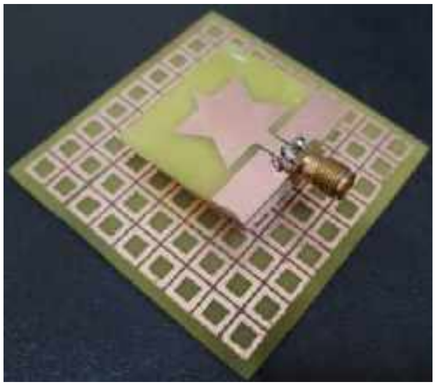


Figure 3 Fabricated Antenna

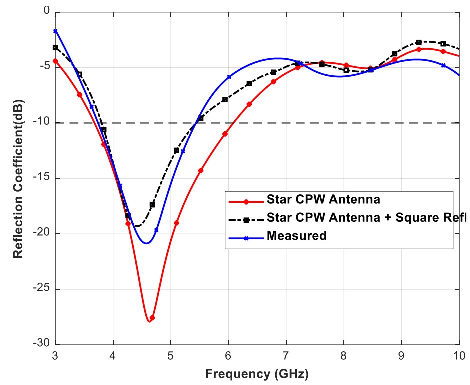
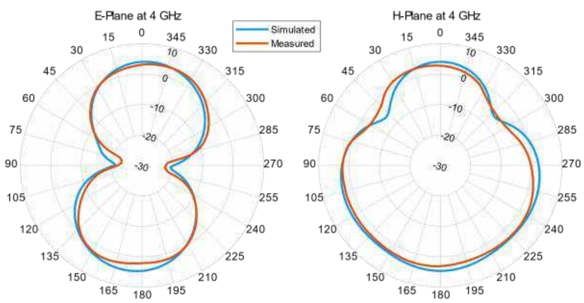
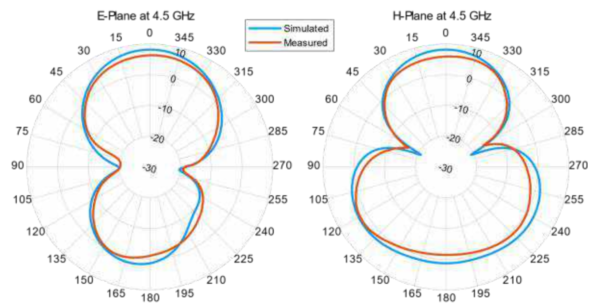


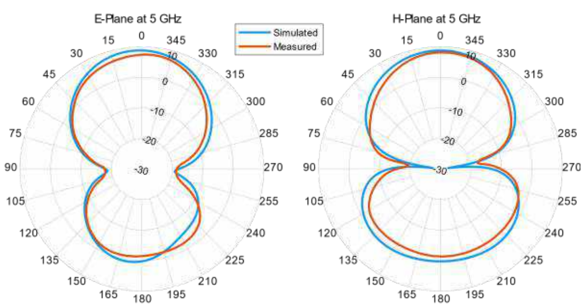
Figure 4 Fabricated Antenna



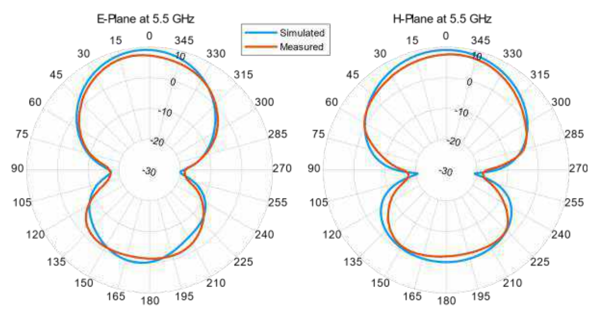
(a)



(b)



(c)

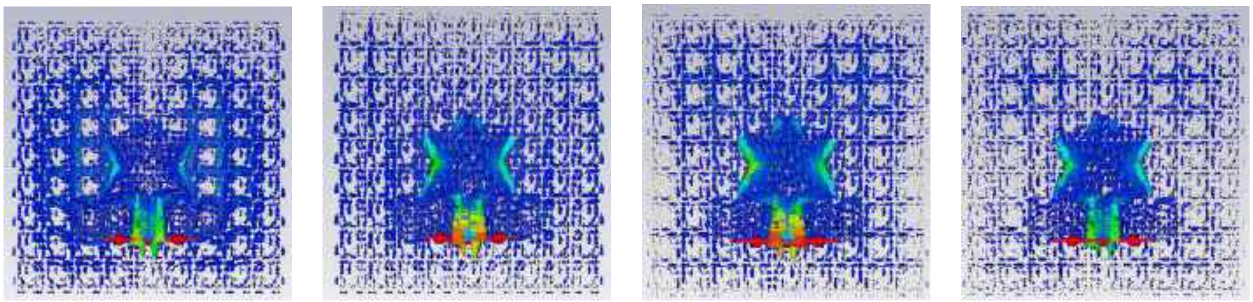


(d)

Figure 5 2D view of Radiation Pattern E-Field and H-field at (a) 4, (b) 4.5, (c) 5 and (d) 5.5 GHz frequency.

Surface Current Distribution of Antenna

The suggested antenna's surface current distribution has been looked at at (a) 4.5 GHz, (b) 5 GHz, (c) 5.5 GHz, and (d) 6.5 GHz frequencies, as shown in Figure 6.At 4.5 and 5 GHz, the microstrip feed line has a concentration of current vectors, whereas the other frequencies have a dispersion.



(a) (b) (c) (d)

Figure 6 shows how the antenna's surface current is spread out at (a) 3, (b) 4, (c) 5, and (d) 6 GHz.

Pattern of 3-D E-Field and H-Field Radiation from the MMES Antenna

Figure 7 depicts the 3-dimensional radiation pattern view of an antenna used in the building of a square 9x9 array reflector using CST. There is a distance of 10 mm between the antenna and the reflector.

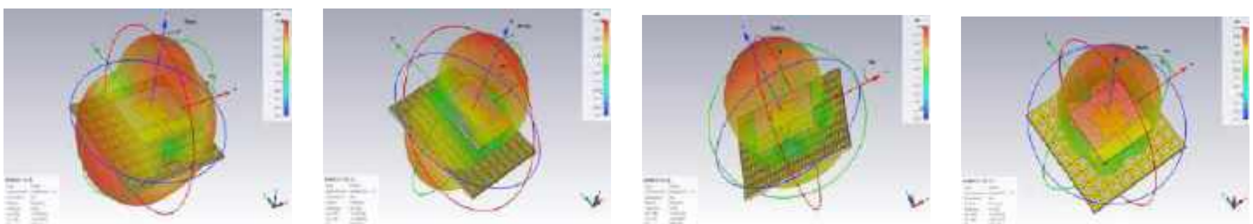


Figure 7 3D view of Radiation Pattern with antenna structure at 4, 4.5, 5, 5.5 GHz frequency

Voltage Standing Wave Ratio

The VSWR of the MMES antenna was assessed within the frequency range of 3.79 to 5.49 GHz, yielding a value below 2. This observation suggests that the anticipated performance of the antenna aligns with the characteristics shown in **Figure 8**.

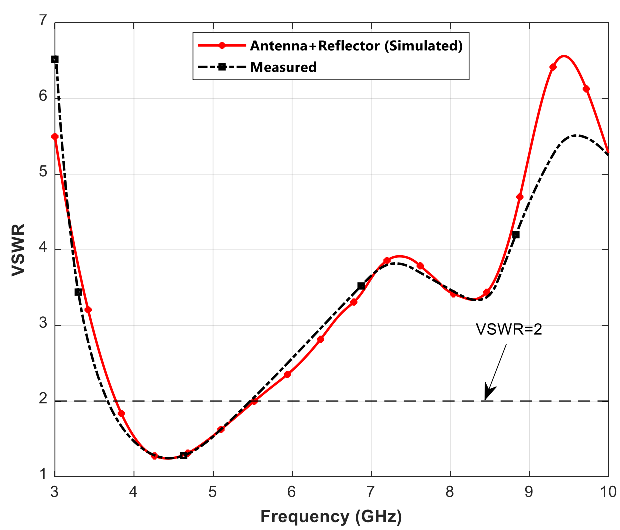


Figure 8 VSWR of Antenna

Gain and Directivity Performance of Antenna

The findings shown in **Figures 9** and **10** indicate that a small star-shaped microstrip patch antenna has notable potential for implementation in wireless applications spanning the frequency range of 3.79 to 5.439GHz, including WiMAX and WLAN. This antenna showcases a peak gain of 9.22dBi and a directivity of 8.838dBi, making it a formidable contender in these domains.

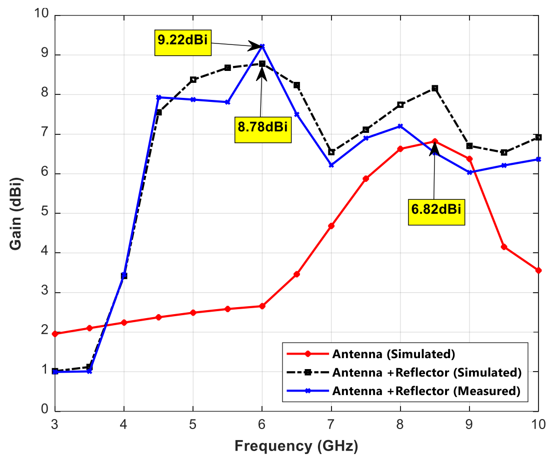


Figure 9 Antenna Gain

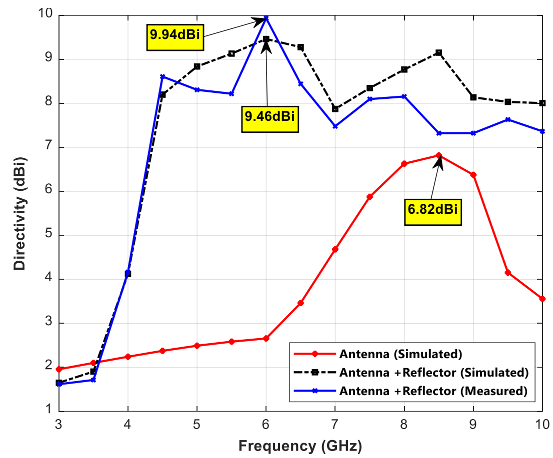


Figure 10 Antenna Directivity

The Efficiency of an Antenna

The plot depicting the effectiveness of the antenna. The proposed antenna exhibits a radiation efficiency of 90% within the frequency range of 5–5.5 GHz, while achieving an overall maximum efficiency of 85% specifically at 5 GHz.

Table 2 presents a comparison between the Gain and directivity of the proposed antenna and another high gain antenna.

Table 2 Comparison of proposed antenna gain with existing high gain antennas

Ref	Technique/ Structure	Dimention Size (mm)	F_{low} to F_{High}	Peak Realized Gain
[15]	DGS, Monopole	28.03x23.45x5.35 mm^3	4.775 to 5.049 GHz	5.49dB (G) 7.12dB (D)
[14]	CPW, AMC	34x30mm	2 to 2.6 GHz	6.68 dBi
This Work	CPW,FSS	59x59x10.035 mm^3	3.79 to 5.439 GHz	9.22 dBi (G) 9.94 dBi (D)

CONCLUSION

This study looked at a square radiating patch with a star antenna. It uses the co-planner waveguide port (CPW) phenomena on an FR-4 substrate. The proposed antenna's fractional bandwidth ranges from 3.79 - 5.439GHz. The highest reflection coefficient ($|S_{11}|$) -19.306dB is found at 4.421GHz, as does the resonance frequency. A 9x9 array reflector plane below the antenna was added for improved Gain and directivity. A filled reflector has 8.375 dBi peak gain and 8.838 dB peak directivity at 5 GHz. The antenna is 59×59×10.035 mm^3. The star-like patch antenna with microstrip demonstrates suitability for wireless applications within the frequency range of 3.79GHz to 5.439GHz, including but not limited to WiMAX and WLAN.

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Reimagining Tomorrow: Shaping the Future through Disruptive and Interdisciplinary Technologies

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Abstract: *Today's market conditions are creating challenging times for all players. Even though consumer revenue is historically high, margins are being squeezed by massive infrastructure investment. Competitions have been heating up from both traditional and non-traditional players. Customer expectations & the market have been shifting and a looming recession & regulatory pressure creating uncertainty.*

The relationship between technology and business has irrevocably transformed. From optimizing operations and harnessing data to elevating customer experiences and driving innovation, technology has become the cornerstone of success in the business world. Embracing new technology not only ensures operational efficiency but also positions businesses to lead the charge in a digitally-driven future. As the business landscape continues to evolve, the organizations that understand and leverage the power of technology will be the ones to thrive and shape the future of industries.

A digitally transformed business will be a future forward, connected, powered and trusted business, resulting in value driven business performance.

There may be similarities between industries, but each has its own unique set of challenges to solve. A strategic vision for future of each sector is hardly needed.

This compilation covers quite in detail about Reimagining Tomorrow.

Keywords:

1) *Shaping the future*
2) *Disruptive technology*
3) *Interdisciplinary Technologies*
4) *Telecom in reimagining tomorrow*
5) *Blockchain*

INTRODUCTION

Rapidly changing Global scenario, growing population, availability of minimum resources, demand-supply gap, technological requirements, huge investments etc. post a lot of challenges for industries in shaping their future and forcing to Reimagining.

Reimagining is to think about again, especially in order to change or improve.

Shaping the future means preparing the mind, the behaviour and the attitude for the future. The desired future has to create a value. Value creating activities that utilize the resources effectively tend to have a higher success rate. Innovation is the engine of development and value creation. Shaping the future through disruptive and interdisciplinary technologies are handled here in detail.

Disruptive Technology

Clayton Christensen Harvard Business School professor and business consultant, is called the Father of Disruptive Innovation, coined the term “disruptive innovation” in the magazine Harvard Business Review back in 1995.

Disruptive technology is an innovation that significantly alters the way that consumers, industries, or businesses operate. It sweeps away the systems or habits it replaces because it has attributes that are recognizably superior. With new technologies are being developed all the time, not all of them are disruptive. To be considered disruptive, a technology must meet certain criteria. First, it must be significantly different from existing technologies in the market. Second, it must be able to create a new market or significantly change an existing one and Finally, it must have the potential to displace established technologies or create new market leaders.

Disruptive technology is a development that allows a new player to service a lower market segment that incumbent players do not cover due to lower profitability. As the disruptive technology advances, the quality improves so that it supplants the incumbent in the more profitable high-end market.

There are two types of disruptive models:

1) Low end disruption, in which a company uses a low-cost business model to enter at the bottom of an existing market and claim a segment.
2) New market disruption, in which a company creates and claims a new segment in an existing market by catering to an under -served customer base.

Potential of Disruptive Technology

The potential of disruptive technology is often underestimated. This is because the technology itself is often misunderstood. Disruptive technology is not necessarily new or groundbreaking. Rather, it is technology that has the potential to disrupt an existing market or industry. This type of technology can be found in a number of industries, from transportation to healthcare. In many cases, disruptive technology is not initially adopted by the mainstream market. This is because it is often seen as too risky or unproven. However, over time, as the technology matures, it can gain mainstream adoption. This can lead to a number of benefits, including lower prices, improved quality, and increased competition. Disruptive technology has the potential to revolutionize an industry. It can make products and services better, faster, and more affordable. In some cases, it can even create entirely new markets.

Blockchain as an Example of Disruptive Technology

Blockchain is an example of disruptive technology, which refers to a new technology that significantly changes the way that business is conducted.

Blockchain is a distributed database that allows for secure, transparent and tamper-proof transactions. The technology is particularly well-suited for financial transactions, but it can be used for a wide range of other applications as well.

One of the most important features of blockchain is that it is decentralized, which means that it is not controlled by any single entity. This has a number of advantages, including increased security and transparency.

Blockchain is still in its early stages of development and it remains to be seen how far the technology will spread. However, it has the potential to revolutionize a wide range of industries and we are only just beginning to see its potential applications.

Blockchain technology is applied in a digitalized workflow to create shared, transparent, and more secure processes. It works like a chain of blocks in which all nodes are connected to each other, so it guarantees the traceability of any process, creating a unique registration network that reduces risks and costs.

Investing in Disruptive Technology

When considering an investment in a company that is developing a disruptive technology, it is important to do your research and to understand the risks involved. You should also keep in mind that these investments can be highly speculative and that there is no guarantee that the technology will be successful. With that said, investing in disruptive technology can be a great way to get in on the ground floor of an innovative new company. These investments can offer high potential rewards, but they also come with a higher degree of risk.

Some specific examples of disruptive technology are illustrated below.

1) 3D printing: It promises big advances in very diverse areas: electronic engineering, automotive, jewellery, architecture, regenerative medicine, and even in the food sector, with the printing of edible items. This technology represents a big change in the development of products and in its manufacturing process, as it allows us to quickly test an idea, continuously produce, and reduce costs in the construction of prototypes.

2) 5G and improved connectivity:Fifth-generation mobile connectivity is here, providing more incredible speed and higher quality video streaming. This increased speed will make remote working a more viable option because you have compatibility with previous versions of the protocols, higher global connectivity, more bandwidth and video capacity, tighter security controls, and more. There will be countless opportunities in this mobile networking field as it continues to grow and evolve.

3) Artificial Intelligence and Machine Learning: Artificial Intelligence (AI) is the combination of algorithms that are programmed so that a machine carries out actions that until now were carried out by humans, such as learning from data analysis or planning. Machine Learning is a discipline within the AI field that allows computers to learn for themselves and carry out tasks autonomously.

4) Automation and Robotics: It is seen the rise of drones, self-driving trucks, and robots in the manufacturing sector, but this is just the beginning. There have already been gigabytes of text written about how robotics is a disruptive force in the workforce, replacing humans with cheaper, more reliable machines. It's easy to find dire predictions of massive unemployment in the wake of a machine takeover. According to the above, over 120 million workers world-wide will need to be retrained over the next few years, owing to robots and AI.

While there will undoubtedly be some attrition in the labour force, the picture isn't as bleak as the prophets of doom would have been believed. After all, greater numbers of robots and automated systems mean more professionals to program and maintain them. Those kinds jobs pay more than simple assembly-line grunt work.

COVID-filled modern society and the unique demands demonstrate the potential usefulness of robots in administering care in assisted living situations, particularly for the elderly. Robots neither get sick nor spread infection, reducing risks for both the caregivers and their patients. Drones can handle contactless delivery of much-needed supplies such as medication.

5) Cyber Security Advances: Cybersecurity or technology security is the set of processes and tools that are implemented to save information that any device, program, or company generates. With the use of network systems, software, and applications, the execution of security protocols is necessary to protect confidential, private, or sensitive information.

6) Cloud Computing: Cloud services, also known as cloud computing, allow files to be saved on the internet without needing external storage equipment. This disruptive technology represents great advantages for companies because it allows users to enjoy management tools from any place in the world by just connecting from their device.

7) Virtual and Augmented Reality: When we speak about Advanced Virtual Reality, we associate this concept with entertainment. However, this technology represents an authentic revolution in many other areas. For example, at Repsol we are working with the Digital Twins technique to model our plants. This allows us to

create a virtual simulation model to be more flexible and agile in the face of possible changing circumstances.

8) Headless Tech.: It describes technology that allows businesses to decouple their front-end user interface from their back-end ecommerce data solutions. Amazon Alexa can be instructed to purchase and ship the latest Stephen King novel, by using headless tech.

Since survey report states it increasingly rising customer acquisition costs, the ecommerce world needs more innovative, cost-effective solutions that attract and retain new users. Headless tech can be that potential game-changer, providing would-be customers with a more engaging, less time-consuming shopping experience.

As this trend catches on, it will upend the entire ecommerce model, with businesses scrambling to incorporate headless tech or get left behind in the dust. Headless tech could make traditional ecommerce purchasing methods obsolete.

9) The rise of “As-a-Service “Computing: This computing model has been available for a while now. There are software-as-a-service (SaaS), infrastructure-as-a-service (IaaS), and platform-as-a-service (PaaS). These cloud-based, on-demand platforms have revolutionized the IT world. For instance, a physical copy of a video game or word processing utility need not be purchased, when can just get access to it via a cloud subscription. The Zoom, which has rocketed to worldwide popularity thanks to the pandemicProviders that offer scalable cloud-based solutions are riding high these days, and the cost, convenience, and reliability make cloud solutions an attractive choice. As more “as a service” options become available in more industries, people and organizations will abandon the older computing methods in Favor of this far superior delivery system.

10) The work from home revolution: The worldwide pandemic has completely turned the lives upside-down and influenced the technological innovations and development. This is unsurprising, as warfare spurns more incredible technological advances, and we are arguably at war with this deadly contagion.

Businesses wanting to continue functioning during these trying times have set up infrastructure to allow better work at home capabilities. Advances in related technology, make working at home a viable, efficient option.

Businesses can have their employees work mostly from home but have them doing their jobs in-house one or two days a week.

If a company’s employees work from home, the business has fewer infrastructure costs, making this a flexible, cost-effective strategy. The COVID-19 situation has shown how easy it is to work from home. If more companies embrace this even after the end of pandemic, citing cost-cutting measures, the end of the modern office space is seen.

11) Voice activated Searches: It is seen the end of the user sitting at their laptop or phone, trying to type in a search on Google. More users are turning to voice-activated searches, asking their phones where the nearest pizza place is or where they can find a deal on novelty face masks.

As more people conduct these voice-activated searches from their cars, jogging track, or local cafe, digital marketers will have to rethink their approach to improving search engine optimization (SEO). Rather than just pulling out a few keywords, marketers will find themselves having to rely more on long-tail keywords.

There will be some interesting days ahead for digital marketers.

12) Cloud Services: Cloud services, also known as cloud computing, allow files to be saved on the internet without needing external storage equipment. This disruptivetechnology represents great advantages for companies because it allows users to enjoy management tools from any place in the world by just connecting from their device.
13) Finger Prints: Digital fingerprinting is a security system that verifies the identity of a person using an electronic device with the aim of defending copyright. To control the unauthorized copy of content, a series of bits are

introduced into a medium (for example, a DVD, Blu-ray, or pen drive) that detects unauthorized copies.

14) Nano Technology: Nanotechnology is the study and manipulation of matter in very small sizes (between one and one hundred nanometres). This disruptive technology will allow stronger, lighter, and tougher materials to be generated than those currently used.

ADVANTAGES OF DISRUPTIVE TECHNOLOGY

When this type of technology enters the marketplace, it changes the entire industry. The internet disrupted previous ways of gathering information, such as libraries, newspapers and even social interactions. It also revolutionized the way that individuals could perform research.

Further, it

1) Make life easier and more efficient
2) Help companies make profit.
3) Enhance customer loyalty.
4) Existing technologies can introduce improvements

Disadvantages of Disruptive technology:

1) Security or safety concerns
2) Can negatively affect the existing business
3) Can be risky
4) Fear of job losses.

Observation:

If disruptive innovation is used as a competitive advantage, need to be prepared for the ongoing commitment. Disruption is not a one-time investment but rather a continuing pledge to transform, develop, and innovate. It isn't easy to achieve profitability quickly with this strategy. Gaining visibility and traction in the market takes time. The focus is to create something that will continuously improve and grow as time goes on. Before committing, one has to think carefully. Gaining a competitive advantage requires giving more than 100 percent.

Interdisciplinary Technologies:

Working with real world applications and scenarios, it is vital to collaborate between different disciplines. Inter-disciplinary plays a key role in the future world. An Interdisciplinary approach involves drawing appropriately from several disciplines to redefine problems outside of normal boundaries and reach solutions based on a new understanding of complex situations.

Bridging Disciplines:

In the tapestry of technological advancement, the introduction of Cloud Computing Infrastructures and the Internet of Things (IoT) Strategies has further exemplified the necessity for an interdisciplinary approach. These technologies are not standalone; they are interwoven with various facets of society and industry, necessitating a comprehensive understanding that spans multiple domains. This is where the concept of Autonomic Computing and Ambient Intelligence play a crucial role, as they represent a shift towards more adaptive, responsive technologies that can seamlessly integrate into human environments.

The emergence of Smart Grid Technologies and Renewable Energy Models in the context of sustainable development underscores the importance of integrating environmental sciences with technological innovation. This integration not only addresses current challenges but also paves the way for future advancements that are ecologically sound and sustainable. Here, the role of visionaries is not just to foresee technological trends but also to ensure that these trends align with the principles of sustainable development and ethical considerations in technology deployment.

The increasing relevance of Biometric Authentication and Genetic Algorithm Optimization in enhancing security and efficiency in various systems further illustrates the need for expertise in both biological sciences and computer science. This blend of knowledge is crucial in developing robust, secure systems that can adapt to evolving threats and challenges.

In the realm of robotics and automation, the integration of Robotic Automation, Drones and Aerial Innovation, and Materials Science Breakthroughs is revolutionizing industries, from manufacturing to agriculture. These advancements underscore the significance of understanding not just the mechanical aspects but also the societal implications and potential applications of these technologies.

As it is explored the frontiers of space with Space Exploration Technologies, the interdisciplinary approach becomes even more critical. The challenges of space exploration require not just advanced engineering and physics but also an understanding of human physiology, psychology, and environmental science.

The integration of technological advancements in societal planning and management, as seen in Urban Planning Technologies and Global Information Systems, demonstrates the broader impact of technology. These systems are reshaping how we live, work, and interact, and their development requires a nuanced understanding of social sciences, urban planning, and technology.

1) Cyber-Physical Systems:The convergence of mechanical engineering, computer science, and network technology, illustrates a harmonious blend of expertise, leading to advancements that transcend the capabilities of isolated disciplines. In the realm of these systems, the interconnection between physical processes and computational models creates a rich tapestry of possibilities, driving innovations that are profoundly changing the world.
2) Neuroinformatics combines neuroscience with information science, unravelling complexities of the brain through computational models.
3) Artificial General Intelligence, a pursuit that promises to revolutionize our interaction with technology, leading to systems that can understand, learn, and respond to complex tasks in a manner akin to human intelligence.
4) The field of Quantum Computing Principles further underscores the significance of cross-disciplinary collaboration. Bridging the gap between quantum physics and computer science, it presents a paradigm shift in computational capabilities
5) In the context of Data Fusion Methodologies, the integration of data from multiple sources and types becomes crucial in extracting meaningful insights. This process, essential in fields like environmental monitoring and urban planning, requires a deep understanding of diverse data types, from satellite imagery to sensor data. The fusion of this data, processed through advanced algorithms, enables a comprehensive understanding of complex scenarios, facilitating informed decision-making in real-time.
6) The concept of Sustainable Tech Development represents a holistic approach to technology, where the focus is not just on innovation but also on the long-term implications of technological advancements. This approach necessitates a broad perspective, encompassing environmental science, economics, and social sciences, ensuring that technological progress aligns with the sustainability goals. Here, the role of interdisciplinary knowledge is pivotal in creating technologies that are not only advanced but also responsible, considering their impact on the environment and society.
7) The trajectory of technological evolution is a labyrinth of complexity and surprise, where Predictive Analytics becomes a beacon, guiding through the fog of uncertainty. In this environment, interdisciplinary knowledge acts as a compass, enabling visionaries to chart a course through uncharted technological waters.
8) The surge in Deep Learning Techniques exemplifies this convergence. These techniques, rooted in artificial intelligence, have transformed from academic concepts to core components in various applications, from autonomous vehicles to medical diagnostics. This transformation was made possible not just by advancements in computer science but also by insights from neuroscience, cognitive science, and mathematics. Visionaries in this field had to not only grasp the technical aspects but also foresee the societal and practical applications of these technologies.
9) In the realm of Biomedical Engineering, the integration of engineering principles with biological sciences has

led to groundbreaking innovations, such as bionic limbs and organ regeneration techniques. Predicting the evolution of this field requires a deep understanding of both the engineering challenges and the biological complexities involved. Visionaries must navigate not just the technical aspects but also the ethical, regulatory, and societal implications of these advancements.

10) Cryptographic Protocols, in the age of digital information, have become more critical than ever. As cyber threats evolve, so must the methods to protect data. The development of new cryptographic methods requires knowledge of mathematics, computer science, and also an understanding of the constantly shifting landscape of cyber threats and data privacy concerns.
11) The advancement of Biometric Authentication technologies also illustrates the visionary's role. Here, knowledge from computer science, neuroscience, and even anthropology converge. Visionaries in this field are not just developing algorithms; they are foreseeing how these technologies can enhance security while respecting privacy and cultural nuances in a globally connected world.

Observations:

These envisioned frontiers are not just the culmination of technological advancements; they are a testament to the power of interdisciplinary knowledge in shaping the future. As we move forward, the role of visionaries in harnessing this knowledge becomes increasingly vital. They are the architects of a future where technology not only advances but also aligns with the complex tapestry of human needs and aspirations. The journey ahead is not just about the technologies we will develop; it's about the innovative ways we will apply them, the challenges we will overcome, and the new horizons we will explore. This journey, fuelled by interdisciplinary insights, holds the key to unlocking the next frontiers of technological progress.

CONCLUSION

Business environments are evolving at an unprecedented pace. To remain competitive, businesses must be agile and adaptable. Technology equips businesses with the tools to pivot swiftly in response to market shifts, regulatory changes, and customer preferences. Flexibility is no longer a perk but a prerequisite, and technology provides the platform for businesses to reinvent themselves as needed.

Those who see” Innovation as a Competitive Advantage” will be “Staying Ahead in a Rapidly Changing Landscape”

Scientists study the world as it is, engineers create the world that never has been.

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A Comprehensive Analysis of UNet Variants for Semantic Segmentation in Medical Images

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Abstract: *Physicians largely depend on biological image analysis to aid in the diagnosis and treatment of patients. This analysis provides crucial information on the location and appearance of lesions and tumors, as well as vital signs. Therefore, it is imperative to partition the tumors and lesions into distinct sections. Magnetic resonance imaging (MRI), computed tomography (CT), X-ray, and other imaging modalities are employed to obtain this information. In the field of medical image analysis, the technique of semantic segmentation is commonly used to precisely identify and assign labels to various regions inside images. Semantic segmentation refers to the procedure of partitioning images into distinct regions based on shared attributes, such as intensity, homogeneity, and texture. UNET is a specialized deep-learning network that is particularly engineered to separate and distinguish significant characteristics. However, the basic framework of UNET lacks the ability to precisely segment complex MRI images. This study showcases the improved and polished iterations of UNET, specifically tailored to boost the precision of segmentation.*

Keywords*: UNET; semantic segmentation; attention model; MRI, Brain tumor; neural network.*

INTRODUCTION

Brain tumor segmentation is a crucial aspect of medical image analysis, playing a pivotal role in accurate diagnosis, treatment planning, and disease progression monitoring [1]. The intricate nature and heterogeneity of brain tumors, coupled with the increasing demand for precise segmentation, have necessitated the development of advanced segmentation techniques. Convolutional Neural Networks (CNNs) have emerged as powerful tools in this domain, demonstrating remarkable performance in various computer vision tasks, particularly in the complex realm of medical image segmentation [1][2]. CNNs possess an inherent ability to autonomously learn and extract complex patterns and associations from medical images, making them well-suited to address the challenges associated with brain tumor segmentation [1]. Their capability to capture fine-grained features and complex spatial relationships holds immense potential for achieving more accurate and efficient segmentation, a critical requirement in the evolving landscape of medical imaging [3]. The integration of CNNs, particularly into architectures like U-Net, represents a transformative advancement in brain tumor segmentation (BTS), holding immense promise for enhancing diagnostic accuracy and patient-centered care.

Magnetic Resonance Imaging (MRI) and BTS

MRI stands as a preferred modality for non-invasive brain tumor detection, providing exceptional resolution and contrast for soft tissues [1]. Traditional segmentation methods, often relying on handcrafted features, face limitations in terms of robustness and precision due to their sensitivity to variations in image intensity. In contrast, CNNs have demonstrated superior performance, particularly in medical image segmentation, by automatically learning hierarchical representations from the data.

Datasets for MRI Image Segmentation

A variety of datasets are available for MRI image segmentation tasks. The MRBrainS18 dataset [2,3] comprises 30 MRI scans of individuals with Alzheimer's, dementia, diabetes, and matched controls, with voxel dimensions of

0.958 mm × 0.958 mm × 3.0 mm. The IBRS dataset [4] includes 18 MRI scans of individuals ranging from 7 to 71 years old, with bias field correction performed using the CMA'autoseg' method. The BREASTS dataset [5, 6] contains multi-contrast MRI images of 10 patients with low-grade glioma and 20 patients with high-grade glioma, along with synthetic images generated for both low-grade and high-grade glioma cases. These datasets provide valuable resources for developing and evaluating MRI image segmentation methods.

U-Net Architecture for BTS

The U-Net architecture was specifically designed for biomedical image segmentation [7]. It consists of a contracting path, a bottleneck, and an expanding path. Skip connections are employed to preserve high-resolution data. This architecture has proven effective in capturing fine details and spatial relationships in medical images, making it well-suited for BTS. While U-Net has shown promising results, there remains room for improvement and exploration of its integration with other methods. Combining handcrafted features with CNN architectures has been demonstrated to enhance segmentation performance, as highlighted in relevant literature.This study proposes a hybrid approach in various literature that combines handcrafted features, such as intensity, texture, and shape-based features, with the U-Net architecture to improve BTS in MRI scans. In the next part of the paper different UNet architectures are discussed. Followed by the performance metrics in section 3. The comparative analysis of different architectures is discussed in section 4. Finally, the section presents the overall conclusion of the study.

UNET - ARCHITECTURE AND BACKGROUND STUDY:

The development of image segmentation techniques in medical image analysis has undergone a significant historical evolution, demonstrating the ongoing pursuit of more precise and advanced methodologies. Image segmentation has always relied on handcrafted features and domain-specific knowledge as its major methods. Nevertheless, the examination of sophisticated architectures has become the focus of a paradigm shift due to the inherent limitations of these traditional methods [3]. Conventional segmentation methods, which rely on manual feature engineering, frequently encounter difficulties in adapting and scaling, especially when dealing with the complex and varied characteristics of medical images [5-8]. Although these methods are somewhat effective, they are sensitive to changes in image intensity and necessitate careful manual adjustment, making them less reliable and accurate [6]. Researchers are motivated to find alternative methods to address the challenges of medical imaging, such as the need for better accuracy, efficiency, and scalability. Advanced architectures like U-Net have emerged as a solution within this framework [7].

The U-Net architecture, characterized by its distinctive contracting-expanding channel and skip connections, has demonstrated its transformative impact on picture segmentation, specifically in the field of medical imaging. The capacity of this design to record subtle features and spatial linkages has effectively resolved significant constraints imposed by conventional approaches [7][8]. As we explore the history of image segmentation, we see a shift from traditional to more complex designs. This change is significant because it shows the continuous effort to develop methods that can fulfill the changing needs of precision medicine and diagnostic excellence.

U-Net Architecture:

The U-Net architecture, proposed by Ronneberger et al. in 2015 [7], is a groundbreaking approach in the field of biomedical image segmentation. It is specifically designed to tackle the difficulties presented by complex structures and patterns in medical images [2][3].

The unique structure of the design is made up of a path that narrows, a path that widens, and a bottleneck. This makes it easier to precisely divide target structures into fragments.The contracting path consists of a sequence of convolutional and pooling layers that gradually decrease the size of the input image, collecting crucial features and patterns [7].

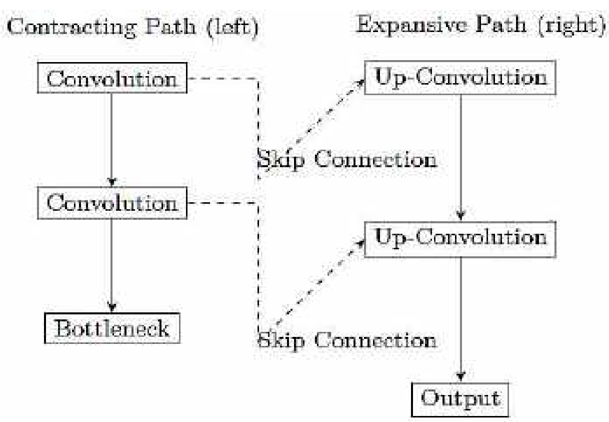
This path functions as a mechanism that extracts important characteristics from the input while preserving a comprehensive context. The bottleneck, located at the central part of the design, functions as a layer that restricts the flow of information and consists of numerous convolutional layers, which further enhance the learned features [8].

The architecture depicted in **Figure 1** is known as U-Net. The contracting path (left) progressively extracts features, leading to a bottleneck layer. The expansive path (right) reconstructs the high-resolution segmentation map. Skip connections (dashed lines) facilitate the fusion of low-level and high-level features, contributing to U-Net's exceptional segmentation capabilities.

Modified UNet Architectures

U-Net++

The U-Net++ architecture, proposed by Zhou et al. in 2017 [9], is a modified version of the U-Net architecture. It incorporates layered skip connections between the contracting and expansive channels, as illustrated in **Figure 2**. The inclusion of skip connections in the network enables the acquisition of more accurate segmentation masks, particularly for intricate images.



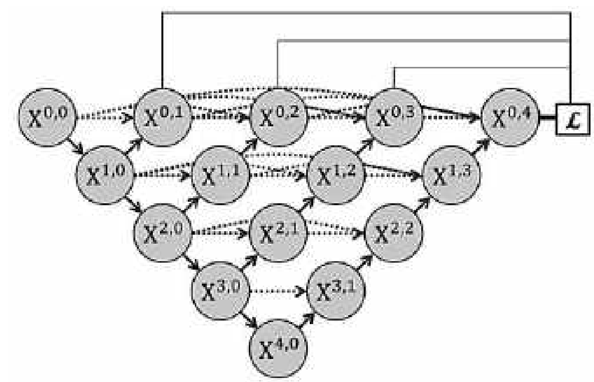


Figure 1 Overview of the U-Net Architecture

Figure 2 U-Net++ architecture [9]

Attention U-Net:

Attention U-Net is a modified U-Net architecture that focuses on the most pertinent portions of the input image via attention mechanisms [10]. This can improve the accuracy of the segmentation mask, especially for complex images. The architecture is presented in **Figure 3**.

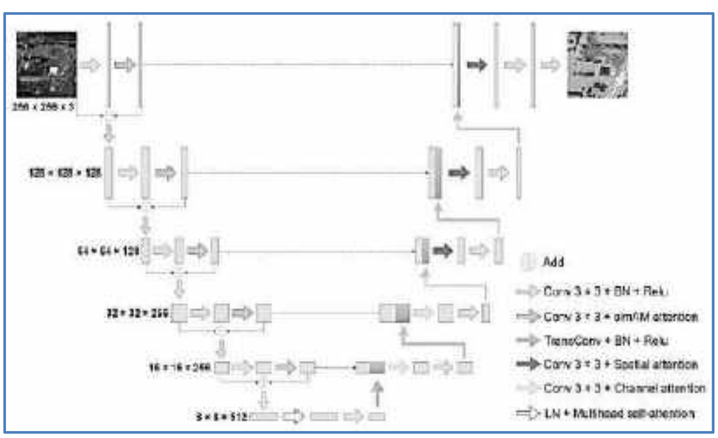


Figure 3 Architecture of Attention U-net [10]

R2-UNet:

R2-UNet (Liu et al., 2018) [11] is a modified U-Net architecture that uses recurrent and residual convolutional blocks. These blocks can help to improve the performance of the network on tasks with limited training data as shown in **Figure 4**.

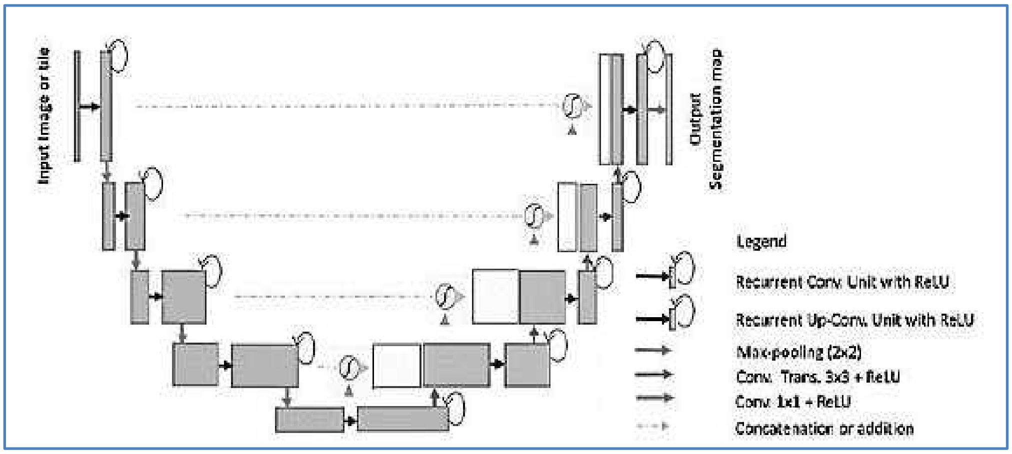


Figure 4 Architecture of R2 U-net [11]

Dense U-Net:

Dense U-Net (Huang et al., 2017) [12] is a modified U-Net architecture that uses dense connections between all layers in the network in figure 5. This can help to improve the flow of information between the layers and improve the performance of the network.

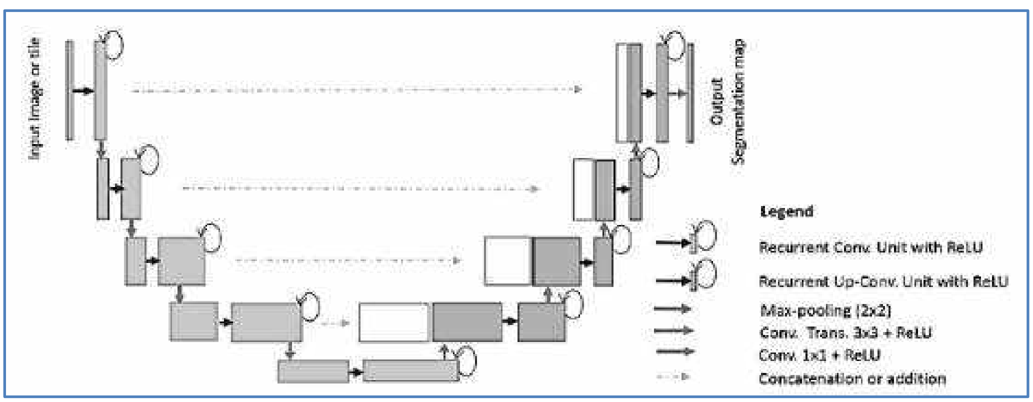


Figure 5 Architecture of Dense U-net [12]

PERFORMANCE METRICS

Dice Score

The Dice similarity coefficient, commonly referred to as the Dice Score or F1 Score [7], quantifies the spatial overlap between the predicted and ground truth segmentations. It is calculated using the formula

$$\text{DiceScore} = 2\text{x}(|\text{Predicted}| \cap |\text{GroundTruth}|)\ /|\text{Predicted}| + |\text{GroundTruth}|$$

Where $|\text{Predicted} \cap \text{GroundTruth}|$ refers to the measure of overlapping pixes between the predicted and ground truth segmentations, and$|\text{Predicted}|$ and $|\text{GroundTruth}|$ denote the combined number of pixels in the predicted and ground truth segmentations, respectively. The Dice Score is a numerical value that goes from 0 to 1, where a score of 1 represents a perfect overlap.

Specificity

Specificity measures the ability of a model to correctly identify true negatives [8][9]. It is calculated using the formula.

$$\text{Specificity} = \frac{\text{TN}}{\text{TN} + \text{FP}}$$

where TN is the number of true negatives (correctly identified non-tumor pixels) and FP is the number of false positives (non-tumor pixels incorrectly classified as a tumor). Specificity provides insights into a model's ability to accurately delineate non-tumor regions.

Sensitivity

Sensitivity, also known as the true positive rate or recall, assesses the capacity of the model to correctly identify true positives [9]. It is calculated using the formula

$$\text{Sensitivity} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$

where TP is the number of true positives (correctly identified tumor pixels) and FN is the number of false negatives (tumor pixels incorrectly classified as non-tumor). Sensitivity emphasizes a model's effectiveness in capturing actual tumor regions.

These performance metrics collectively offer a comprehensive evaluation of a brain tumor segmentation model's accuracy and efficacy, providing valuable insights into its strengths and potential limitations.

COMPARATIVE ANALYSIS OF DIFFERENT UNET ARCHITECTURES FOR IMAGE SEGMENTATION

This **Table 1** compares the performance of different U-Net segmentation techniques based on three metrics: dice similarity, sensitivity, and selectivity. The dice similarity coefficient measures the overlap between the predicted and ground truth segmentation masks. Sensitivity, also known as recall, measures the proportion of true positives that are correctly identified. Selectivity, also known as precision, measures the proportion of identified positives that are actually true positives.

As can be seen in the table, Ensemble U-Net outperforms the other models in terms of all three metrics. This is likely due to the fact that it combines multiple U-Net models, which allows it to learn a more comprehensive representation of the data.

Here is a more detailed breakdown of the results:

- Dice similarity: The dice similarity coefficient for the original U-Net is 0.85, which is a good score. The other models all achieve higher dice similarity scores, with the highest being 0.92 for Attention U-Net and Ensemble U-Net.

- Sensitivity: The sensitivity scores for all of the models are high, ranging from 0.87 to 0.94. This means that all of the models are able to correctly identify a high proportion of true positives.
- Selectivity: The selectivity scores for all of the models are also high, ranging from 0.83 to 0.90. This means that all of the models are able to avoid identifying false positives.

Overall, the results of this table show that Ensemble U-Net is the best-performing U-Net segmentation technique for the metrics of dice similarity, sensitivity, and selectivity. However, the other models are also good performers, and the best choice of model will depend on the specific task and the available data.

Table 1 Comparative study of different UNet architectures

Model	Dice Similarity	Sensitivity	Selectivity	References
Original U-Net	0.85	0.87	0.83	[7]
U-Net++	0.9	0.92	0.88	[13]
Attention U-Net	0.91	0.93	0.89	[10]
R2-UNet	0.88	0.9	0.86	[11]
Dense U-Net	0.89	0.91	0.87	[12]
FCN-U-Net	0.87	0.89	0.85	[14]
Attention-guided FCN-U-Net	0.9	0.92	0.88	[13]
Ensemble U-Net	0.92	0.94	0.9	[14]

CONCLUSION

The analysis and processing of medical data have a substantial impact on both clinical applications and academic research. Deep learning has the capability to create new ideas for medical picture approaches that can determine texture morphology only based on data. It has become the predominant element in various medical picture studies. The findings show that the deep learning method utilizing convolutional neural networks (CNN) has received a lot of attention for its effectiveness in classifying and segmenting medical images, among other related areas. This article analyses the development of the UNET architecture for accurately separating the region of interest from various internal organs. Additionally, this review outlined the criteria for evaluation and divided the areas drawn from the UNET models based on the disorders. It is possible to improve the segmentation validation methods for future studies to make the segmentation more accurate. When UNET and GAN are used together, they can make medical images and divide, sort, and put together those images successfully. The layout of UNET can be changed to predict the statistical data from the divided area.

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Machine Learning for Improving Grain Quality and its Development: A Review

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***Abstract**: millions of people around the world depend on wheat-based foods as an essential source of energy. People can get a lot of nutrients from wheat-based foods, including carbohydrates, protein, and fiber. However, because most food is made from milling wheat and turning it into white wheat flour or refined flour, some important nutrients are lost. The body should mainly rely on carbohydrates for energy, but whole-grain diets are recommended for preventing cardiovascular disease. To ensure that whole grains make up a large part of the diet, we need to emphasize the importance of whole-grain foods, as well as their protective qualities. The wheat grain's composition, structure, and unique characteristics have enabled the development of many unique culinary products around the world.*

***Keywords**: Machine Vision; Wheat; Seed Quality; Classification; Quality; Deep Learning.*

INTRODUCTION

Mobile grains are the seeds of harvested grasses such as wheat, oats, corn, rice, millet, rye, and barley. Cereals play an important role in meeting the nutritional needs of mankind. Humans get an average of 48% of their calories, or dietary energy, from grains. Grain quality is an important aspect and a key factor for market acceptance. The grain quality determines the price, and the quality index depends on the end-use requirements. In grain processing units, quality is expressed based on physical characteristics such as grain firmness,shape, moisture content, size,and visual attributes such as damage, infection, discolored grain, and the presence offoreign matter. Acceptable grain quality also means that the grain is free of contaminants and ingredients that are harmful to health. The traditional method of assessing grain quality, visual inspection (manual method), is fast, reliable, and efficient even for trained personnel and licensed traders in the grain market (anajmandi). It's a challenge in terms of accuracy. Also, this quality analysis is influenced by the sentiments of traders in the grain market, which is incorrect, and farmers cannot get the right price for their grain.

Wheat: wheat is a type of cereal grain that is widely used for food production. The structure of wheat consists of three main parts: the bran, the germ, and the endosperm. Bran is the outer layer of wheat grains and contains fiber, vitamins, and minerals. Germ is the embryo of wheat grain and is rich in minerals, healthy fats, and vitamins. The endosperm is the largest part of the wheat kernel and contains starch and protein. Wheat-based products include a wide variety of foods such as bread, pasta, noodles, cereals, and baked goods. The type of wheat used, and the processing method can affect the nutritional value and texture of the final product. Whole grain products are made from whole wheat, and contain more fibre and nutrients than refined wheat products that have had the bran and germ removed.

Computer vision systems (cvs) computer vision systems have the potential to replace manual (visual) inspection methods and are widely accepted in the industry as quality assessment tools for many agricultural products. Computer vision is a research field aimed at developing techniques that help computers understand the content and "see". Digital images such as photos and videos. Computer vision aims to use computer software and hardware to model and replicate human vision on multiple levels.

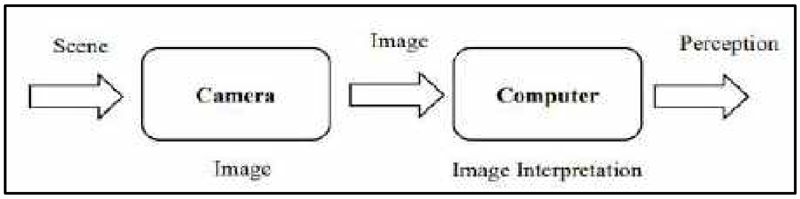

Figure 1 Computer vision block-diagram

Cvs is computerized and can provide a low-cost, fully automated quality assessment. A system that can replacemanual inspection methods and eliminate errors and discrepancies in results. Their use can also reduce the fatigue encountered in manual inspection. Grain quality depends on protein, carbohydrates, etc., and is related to their physical properties. This work focuses on the physical aspects relevant to grain analysis. This chapter presents research conducted in the field of physical characterization. The problem needs to be addressed. It mainly involves manual and mechanical techniques. Both techniques are further divided into different categories. Every technique has its limitations and advantages are described in the sections that follow. With the research, the focus is on wheat quality analysis. By setting different parameters, this analytical technique helps analyze other grains' quality.

Wheat grain structure endo sperm is the latent white powder in the centre of the wheat grain. The endosperm breaks along the cell wall upon crushing and separates from the bran layer[1]. The separability of the endosperm from the bran layer is determined by the wheat properties. Durum wheat (used in bread making) separates easily, while soft wheat (used in biscuit flour) does not allow the endosperm to separate cleanly from the bran layer. I'm here. Bran is nutritionally rich in protein and is used to make brown and whole wheat flour. The wheat germ is the embryo that eventually develops into the wheat plant. Rich in certain vitamins, proteins, and oils. Therefore, it is widely used in healthy foods such as fortified bread and whole wheat flour.

Grain quality parameters generally, wheat quality can be divided into three groups: plants (species and varieties), and physical and chemical properties. The physical characteristics of wheat quality include grain weight, firmness, size [3], shape, virtue, and color. Wheat test weight is considered the most common and easiest way to quantify wheat. This is a valuable quality factor in wheat grading and provides a rough estimate of flour production. The fundamental factors affecting wheat test weight are grain size, shape, density, and maturity. Wheat endosperm hardness is important in determining whether the wheat is suitable for different end products and affects wheat processing and milling. This is a feature commonly used by millers and traders to grade wheat. Wheat is divided into durum wheat and soft wheat according to the hardness. In terms of color, wheat is divided into two classes (red and white). Hard red winter wheat is considered premium and is often used to make breadcrumbs. White wheat is commonly used for pastries, chapattis, and pasta. Used for (pasta) different types of wheat have different characteristics such as flavor, unit, and milled yield. Wheat vitreousness is an optical property used in many countries to classify or quantify durum wheat. Based on vitreousness, wheat can be divided into three main categories, glassy, powdery, mottled. Glass wheat differs from non-glass wheat in the grain appearance (starchy and opaque). Glass wheat is considered of superior quality to non-glass wheat because of its high-quality semolina protein, beautiful color, and consistent coarse grain.) Content, amylase content, and fibre content.

Grain shape is a very substantial property of the grain, which is mostly defined by the aspect ratio [4] (length-width ratio). The aspect ratio is the ratio of the length of the seed to the ratio of the width of the seed.

$$\boxed{\text{aspect ratio} = l / w}$$

where: l: length of the kernel, w: width of the kernel.

For any grain sample, generally ,the average value is considered:

$$\boxed{\text{aspect ratio}_{(avg)} = l_{avg} / w_{avg}}$$

where: l_{avg}: the average length of the kernel, w_{avg}:the average width of the kernel

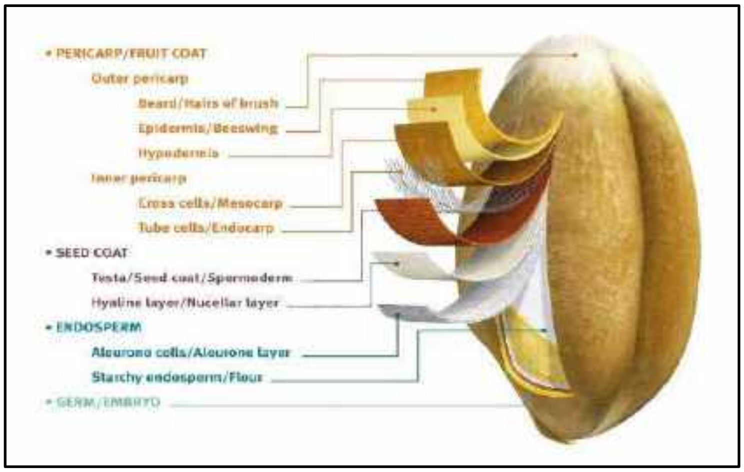

Figure 2 Wheat grain structure

The aspect ratio is generally measured in millimeters. Classification of seeds depends on the aspect ratio i.e., based on the seed length/width ratio appearance mainly depends on the aspect ratio of the product. This can be an important selling factor and affect your sales consumers are capricious, and even if a product has excellent nutritional value, it may not sell if it is not attractive. Another important aspect of length and width is uniformity. All particles in the sample should look the same. At first glance, samples of uniform length and width have a price advantage (Kaur and Singh 2013).

Damaged / discolored grains spoiled grains are cereal grains that have a different appearance and decrease in nutritional value due to biochemical changes that give rise to strange flavors and changes in appearance. These types of damage are caused by moisture levels, pest damage, physical damage, insects, and heat exposure. Damaged/discolored kernels include broken, intact pieces that are internally damaged or discolored, and immature, yellow, red, or green seeds. It can be measured as:

$$\boxed{\%\ \text{damaged grain} = (\text{total damaged seed} / \text{total seeds}) \times 100}$$

Grain weight provides information about grain size and density. Grains of different densities may be ground differently, retain moisture, and be cooked differently. A uniform grain weight is important for consistent grain quality. The two samples appear to be the same size but differ in weight.

HYPOTHESIS

As we are in the world of technology where humans can train a machine to provide a better-resulting application and automate the work to reduce the human effort by machine learning algorithms. Over the past few years, ml appliances have increased very rapidly, but there is room for improvement in the agriculture field, where machine learning algorithms can play a significant role in improving accuracy, precision, and decision-making. So, the hypothesis is that we can build a machine learning algorithm that will provide a better estimation for gain quality and its evolution by conceding grain structure, grain quality parameters, physical characteristics, and grain weight over a manual or semi-manual process which is a time-consuming task and may be affected by the mood of traders in the grain market, which should not be an ideal way. Hypothesis resulting improvement on:

- reduce time and provide better accurate results.
- providing farmers to use this application without depending on any agent farmer to sell the grain to any grain market and get the correct quality and price.

LITERATURE SURVEY

Manual grain analysis technique in the manual technique, grain samples are analysed with crossed eyes. Micrometers and vernier calipers are commonly used to measure dimensional parameters. Results from these technologies are highly subjective and depend on the expertise and mindset of the analyst. The same analyser may give different results depending on the experience and mood of the analyser. Even with the same sample and the same analyzer, repeated measurements of the same sample may yield different results. Therefore, the results are less reliable. If individual seed parameters are also of interest, manual measurements using micrometer screws and optical controls are very time-consuming and cumbersome. It is very difficult to measure quality parameters and memorize the characteristics of each seed individually. Average characteristics such as length, width, colour, and the number of broken seeds are commonly measured using this method. There is also the possibility of physical damage or deformation. It becomes even more complicated when many samples need to be analyzed. An inexperienced human analyst may produce unacceptable results. Manual analysis is highly subjective and subject to human physiological conditions and other environmental configurations, leading to erroneous results.

Semi-automatic particle analysis techniques sieve analysis [5] is used to divide particulate matter into size fractions and determine the weight of those fractions. In this method, the sample is poured into a sieve tower as shown. As shown in **Figure 4**, the base contains a mechanical shaker. In typical sieving, a series of sieves with different hole sizes divide the seeds into different size categories at each level. Each level resizes chronologically.

Manual and mechanical screening the manual method does not use a power supply. Manual motion is generated by the mechanical energy of the mechanical sieve. Screens are further divided into throwing screens and horizontal screens according to the direction of rotation.

Single sieve and sieve set sieves this is only used to determine the undersize and oversize percentages. Not useful for particle size distribution. For individual screening, only a single screen with a defined mesh size is exposed to the screening operation along with the collection pan. Usually just a guide. You can find particles/particles of different sizes at each stage. The sieving method is also useful for corn particle size determination. However, this method is not accurate as grain seeds may pass in a vertical position. This type of method is usually useful for round or nearly round seeds. This type of method is commonly used in particle size analysis and does not provide information on other properties such as aspect ratio, color, etc. Over the last decade, image-based particle analysis has become established and various techniques have been developed. Image-based particle analysis can use captured images of particles under test to provide multiple parametric analyzes. In the next section, we present different techniques for particle analysis based on image processing approaches.

Figure 3 Sieves sets

Figure 4 Sieve shaker

Traditional image-based particle analysis techniques recent technological developments in the image processing field have made image processing a highly adaptable and accepted method of feature extraction in particle quality analysis. In image-based grain analysis, grain kernels are placed/dispersed on grain trays or conveyor belts. Grain sample images are captured by scanning (using scanners) or capture (using various types of cameras). This image is processed for feature extraction for each seed. Captured images are pre-processed for better results. Sorting is performed based on the extracted features of each seed in the grain sample image. Image-based particle analyzers can be divided into two categories:

1. Offline grain analyzer
2. Online grain analyzer

Both techniques bring in an image of the wood grain pattern for processing. In the online grain analyzer [6] the grain moves while taking a picture of the grain sample. With offline grain analyzers, the grain remains stable while the grain sample is photographed.

Machine getting-to-know strategies had formerly been efficiently carried out in lots of manufacturing chains for the seed and cereals category [53, 54, and 55]. In [56], the study suggests the functionality and opportunities of system imaginative and prescient for shapes, sizes, and varietal kinds the use of well-skilled multilayer neural community classifiers. They applied weka class gear which includes function, bayes, meta, and lazy processes to categorize the seeds. In [57], the authors proposed a fuzzy theory primarily based on the total technique for spotting wheat seed kinds that recall the capabilities of the seed. The tabu seeks method changed into used. In [58], the authors used a synthetic neural community for classifying wheat seeds primarily based totally on vlc and acquired an accuracy of 92.1 percent and 85. Seventy-two percent, respectively. In [59], the authors have mentioned the morphological, color, and textural traits of the seed. If there's a completely minute distinction in morphological capabilities, then seed class could be very difficult. Cereal yield is decided via way of means of the number of grains consistent with the ear and the dimensions of the grains. Counting seeds and morphometry via way of means of sight is time-consuming. As a result, distinctive methods for powerful grain morphometry using photograph processing strategies have been proposed [60, 61].

In [62], the authors created a computer to resource in grain evaluation for class, and a video colorimetry technique is offered to aid in figuring out cereal grain colour. The categorization of chickpea seed types changed accomplished primarily based totally on the morphological traits of chickpea seeds, the use of four hundred samples from 4 kinds: kaka, piroz, ilc, and jam [63]. According to the industrial factor of view, a system imaginative and prescient constructed of present neural community fashions can be applied for rice first-rate assessment [64]. In this, it makes use of neural networks to categorize rice types, the use of a complete of 9 separate styles of rice. The authors appoint seed photograph acquisition to categorize those variations. They additionally created a technique for extracting thirteen morphological capabilities, 6 color capabilities, and 15 texture capabilities from color pics of seeds. Their version has produced an average class accuracy of 92%. The k-nearest acquaintances classifier necessitates storing the whole education set, which may be prohibitively luxurious whilst the set is huge, and numerous researchers have tried to get rid of the education setting’s redundancy to alleviate this hassle [65, 66].

For plant categorization, the authors have applied deep getting-to-know fashions [67]. Two inclinations can be visible inside the contemporary country of art. The first is connected to high-throughput phenotyping and plant identity, as evidenced byubbens and stavness’ paintings on this area [68]. The 2nd hassle is plant ailment identity and monitoring [69, 70]. In [71], the authors gift many balloting strategies for trying out ensembles of classifiers and discovered the use of the bagging technique. The multilayer perceptron is used as a classifier. Using agencies of classifiers instead of personal ones is one option. Bagging [72] and boosting [73] are the maximum famous ensemble strategies, wherein many classifiers are mixed to generate asingle, extra correct result. In [74], the authors studied the overall performance of numerous balloting strategies, with bagging being applied for the reconciliation version which is a method of merging class fashions. Table 1 includes numerous capabilities taken into consideration in system imaginative and prescient structures for meals grain first-rate evaluation.

Zayas et al.[17] illustrate the use of image analysis to distinguish between wheat and non-wheat components in a grain sample. They presented two methods, a multivariate discriminant method and a structural prototype method for pattern recognition. The main concern with this method misclassification of irregularly shaped stones such as wheat. The limitation of the proposed method is the need to manually orient the kernel. Grain per cob and grain size are important characteristics of grain yield. Counting seeds and morphology "by eye" is laborious. Therefore, many different approaches have been proposed for efficient particle morphology measurement by image processing techniques [3], [18]. Classification testing was performed through non-destructive analysis and classification methods of particle characteristics [51], [52]. Machine learning is often used in various applications such as classification, regression, and forecasting to meet these needs. [53].

Vishnu et al.[19]proposed a technique based on pca and k-mean cluster analysis also presented for the quality analysis of rice bran collected from rice mills. Based on oil contents, there are different types of rice bran e.g.,the oil contents of boiled rice bran are ranging from (20~26%), and oil contents for raw rice bran are ranging from (16~18%).

Parveen et al.[20]presented optimal and image processing-based techniques for the characterization and quality analysis of rice grains based on the chalky white part of rice grain. A white chalky area of grains is detected using an extended maxima operator.

Ahmad et al.[21]present color machine vision systems that have been used in grain quality analysis to distinguish between seeds, grades, varieties, impurities, and seeds contaminated with fungi and insects. The color image of each grain is described by its color, texture, and morphological characteristics and is used in the assessment of grain quality.

Gowen et al. [22] proposed thermal imaging systems, which use thermal ir radiation detectors (long-wave), have also been investigated for their applications in the quality and safety inspection of agricultural and food products.

Momin et al. [23]presented the detection of materials other than grain in soybean harvesting successfully identified with an accuracy of 96% for split beans, 75% for contaminated beans, and 98% for both defective beans and stem/pods.

Aran et al. [24] implement an automated grading system using machine vision which takes the cashew input image and processes it and transfers it to a pattern recognizer. The pattern recognizer performs processing and classifies the object. Grading is performed using color, texture, size, and shape features. Five different classifiers were used among these classifiers back propagation neural network proved more optimal.

R. Siddagangappa et al. [8] propose an automated system for classification and quality determination using a neural network. The proposed model uses color and geometrical features for classification. The success rate for identification was 98% and the success rate of quality analysis and grading of rice grain was 90% and 92%.

H. S. H. Chitra et al. [29] proposed a methodology for the identification and classification of seeds. By using this technology, the author can discriminate the defective seed from the normal seed. The proposed methodology includes noise removal, edge detection, segmentation, and classification for seed identification.

Bejo et al. [25] combined two non-destructive sensors to predict the sugar content of mango sweetness. A spectrophotometer and computer vision system implemented online resulted in an accuracy of 87% for the prediction of sugar content.

Radhika v. Rao et al. [30] proposed an algorithm for determining the protein content of the seed using a machine learning algorithm.

Zareiforoush h et al. [31] proposed an algorithm based on the nearest neighbor approach, mlp, and support vector machine method which provides higher classification accuracy. Quality measurement of milled rice grading developed by fuzzy inference system combined with image processing to give qualitative decision support system.

Singh CB et al. [32] proposed an image analysis technique for both the identification and classification of the materials and used to detect the infestation seed materials to detect infestation inside the wheat kernels using thermal imaging.

Tajane et al. [33] developed techniques that work on ayurvedic plant leaf detection by image analysis technique.

Singh and chaudhury et al. [34, 35, and 36] proposed a classification directly from the given images, this breakdown is useful to cluster the approaches in the literature for further analysis and comparisons.

Fernandez-gallego et al. [37] proposed a robust, inexpensive, and effective method to evaluate the density of wheat ears in the visible spectrum. Also, focus on using inexpensive and readily available equipment.

Kaisaat et al. [38] proposed a flat-surface scanner to measure thecolorof the rice and its corresponding uniformity.

Kozłowski et al. [39] propose a flatbed scanner to acquire images and perform recognition of barley varieties.

Komyshev et al. [40] proposed an approach to evaluate the phenotypic parameters of the grains using mobile devices obtaining quite precise results.

Kar et al. [41] proposed a deep learning-based system to estimate food grain quality using a mobile device with limited resources.

Gomez et al. [42] proposed an approach to classify cocoa beans, based on the spectral signatures of the visible and near-infrared spectral bands.

Ribeiro [43] proposed an approach to classify five cereals, extracting morphological, color, and texture characteristics. To increase classification accuracy, the original rgb color space is converted to hsv color for best results.

Singh and chaudhury et al. [44] present an approach to classify five types of rice, using a vector of characteristics applying the bpnn algorithm using the luminance component of the converted hsvcolorspaces.

Wah et al. [45, 46, 47, and 48] proposed converting the given images to grayscale and using them as inputs to the system. Working in grayscale, just one dimension is considered, hence in these cases the texture or intensity analysis is considered.

Toda et al. [49] proposed a deep learning-based grain detection method to identify seeds of various types, for example, barley, rice, lettuce, oats, and wheat.

Kar et al. [50] perform the classification of wheat grains by using a hybrid strategy where real images are used in a virtual environment for training the instance segmentation architecture.

P. Hart et al. [76, 77, 78, and 79] k-nearest-neighbours classifier requires storing the whole training set and may be too costly when this set is large, many researchers have attempted to get rid of the redundancy of the training set to alleviate this problem.

Chu et al. [81] proposed an approach to classify infected corn seeds is proposed. It uses infrared hyperspectral images in the range of 900 to 1700 nm.

Aznan et al. [82]proposed an application of computer vision (cv) and machine learning (ml) to classify commercial rice samples based on dimensionless morphometric parameters and color parameters extracted using cv algorithms from digital images obtained from a smartphone camera.

RESEARCH METHODOLOGY

Grain quality evaluation steps

1. Image acquisition (input test image): the image of the grain sample is taken by the camera.

2. Pre-processing: in pre-processing first, we convert rgb to the grey image. And then we place a low pass filter so that the pixel noise can be removed.

3. Segmentation: in this step, the captured image is resized. The background is eliminated, and the foreground is extracted, the region of interest. And then the thresholding is done. Thresholding is used to separate the region in an image concerning the object, which is to be analyzed and this is based on the variation of intensity between the object pixel and the background pixel.

4. Image binarization: binarization of an image based on its contrast levels.

5. Database image: collecting grain image samples.

6. Feature extraction: in this step, qualitative information about the object is extracted from the image. The geometrical features of the grain are extracted from the sample image. These features are:

A. Area

B. Major axis length

C. Minor axis length

D. Perimeter.

7. Nn training/classifier: nn classifier is first used to train the collective data. And then it classifies the images according to features.

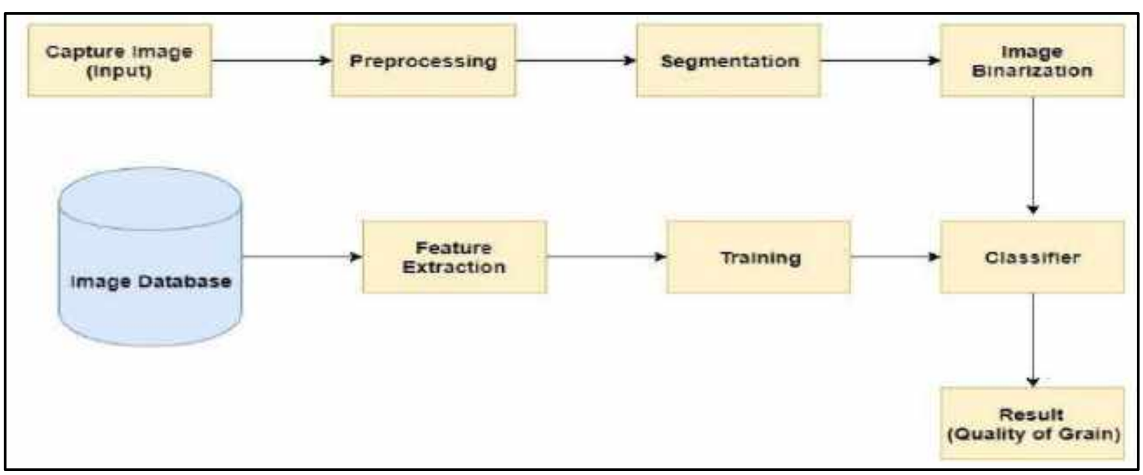

Figure 5 Grain quality evaluation steps flowchart

CONCLUSION

Machine learning and image processing have revolutionized the field of seed classification by enabling accurate, fast, and automatic seed classification based on their physical properties. With computer hardware and software advances, these techniques have become more accessible and effective, making them particularly useful in the agricultural industry. Using machine learning algorithms like neural networks, decision trees, and image processing techniques like segmentation and feature extraction, seeds can be classified based on size, shape, texture, and color. Compared with traditional manual methods, these techniques have been proven to be highly effective in improving the accuracy and speed of seed sorting. Furthermore, the application of these techniques in seed grading is not simply to improve the efficiency of the agricultural sector.

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Sentiment Analysis of Amazon Review Dataset using One-way ANOVA Feature Selection Technique

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Abstract: *When irrelevant, redundant, and high-dimensional features are chosen for SA, the results may be erroneous. Feature selection (FS) is a stage in the SA preprocessing process that enhances classification accuracy by reducing feature dimensionality and overcoming underfitting and overfitting by picking important features. Additionally, FS reduces computing time, storage, and complexity. In this paper, a one-way ANOVA feature selection strategy is proposed to handle the high-dimensional Amazon review dataset problem, which finally improves the performance of Amazon review classification precision. Filter feature selection approaches such as one-way ANOVA are used to identify the most significant features of Amazon review datasets. The selected features were then further used by the SVM, NB, and LR classifiers. Amazon review datasets were used in this research to assess the efficacy of the proposed method. The proposed approach gives impressive results using the Amazon Review dataset and SVM with an accuracy of 89%, with NB and LR giving 86% and 86%, respectively. The result shows that the SVM with one-way ANOVA outperforms other algorithms with nearly 50% fewer features for the Amazon Review datasets. The experimental results reveal that the suggested one-way ANOVA-based feature selection strategy outperformed various classifiers to improve accuracy, recall, precision, and F-measure.*

Keywords: *Feature Selection; Sentiment Analysis; Preprocessing; Filter method; Machine learning; One-way ANOVA.*

INTRODUCTION

In the last few years, the global corpus of both structured and unstructured data has grown tremendously, owing primarily to the increased popularity of social networking sites, which have created vast volumes of data. This tremendous data increase has made it difficult for companies, institutions, governments, and even people to obtain knowledge and make decisions that will allow them to successfully profit from the data [15]. One of the most well-known online retailers is Amazon. Potential consumers can examine hundreds of customer reviews that have been submitted about the goods they are interested in. These product reviews offer useful details, assisting customers in finding the majority of a product's qualities. Customers gain from this, but it also helps sellers or manufacturers gain a better understanding of customers' demands. There are many opportunities to use sentiment analysis as a result of the large number of views. As a result, sentiment analysis is used to collect and transform opinion and other data into valuable information.

Sentiment analysis (SA) is the method of determining if a text's sentiment is positive, negative, or neutral [9,14]. When irrelevant, redundant, and high-dimensional features are chosen for SA, the results may be erroneous. The presence of redundant and irrelevant features in the huge dataset can significantly reduce the efficacy of machine learning models and result in severe performance deterioration [8]. They may also create overfitting, underfitting, and curse of dimensionality problems.

In this paper, a filter feature selection strategy is proposed to handle the high-dimensional Amazon review dataset problem, which finally improves the performance of Amazon review classification precision. This approach takes advantage of the speed of a filter method. In our methodology first, we employ a filter method, One-way ANOVA, which reduces the feature subset search space. By using ANOVA, the feature set size is reduced significantly, which results in a lesser computational cost for the model. The Amazon dataset is used to perform this experiment. This experiment has used SVM, NB, and LR classifiers with FS techniques. We have assessed the performance of classifiers with feature selection techniques and other state-of-the-art techniques by comparison of results. According to the findings, the suggested strategy can provide better accuracy with fewer features.

This article's structure is as follows: In Section 1, Introduction, In Section 2, Literature Review, In Section 3, Methodology, In Section 4, Word Cloud, In Section 5, Feature Extraction and Feature Selection, In Section 6, Classifiers and Evaluation Metrics, The result and discussion are discussed in Section 7. Finally, in Section 8, there are conclusions.

LITERATURE REVIEW

Alassaf and Qamar investigated one-way ANOVA as a feature selection method to handle the curse of dimensionality and enhance classification performance for classifying Qassim University, Saudi Arabia, tweets from the Twitter dataset. TF-IDF as a feature extraction method and SVM, k-NN, LR, MLP, and NB classifiers were used in this study. SVM has achieved the best performance with a f1-score of 88%.

Yuce, Nielsen, and Wargocki used the Taguchi method, ANOVA, and Grey Relational Analysis (GRA) to achieve optimization in CFD analyses of ventilation performance in buildings.

Kausar, Fageeri, and Soosaimanickam evaluated the Bag-of-Words feature extraction approach to classify Amazon reviews. Word clouds were used to illustrate the text data in the form of the frequency with which they appear in the review. Decision trees and logistic regression machine learning methods were used to achieve an optimum accuracy of 99% with decision trees.

J. and U investigated the Pearson correlation coefficient-based Harris Hawks optimization-based Recurrent Neural Network-Long Short-Term Memory (PCCHHO-RNN-LSTM) algorithm to reduce the data's dimensionality. RNN-LSTM in MATLAB software for Amazon data got 95.8% accuracy.

Khare et al. explored support vector machine (SVM) and TF-IDF feature extraction techniques to remove sarcastic tweets from Lok Sabha election Twitter data.

Chakraborty, Nawar, and Chowdhury used traditional methods. The Random Forest Classifier (RF), AdaBoost, Naive Bayes (NB), Support Vector Machine (SVM), Decision Tree (DT), Random Forest Classifier (RF), and deep learning methods Convolutional Neural Network and Long short-term memory Network (LSTM) To determine the polarity of Bengali textual Facebook posts and comments, LSTM got a better accuracy of 96.95%. SVM and RF got maximum accuracy of 78.23% and 78.37%, respectively, in the classical approach.

METHODOLOGY

The process of this method is depicted in **Figure 1**, which starts with data collecting and ends with each classification model's evaluation.

DATA COLLECTION

The Amazon dataset was obtained from https://kaggle.com. In this dataset, 568454 user ratings concerning food are included. A product rating is expressed in a single column called score. To indicate the review sentiment as positive, neutral, or negative, we have included one more column sentiment. For ratings 4 and 5, we have assigned positive reviews, and for rating 3, we have assigned neutral reviews. For ratings 1 and 2, we have assigned negative reviews. This data set has 443777 positive reviews, 82037 negative reviews, and 42640 neutral reviews. Figure 2 represents the required dataset and its necessary columns for analysis, and their structure is stored in a CSV format [11].

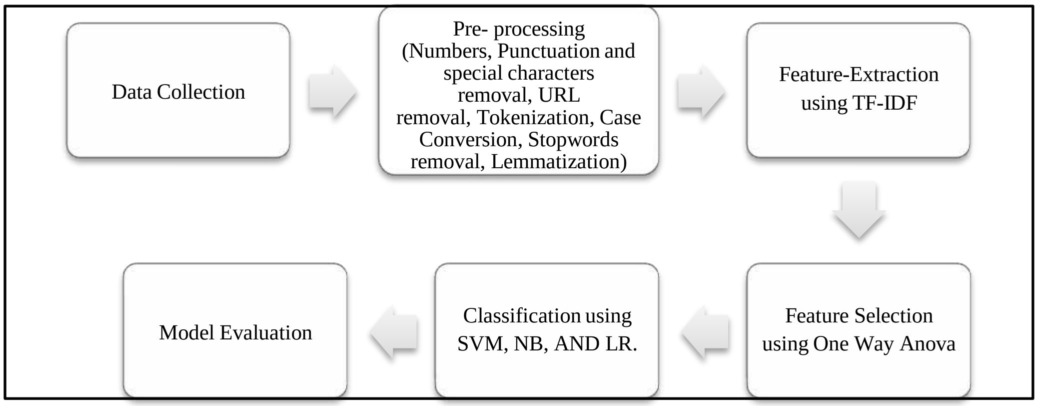

Figure 1 Framework of Proposed System.

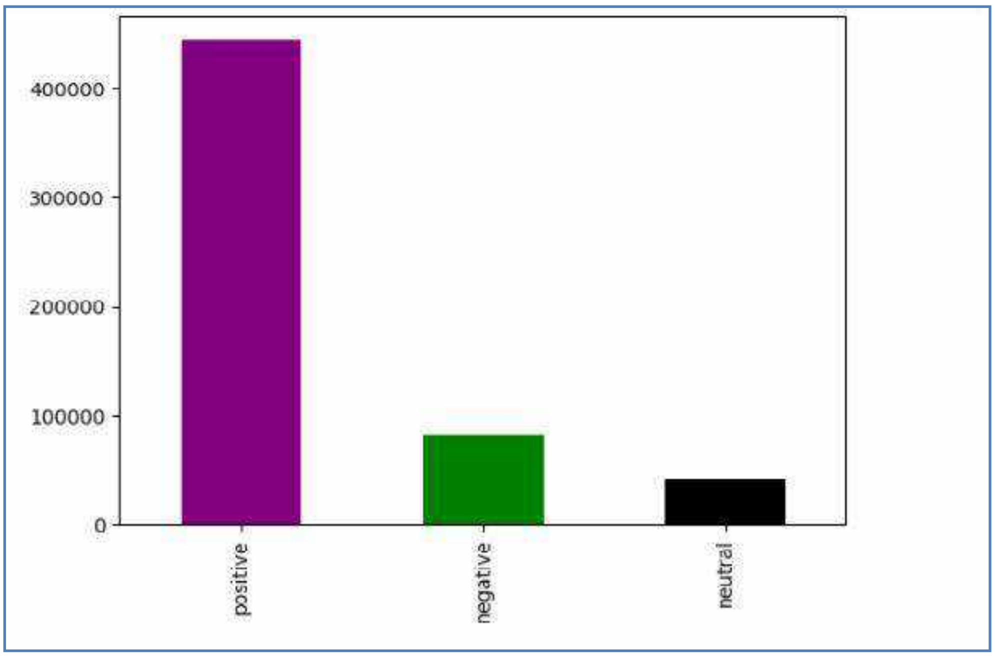

Figure 2 Classification of reviews

PREPROCESSING

Generally, data collected from social media sites like Amazon is in unstructured format. These collected data may contain noise, typographical errors, and grammatical errors. The text must therefore be cleaned and pre-processed before any analysis is done. Pre-processing aims to reduce the dimensionality of the input data as well as the analysis. Many redundant words do not affect the polarity of the text, so they should be removed. Data preprocessing includes case conversion, null value removal, HTML tag removal, URL removal, punctuation mark removal, number removal, slang word removal, stop word removal, tokenization, and lemmatization [1].

Numbers, Punctuation, and Special Characters Removal

Numbers, punctuation marks, and special characters do not play any significant role in deciding the sentiment of the text. Therefore, they must be eliminated. Elimination of these words reduces the dimensions of the data [6, 11]

URL Removal

Uniform Resource Locator (URL) does not play any significant role in deciding the sentiment of text, so they must be removed from the text review given by the user [3].

Tokenization

Statements, or strings, are split into a set of symbols, words, phrases, and keywords called tokens. A sentence like "Mohan is the best player" for instance, splits into tokens: "Mohan", "is", "best" and "player" [4].

Case conversion

The words and tokens were changed from uppercase to lowercase in preparation for processing [6]

Stopwords removal

Stop words are a group of words that don't have any significance or importance, such as "a," "is," and "the". These words were now eliminated to improve the accuracy of sentiment polarity identification. So, we now have a collection of relevant tokens [4,6].

Lemmatization

There is no standard format for writing words in text. Therefore, one word in a review text can be written differently, but they all have the same meaning. Lemmatization can help to remove this condition by changing all these words into their dictionary-based form. This form is known as a lemma. This study used WordNet Lemmatizer for lemmatization[7, 12].

Word Cloud

The dataset has many common words. The Word Cloud visualization technique represents these most common words in visual form. Three visualizations—one for positive sentiments, one for negative sentiments, and one for neutral sentiments—are described in this study. It is observed that all positive, negative, and neutral words frequently pop up in their respective word clouds in **Figure 3** and **Figure 4**[3, 12].

Figure 3 Most common words used in positive reviews

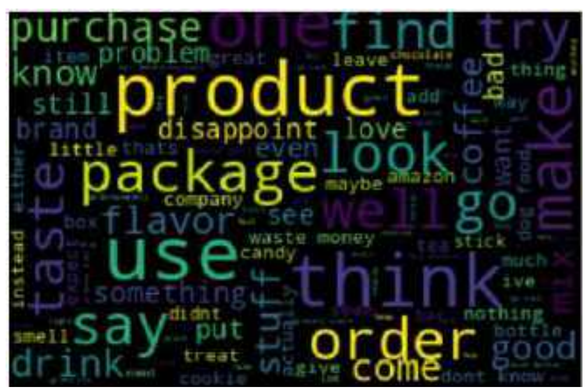

Figure 4 Most common words used in negative reviews

FEATURE EXTRACTION

A critical step in the sentiment analysis method is feature extraction (FE). It lists the feature words collected from the text to describe the text content and transforms it from unstructured to structured data. During the text feature extraction process, irrelevant or extraneous features will be eliminated, and the significant elements (such as words, phrases, or characters, for instance) will be linked with their weights to represent the information contained in the text [6].

The TF-IDF Term Frequency – Inverse Document Frequency feature extraction approach converts text into a machine-understandable mathematical representation, which is later used by machine learning algorithms for classification [6]. The TF-IDF is a form of metric used to find the relevance of a word in a particular document D. TF denotes how many times a particular term appears in a document D.Term frequency (TF(t,d)) represents the occurrence of words in a document, while document frequency (DF(t)) shows the number of documents that contain words. Inverse Document Frequency (IDF (t)) measures the respective weight of a word. IDF (t) will be low if the word is occurring more frequently, and IDF (t) will be high if the word is occurring less frequently [4, 6, 7] Hence, it can be represented by the equations below.

$$F(t,d)=\frac{\text{Frequency of the word t in the document d}}{\text{Sum of all words in the document}} \quad (1)$$

$$IDF(t)=\log\frac{\text{The number of documents}}{\text{The number of documents with word t}} \quad (2)$$

The following equation is used to calculate the TF-IDF (t, d) score of a word.

TF-IDF(t,d)=TF(t,d)*IDF(t) (3)

The weight of general words or more common words adverse to specific or less common words is balanced by the TF-IDF score. A feature matrix is created by TF-IDF vectorization and is then used to train the machine learning algorithm.

Feature Selection

Statistical selection of the significant features is done using one-way ANOVA along with F-value[1].

One-way ANOVA approach, the features were chosen based on the specified percentile (m%) of the initial feature number and the F-values. The ML classifiers were trained using only the m% highest-scoring features [1].

The process of selecting features for the one-way ANOVA approach is demonstrated in Algorithms 1 [1].

Algorithm1:Pseudo code of one-way ANOVA based onF-values.

INPUT: A pair (E, Y), where E represents features extracted by TF-IDF, and Y is the class of each feature. Also, the percentage of the selected features %m.

OUTPUT: A subset of features based on the F-value.

Begin

1. n_classes = count(y)

2. For each E_j€ (E, Y)

3. n_sample_per_classes = Count (Yi)

4.n_samples = Count ((E, Y))

5. df_{bg} = n_classes-1// Degrees of freedom between classes

6.df_{wg} = n_samples-1 //Degrees of freedom within classes

7. ss_all_features= sum (square (E))

8. sum_all_features= sum (E)

9. square_of_sum_all_features = square (sum_all_features)

10. $SS_{total}=ss_{all\_features}-\frac{square\_of\_sum\_all\_features}{n\_samples}$

11. $SS_{bg} = 0$

12. For each Y_i€ Y do

13. $SS_{bg}= SS_{bg}+ \frac{square(sum(Eyi))}{count(E, Yi)}$

14. End For

15. SSbg = SSbg - $-\frac{square\_of\_sum\_all\_features}{n\_samples}$

16. $SS_{wg}=SS_{total}- SS_{bg}$

17. $M_{sb} = \frac{SSbg}{dfbg}$ // Variance between classes

18. $M_{wb} = \frac{SSwg}{dfwg}$// Variance within classes

19. F- value = $\frac{Mwg}{Mwg}$//Score of the feature

20. End For

21. Ascending Order (Based on-value)

21. FS=Select (The highest%m of E based on the F - value)

22. Return (FS)

End

CLASSIFIERS

In this experiment, four classical algorithms (SVM, NB, and LR) are used for prediction.

Naive Bayes Classifier-Based on the Bayes theorem, the Naive Bayes classification is a probabilistic statistical classification. It assumes that in a category, one feature is not affected by the effects of other features [6, 11].

The most straightforward supervised method, Naive Bayes, yields superior outcomes in practical situations [8]. This algorithm functions well on big text data corpora since it is accurate, quick, and reliable. The fundamental shortcoming of Nave Bayes is the assumption that each feature is independent of the others, even though there remains a degree of relationship between them.

Linear SVC-Support Vector Machine (SVM) is a machine learning algorithm that can be used in classification, regression, and outlier identification. (7) Support Vector Classifier (Linear SVC) determines the best-fitting line or hyperplane based on the problem's dimensions. Dimension is a synonym for the number of features. SVC is selected because it only selects the best hyperplane to differentiate between the classes; it ignores all outliners [5].

Logistic regression-A logistic regression classification algorithm is used to classify linear logarithms [8]. It is defined by the Eq. (4), and (5).

$$P(x)=\frac{\exp(w.x+b)}{1+\exp(w.x+b)} \quad (4)$$

$$P(x)=\frac{1}{1+\exp(w.x+b)} \quad (5)$$

Where $x \in R^n$ is the input feature, w is the weight, $Y \in \{0, 1\}$ is the label vector, w.x is the dot product from the matrices, and b is the offset value. After comparing the two probability values, the logistic regression designates x to the category with the greater likelihood value [13].

EVALUATION METRICS

Our study involves classification tasks; therefore, Accuracy, Recall, Precision, and F1-score are used as performance metrics.Accuracy-Accuracy is defined by the ratio of correctly classified reviews to all reviews. It is represented by Eq. 6 [3].

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} \quad (6)$$

Recall- it is defined by the ratio of correctly identified positive reviews to all reviews that were supposed to be positive by Eq. 7[4].

$$\text{Recall} = \frac{TP}{TP+FN} \quad (7)$$

Precision-Precision is defined by the ratio of actually classified positive reviews to all reviews that are predicted to be positive by Eq. 8. [4]

$$\text{Precision} = \frac{TP}{TP+FP} \quad (8)$$

F1 score- The F1 score is defined by the harmony mean of recall and precision. It is used to rectify recall and precision issues when dealing with multi-class imbalanced data. It is represented by Eq. (9)[10].

$$\text{F1 score} = 2\times\left(\frac{\text{Precision}\times\text{Recall}}{\text{Precision}+\text{Recall}}\right) \quad (9)$$

RESULT AND DISCUSSION

This study performed pre-processing, ML modeling, visualization, and data purification using Python 3 and Google Colab with the help of auxiliary libraries. Supervised ML was employed to construct training and testing sets to generate sentiment classification. A classifier model, such as Support Vector Machine (SVM), Naive Bayes, and Logistic Regression (LR), was then fed a set of features, which were extracted from the training and testing data after feature extraction and selection.

Table1 Accuracy of models

SI No.	Model	Accuracy Percentage with all features without using one-way ANOVA	Accuracy Percentage with 50% features by using one-way ANOVA
1	SVM	89%	89%
2	NB	84%	86%
3	LR	85%	86%

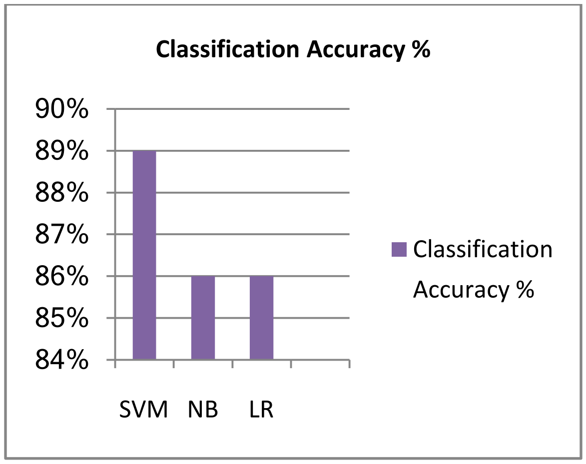

Figure 5 Classification accuracy with various classifiers.

Table 1 depicted that when classifiers SVM, NB, and LR were used without one-way ANOVA feature selection techniques gave an accuracy of 89%, 84%, and 85% but when used with one-way ANOVA it reduced the feature set by 50% from the original feature set with accuracy of 89%, 86%, and 86% respectively. SVM with one-way ANOVA feature selection techniques gives a maximum accuracy of 89% with 50% fewer features.

CONCLUSION

Feature selection (FS) is an important stage in the SA preprocessing process that enhances classification accuracy by reducing feature dimensionality and overcoming underfitting and overfitting by picking important features. Additionally, FS reduces computing time, storage, and complexity.

One-way ANOVA is one of the best filter feature selection strategies and gives the same accuracy of 89% in SVM with 50% fewer features than the original number of features. In the future, we can explore the possibility of hybrid feature selection methods like One-Way ANOVA with another wrapper method on the Amazon dataset with TF-IDF feature extraction methods by using SVM, NB, and LR classifiers.

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Analysis of Different Machine Learning Algorithms for Hand Gesture Recognition using Principal Component Analysis (PCA)

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***Abstract**: An expanding field of recent study on the machine learning paradigm is gesture recognition systems. So, it is essential for effective communication to grasp the real meaning behind every hand gesture so that the recipient can respond with a suitable response. The interaction between humans and computers is improved by accurate hand gesture prediction. Data preparation and classification are the two separate components of the proposed study. To accomplish the gesture detection and classification procedure, a variety of classifier techniques are available. In this study, analysis was carried out using a number of the most widely used machine learning classifiers, including Stochastic Gradient Descent (SGD), Decision Tree (DT), Random Forest (RF), Gaussian Nave Bayes (NB), Logistic Regression (LR) and K Nearest Neighbors (KNN).The experiments were performed using a standard KAGGLE dataset containing a total of 20,000 hand gesture images of 10 different gesture positions. Based on experimental analysis of every technique, Random Forest and KNN predicted more accurate results than the other algorithms like Stochastic Gradient Descent (SGD), Decision Tree (DT), Gaussian Nave Bayes (NB), and Logistic Regression (LR).*

***Keywords**: Machine Learning, Stochastic Gradient Descent (SGD), Decision Tree, Random Forest, Gaussian Nave Bayes, Logistic Regression (LR) and K-Nearest Neighbors (KNN).*

INTRODUCTION

In today's world, Natural Human-Computer Interaction (HCI) is required. According to surveys and studies on sign language, the hand gesture is the simplest and most natural form of communication among the several gesture communication modalities [1]. With the support of recent developments in the field of pattern recognition and computer vision, real-time vision-based hand motion detection is thought to be becoming more and more realistic for Human-Computer Interaction. The use of gesture recognition systems, particularly those that recognize face and hand gestures, has grown significantly in the field of study in recent years. With the help of hand gestures, we may interact with computers more naturally by pointing or spinning a 3D model with our hands. For instance, it is crucial in dangerous environments to translate human hand action for manipulation. One of the most significant uses of hand gesture detection is the simple way that a hand-gesture-to-voice system can facilitate communication with non-verbal or deaf people to enhance their quality of life. Due to congenital defects, illnesses, or head injuries, people who are deaf or non-vocal are unable to speak with others they communicate with hand gestures or sign language [2]. As a result, the study of hand gesture recognition has gained substantial importance for creating systems that are more effective and reliable for recognizing gestures [3].In the proposed work, the PCA method is used to simplify the data, and classification is carried out by seven different machine learning classifiers, including Stochastic Gradient Descent, Decision Tree, Random Forest, Logistic Regression, Gaussian Naive Bayes and K-Nearest Neighbor, which was examined for hand segmentation on Leap Gesture Dataset.

This study is structured as follows: Data Preprocessing, PCA and Different Machine Learning based Hand Gestures Recognition Systems, Performance Analysis, Conclusion, and References.

RELATED WORK

This section discusses some recent research on various gesture recognition approaches, including several classifiers. It contains already proposed works that discuss the difficulties that researchers face and the solutions that they propose.

Bhushan, S. et al. (2022) used Nave Bayes, K-Nearest Neighbor (KNN), random forest, XGBoost, support vector classifier (SVC), logistic regression, Stochastic Gradient Descent Classifier (SGDC), and convolution neural networks to analyze some of the most prominent classification approaches (CNN). Conducting a comparison and analysis of gesture recognition classifiers contains some experimental data aimed at improving gesture recognition through the use of the aforementioned algorithms. Convolutional Neural Networks (CNN) produced the greatest results, with an accuracy of 91.41%. Apart from CNN, the results of random forest are superior to those of other standard algorithms, with an accuracy of 84.43% [4].

Gupta R. et al. (2021) presented a project in which data from various surface electromyograms, as well as gyroscopes and accelerometers on the signers' forearms, is used to classify 50 signs from the Indian sign language. The use of ensemble machine learning models to create an innovative multistage classification of signs is offered. To begin, a binary classifier is utilized to determine if the sign is in a static posture or contains dynamic hand motion. The sign is then classified using one of two multi-class classifiers, each of which has been trained to distinguish between static and dynamic signs. For selecting the features important for the categorization of signs from the two groups, the random forest (RF) and extreme gradient boosting machine were compared. It has been discovered that electromyogram features are more relevant for static sign classification than those retrieved from accelerometer and gyroscope data for dynamic sign classification. The overall classification accuracy of the suggested multi-stage classification strategy increased to a maximum of 98% with RF, which is higher than the accuracy reached when a single classifier is employed to categorize all the indications [5].

Rakesh, S. et al. (2021) use the Leap motion sensor to recognize palm sign gestures and extract geometric elements from the recordings. The Genetic Algorithm (GA) for feature selection is then encoded. For gesture recognition, genetically chosen features are supplied to several classifiers. To compare the findings, we employed Support Vector Machine (SVM), Random Forest (RF), and Naive Bayes (NB) classifiers. On the Leap Motion Sign Gesture dataset, the RF classifier recorded a gesture identification accuracy of 74.00% [6].

Alksasbeh, M. Z., et al. (2021) present a method for converting such gestures into annotated explanations. The proposed system employs visual data processing, which has recently been identified as among the most advanced techniques. As an initial input, the system evaluates a classroom video, and The vocabulary of twenty gestures is then extracted. Several methods were used sequentially, including motion detection, RGB to HSV conversion, and noise removal using labeling algorithms. A K-NN algorithm determines the retrieval of hand parameters to eventually evaluate the hand gesture and, thus, show their meanings. An experiment with a hand motion dataset is carried out to estimate the effectiveness of the proposed technique. The system's performance can be evaluated using 120 different hand gestures [7].

Yasen et al. (2019) conducted a study to identify the most common hand gesture recognition and classification methodologies, applications, and problems. Hand gesture recognition is accomplished by performing a series of procedures, such as image frame acquisition or gesture acquisition, using a computer to capture a human hand gesture image. Several methods can be used to extract the characteristics, including Fourier descriptor and centroid. The collected features are then submitted to a classification method (such as Artificial Neural Networks (ANN), K-nearest neighbor (KNN), Naive Bayes (NB), Support Vector Machine (SVM), and so on) for training and testing. Surface electromyography (sEMG) sensors with wearable hand gesture devices were the most regularly obtained instrument in the work studied, and Artificial Neural Network (ANN) was the most commonly used classifier.

Shitole, S. M. et al. (2013) present a vision-based dynamic hand gesture recognition system based on PCA, pruning, and ANN. The hand will be located by the system. Two systems—one that employs a color marker and the other that does not—are included in the suggested architecture. A Principal Component Analysis (PCA) strategy is used for the system with the color marker, and gesture is determined by computing Euclidean distance. In the absence of a color marker, the system uses pruning and an ANN technique. The system does not use color markers and instead uses an ANN Cascade-feed forward network and two classifiers that can reduce. Two classifiers pruning and an ANN Cascade-feed forward network are used to optimize training input data, with trimming providing an 84% identification rate and ANN providing an 86% recognition rate.

PROPOSED METHODOLOGY

This Section describes the different classifiers techniques with their parameter, which are widely used for the classification process and in this work we employed Stochastic Gradient Descent (SGD), Decision Tree (DT), Random Forest (RF), Gaussian Nave Bayes (NB), Logistic Regression (LR) and K Nearest Neighbors (KNN) classifier techniques. Here dataset is also described on which the algorithms are implemented for the process. **Figure 1** shows the working procedure of the entire process.

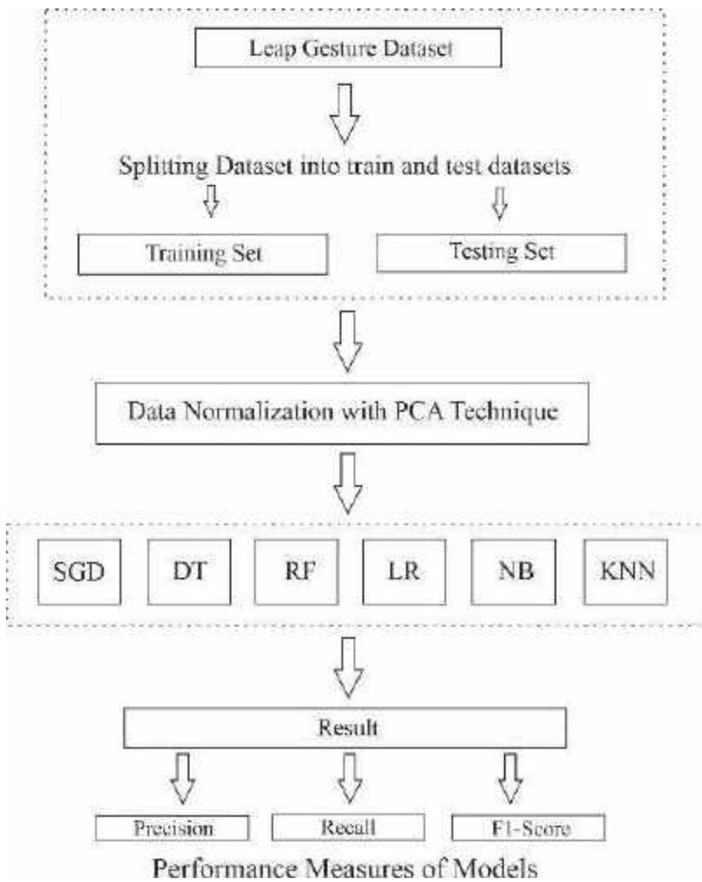

Figure 1 Framework of proposed system

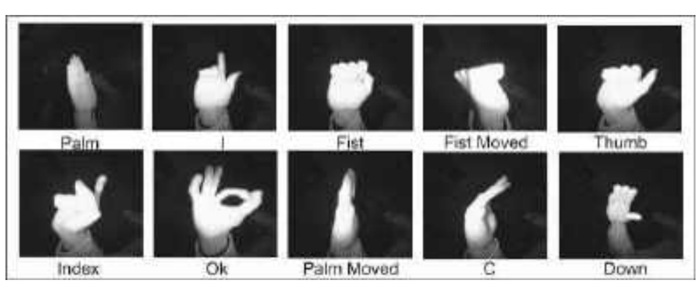

Figure-2 Sample images of 10 different gesture phases of the dataset

```
Before PCA (20000, 9600)

[0.25498139 0.08075452 0.06690615 0.041779   0.03379988 0.03188952
 0.02433627 0.02123843 0.01862449 0.01679004 0.01509599 0.01309636
 0.01163883 0.01093523 0.00949857 0.00920229 0.00874922 0.00804041
 0.00764498 0.00756176]
[1529.79553924  860.91952673  783.6320034   619.23884469  556.97628433
  541.00728367  472.61356718  441.5097674   413.44844397  392.55902694
  372.22881781  346.7004456   326.72655696  316.80585283  295.26251169
  290.62114592  283.37643692  271.65533397  264.89112193  263.44545822]

After PCA (20000, 20)
```

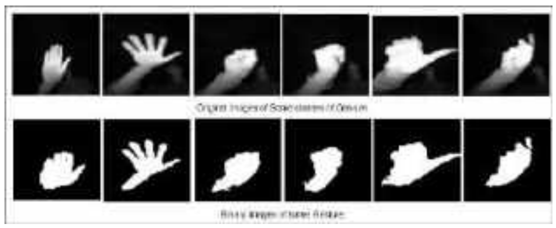

Figure 3 Sample of original images and their converted grayscale images

DATASET

Data collection is a basic step to collect the data for experiments in the proposed system. In the context of gesture recognition, a well-known KAGGLE competition dataset was used for the experiments [8]. The standard KAGGLE contains a large number of gesture images with a high resolution. The dataset includes 10 static gestures (I, Index, Fist, Fist Moved, Palm, Palm Moved, OK, Thumbs, C, and Down). Each class contains 2000 images for instruction and another 2000 images for assessment. As a result, the total number of images is 20,000. Figure 2 depicts a sample of the finalized dataset.

PCA BASED FEATURE EXTRACTION

Principal component analysis (PCA) is a multivariate statistical analysis method that selects a few important variables by linear transformation of several variables [9]. However, the conventional PCA could be used as a straightforward background to develop a comparatively more operative feature extraction approach. This newly developed PCA-based method can be able to collect the most useful and subtle information for classification purposes [10]. Here we are showing the total parameters with the input shape before and after applying the PCA. Here the total number of parameters is 9600. After applying the PCA technique, it reduces thecomplexity of input, and then the total parameter is only 20.

CLASSIFICATION

Decision Tree (DT), Random Forests (RF), Logistic Regression (LR), Gradient Descent Classifier (GDC), Gaussian model Nave Bayes classifier (NB), and K-Nearest Neighbors are the six classifiers employed in this study (KNN). The training process and the classification process comprise the classification task, which is the same for each of the six possible classifiers. To select the most effective classifier based on the scoring classifier phase, the data were pre-processed and turned into grayscale images. The dataset was split into training/validation and testing sets in the scoring phase at an 80:20 ratio. However, it should be mentioned that each subject was split individually; one

group of individuals was used for testing, while a completely different group of subjects was employed for training. The situation that allows for more general results and conclusions is this one, which is more difficult than within-subject testing. Additionally, a portion of the training data was used for hyperparameter optimization to confirm performance, and the test set was solely applied to the best-performing model configuration.

STOCHASTIC GRADIENT DESCENT (SGD)

Stochastic Gradient Descent (SGD) is a simple yet effective optimization computation used to find the benefits of capacity boundaries and efficiency coefficients that restrict cost-intensive operations. Across both gradient descent and stochastic gradient descent, an error function is minimized by iteratively updating a set of parameters. One of the faster training algorithms is SGD. SGD is well-liked for training a variety of machine learning models. When using logistic regression, is used for the discriminative training of straightforward classifiers under asymmetrical tragedy. Since the coefficients are changed for every preparation occasion rather than after instances, it has been successfully applied to datasets with vast scope. The results from SGDC will be the worst if the hyperparameter selection is improper.

K-NEAREST NEIGHBOR (KNN) ALGORITHM

The K-Nearest Neighbor (KNN) method is a supervised machine-learning technique for gesture recognition which is utilized for classification, and each data point's categorization is influenced by the classification of its neighbors. In KNN, the closest neighbor is determined using the Euclidean distance [11]. KNN assumes that related classes exist nearby in feature space rather than making any underlying assumptions about data distribution. Finding the distances between a new input and each sample in the data is the basis of the method. While utilizing KNN, classification is done using a threshold value that is determined by averaging the k closest data points. The closest neighbor's distance, a similarity metric, and a threshold value serve as the primary determinants of performance. Euclidean distance between two data points, $X = (x_1, x_2, \ldots x_n)$ and $Y = (y_1, y_2, \ldots y_n)$ is:

$$d(X, Y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2} \quad (1)$$

DECISION TREE (DT)

A supervised machine learning technique called the DT constantly partitions data based on model attributes to solve classification issues [12]. This algorithm follows the branch and jumps to the following node by comparing the values of the root attribute with those of the record (real dataset) attribute. The algorithm verifies the attribute value across all sub-nodes once again for the following node before continuing. It keeps doing this until it gets the tree's leaf node. The algorithm's name comes from the fact that it is frequently depicted as a graph with all options and outcomes taking the shape of trees. The Sum of Product (SOP) representation is used in decision trees. The sum of Product (SOP) is also called The Disjunctive Normal Form.

RANDOM FOREST (RF)

The foundation of Random Forest is the idea of supervised methods, which is the act of mixing various classifiers to resolve a challenging problem and enhance the model's performance. Decision tree outputs from RF are combined to provide a single outcome. The algorithm builds a large number of decision trees during training and outputs the class that represents the mean of the categories (classification) or mean prediction (regression) of the different trees. Random forest approaches are selected because of their features, such as their effectiveness in big datasets, lack of overfitting, use of numeric and categorical variables, ease of application in multi-class environments, and need for fewer parameters than other cutting-edge techniques.

LOGISTIC REGRESSION (LR)

Regression is a supervised learning method that enables us to predict the continuous outcome variable based on one or more predictor variables and supports determining the correlation between variables. Because it uses a linear equation to predict values between 0 and 1, the probability-based logic of logistic regression is known as a predictive analytic algorithm. Regression using the logistic function, also known as the sigmoid function, is referred to as logistic regression. In logistic regression, the data are modeled using this sigmoid function.

The function can be shown as follows:

$$f(y) = \frac{1}{1+e^{-(y)}} \tag{2}$$

where $-\infty \leq f(y) \leq +\infty$

NAÏVE BAYES FOR GAUSSIAN MODELS

The NB classifier gives the drawn conclusions a statistical dimension [13]. The probability distribution determines who belongs in each cluster (class). Consequently, the distribution of probabilities to which every vector belongs can be taken into account to calculate the ideal categorization (aligning each feature in each group). The weighted probability that the computed value represents, which can be employed subsequently in other computations, is one of the main benefits of the NB algorithm. The Naïve Bayes Gaussian model only uses continuous data and supports the Gaussian normal distribution. It is also a Bayes theorem-based supervised machine learning algorithm [14]. Using each class frequency, the probability of input values will be calculated. The mean and standard deviation of each class must also be kept on file. It is based on follows when there are two events A and B.

$$P(A|B) = \frac{P(B|A)\,P(A)}{P(B)} \tag{3}$$

Where,

- P(A|B) is Posterior probability: Probability of hypothesis A on the observed event B.
- P(B|A) is Likelihood probability: The probability of the evidence given that the probability of a hypothesis is true.
- P(A) is Prior Probability: The probability of the hypothesis before observing the evidence.
- P(B) is Marginal Probability: Probability of Evidence.

EXPERIMENTAL WORKS AND RESULT

In this section, we analyze the above-discussed algorithms based on different criteria like training and testing accuracy and loss. The performance of the different classifiers such as Stochastic Gradient Descent, Decision Tree, Random Forest, Logistic Regression, Gaussian Naive Bayes, and K-Nearest Neighbor is represented by the confusion matrix shown in **Figure 4**.

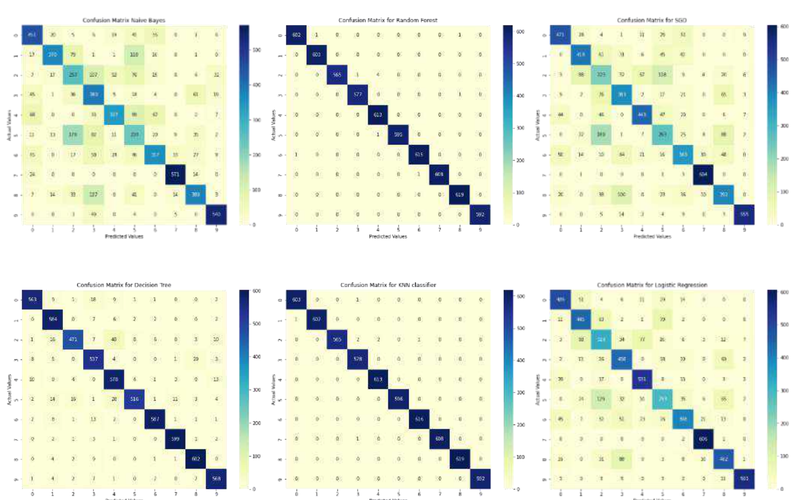

Figure 4 Confusion Matrix of all Classifiers

The confusion matrices corresponding to all the defined classifiers were used to compare the various classifiers. The key terms in confusion matrices are False Positive (FP), False Negative (FN), True Positive (TP), and True Negative (TN). This study used the confusion matrix to identify the multi-class classification by calculating metrics for one label versus all other labels because it was reduced to a binary problem for each gesture (label) separately. The following definitions describe the criteria used to score the specific classifier.

Precision- According to Equation, precision is a performance indicator that is determined as the proportion of true positive predictions divided by the total number of positive predictions (the sum of false positives and true positives).

$$\text{Precision} = \frac{\text{TP}}{\text{FP} + \text{TP}} \quad (4)$$

Recall- The proportion of positives that are accurately classified as such is measured by recall (also known as Sensitivity or True Positive Rate). The equation defines the recall as the ratio of true positive samples to the total of False Negative and True Positive samples.

$$\text{Recall} = \frac{\text{TP}}{\text{FN} + \text{TP}} \quad (5)$$

F1-Score- A more useful metric than accuracy is the F1 score, which is the harmonic mean of recall and precision, as shown in the equation

$$\text{F1} = 2 * \frac{\text{Precision} \; *\text{Recall}}{\text{Precision} \; +\text{Recall}} \quad (6)$$

All classifiers were compared, based on precision, recall, and F1-score, as shown in **Table 1,2** and **3**.

From **Tables 1, 2**, and **3** we can observe that Random forest and K Nearest Neighbors classifiers achieve the highest Precision, Recall, and F1-Score values than the other classifiers such as Stochastic Gradient Descent (SGD), Decision Tree (DT), Gaussian Nave Bayes (NB) and Logistic Regression (LR).

The plot of these Precision, Recall, and F1-Score values of all classifier methods corresponding to the different classes are shown in the below **Figure 5, 6** and 7 respectively.

Python is utilized to complete the task along with the Anaconda Python IDE, which is used to create and run code. The SKlearn package was used to generate the classifier. Sklearn is also used to calculate the confusion matrix. Matplotlib was used to display the model's accuracy, loss values, and confusion matrix. NumPy is used to execute array operations.

Table 1 Precision Measures of the classifiers for 10 different classes

Class	**Precision**					
	SGD	**DT**	**RF**	**LR**	**NB**	**KNN**
1	0.79	0.96	1.00	0.81	0.67	1.00
2	0.73	0.90	1.00	0.71	0.85	1.00
3	0.35	0.95	1.00	0.52	0.42	1.00
4	0.61	0.89	1.00	0.66	0.46	0.99
5	0.79	0.85	0.99	0.81	0.75	1.00
6	0.47	0.97	1.00	0.62	0.35	1.00
7	0.63	0.98	1.00	0.80	0.66	1.00
8	0.92	0.97	1.00	0.94	0.90	1.00
9	0.63	0.95	1.00	0.74	0.72	1.00
10	0.95	0.94	1.00	0.98	0.88	1.00

Table 2 Recall Measures of the classifiers for 10 different classes

Class	Recall					
	SGD	**DT**	**RF**	**LR**	**NB**	**KNN**
1	0.78	0.93	1.00	0.81	0.75	1.00
2	0.69	0.97	1.00	0.74	0.61	1.00
3	0.39	0.83	0.99	0.57	0.45	0.99
4	0.66	0.93	1.00	0.76	0.67	1.00
5	0.72	0.94	1.00	0.87	0.55	1.00
6	0.44	0.81	1.00	0.49	0.39	1.00
7	0.59	0.95	1.00	0.65	0.58	1.00
8	0.99	0.98	1.00	1.00	0.94	1.00
9	0.63	0.97	1.00	0.75	0.61	1.00
10	0.94	0.96	1.00	0.95	0.91	1.00

Table 3 F1-Score Measures of the classifiers for 10 different classes

Class	F1-Score					
	SGD	**DT**	**RF**	**LR**	**NB**	**KNN**
1	0.78	0.95	1.00	0.81	0.71	1.00
2	0.71	0.94	1.00	0.72	0.71	1.00
3	0.37	0.88	1.00	0.54	0.44	1.00
4	0.64	0.91	1.00	0.71	0.55	1.00
5	0.76	0.90	1.00	0.84	0.63	1.00
6	0.45	0.92	1.00	0.55	0.37	1.00
7	0.61	0.96	1.00	0.71	0.62	1.00
8	0.95	0.98	1.00	0.97	0.92	1.00
9	0.63	0.96	1.00	0.74	0.66	1.00
10	0.95	0.95	1.00	0.96	0.89	1.00

During the experiment, different classifiers are used to classify and predict the gesture phases of the Leap Gesture Dataset. We also provide **Table 4** where the accuracy and loss are presented for the training set as well as the accuracy and loss for the test set. Presented values show that there is a difference between performance on the test and training set which was expected. From **Table 5** we can measure that Stochastic Gradient Descent achieved 68.58%, Decision Tree achieved 93.41%, Random Forest achieved 99.81%, Logistic Regression achieved 75.78%, Naïve Bayes achieved 64.76% and K-Nearest Neighbor outperforms the other methods which achieved highest accuracy i.e. 99.86%.The observation was conducted on factors such as accuracy, classification report, and confusion matrix. The advantages of SGDC over gradient descent, a more expensive technique for performing classification, include its effectiveness as a linear classifier, simplicity in application, and capacity to get around this issue. In logistic regression, a linear equation is employed to forecast a value. The objectivity of all the traits and variables in the dataset. Because it is quick and simple to construct, the Gaussian Naive Bayes algorithm is employed for class prediction in multiclass datasets.The findings in **Table 4** show that the K-Nearest Neighbor model had the maximum prediction rate with (K=5), the number of closest neighbors.

Figure 8 shows a plot for the performance variations from several neighbors. This graph demonstrates how accuracy decreases as neighbor value rises.The second-best algorithm is RF. Whether or not the data can be linearly separated or if outliers are a problem is irrelevant because they are non-parametric and manage feature interactions with ease. Every time new instances are given, the tree needs to be rebuilt because RF does not offer online learning. This is the main negative aspect. The performance of all the different classifiers is compared graphically in **Figure 9**.

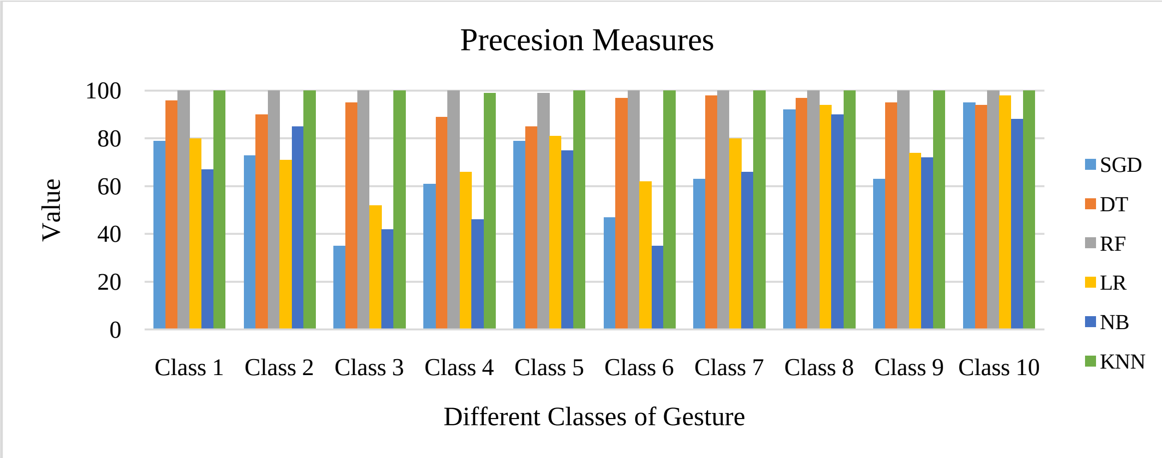

Figure 5 Precision Measures of all Classifiers corresponding to different classes

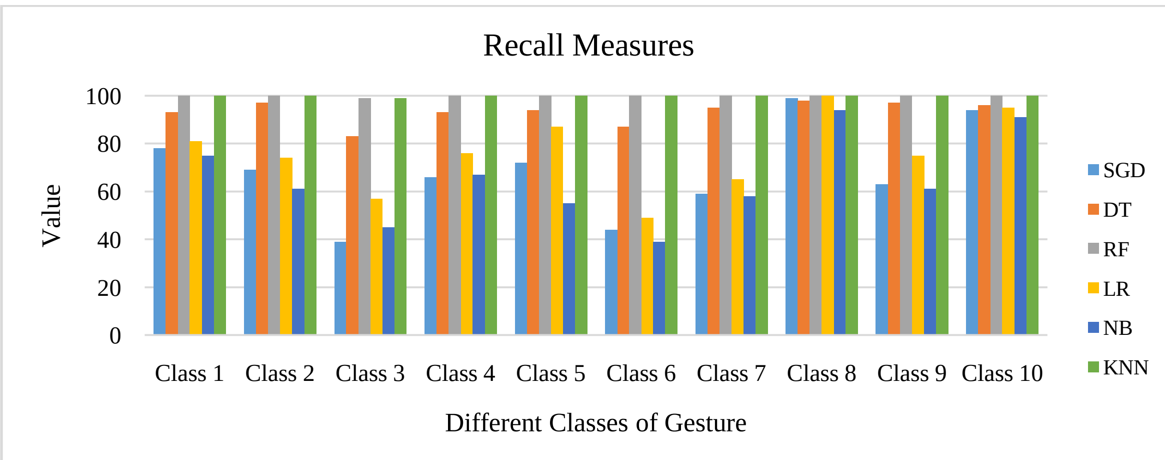

Figure 6 Recall Measures of all Classifiers corresponding to different classes

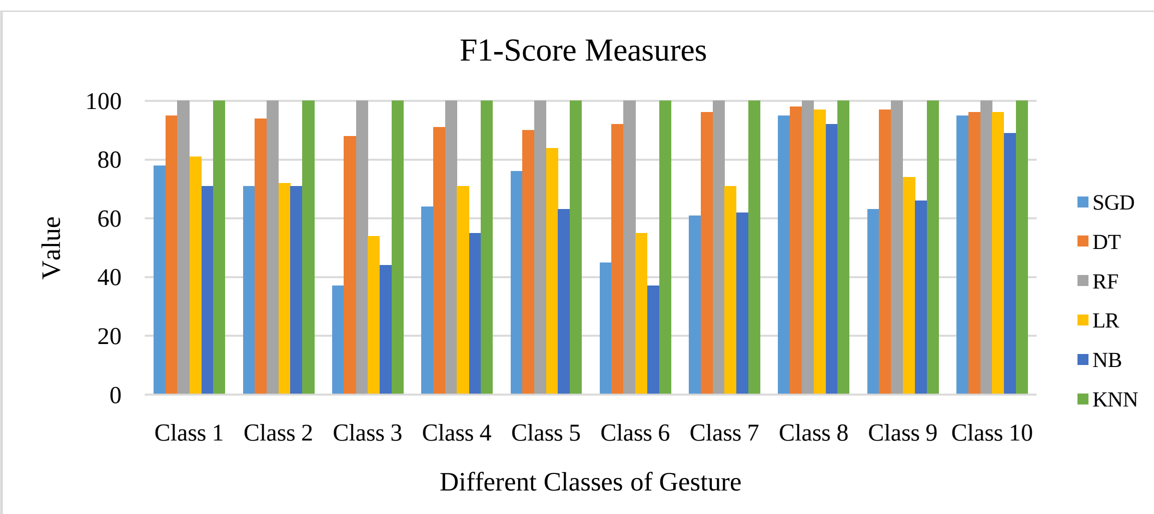

Figure 7 F1-Score Measures of all Classifiers corresponding to different classes

Table 4 Accuracy and Loss of the Different Classifiers

Method	Training Accuracy	Training Loss	Test Accuracy	Test Loss
Stochastic Gradient Descent	68.31%	31.41%	68.58%	31.41%
Decision Tree	95.04%	4.95%	93.41%	6.58%
Random Forest	100%	0.0%	99.81%	0.18%
Logistic Regression	76.1%	23.9%	75.78%	24.21%
Naïve Bayes	65.56%	35.23%	64.76%	34.43%
K-Nearest Neighbor	99.83%	0.06%	99.86%	0.1%

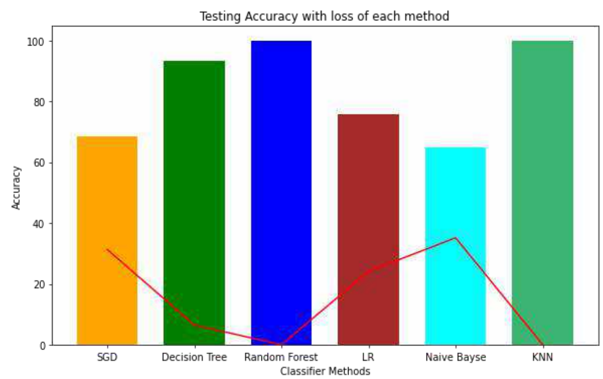

Figure 8 Training and Testing Accuracy varying from different neighbors in KNN 000

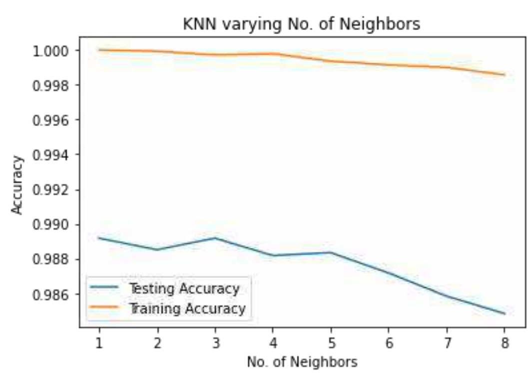

Figure 9 Comparison of Accuracy of the Classifiers

CONCLUSION AND FUTURE WORK

Hand gestures are an effective means of human communication that have a wide range of possible HCI applications. That being said, hand gesture classification is a challenging topic, and our effort only makes a small dent in the outcomes that the profession needs. The Stochastic Gradient Descent Classifier (SGDC), Decision Tree (DT), Random Forest (RF), Logistic Regression (LR), Naïve Bayes Gaussian, and K-Nearest Neighbor (KNN) have been compared in this work to their applications in the classification and recognition of ten distinct phases of the Leap Gesture Dataset. KNN attained the greatest accuracy of 99.86% in this work. Aside from KNN, random forest performs better than other algorithms, with 99.81% accuracy.So the proposed objective can be used to predict more accurate results in terms of better communication between humans and machines.

As future work and major development prospects, it is suggested:

- Examine alternative machine learning methods used to tackle the hand gesture categorization problem and contrast the outcomes.
- Examine and attempt to identify more dependable methods for determining a gesture's start and finish.
- Develop systems that can identify continuous gestures, meaning that there won't be any need to include gaps for the creation of gestures or commands.

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Alleviate Cold Start Problems in Recommendation Systems using Machine Learning Algorithms

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***Abstract**: Recommendations are data filters that can predict the ratings of customers and products, basically showing their preferences from big data. The recommendation system provides a mechanism that helps users categorize users with similar interests. Most traditional recommendation systems are not accurate if the information used in the recommendation process is sparse. This article addresses the cold start problem and aims to eliminate it with numeric value parsing collaborative filtering applied to web product recommendations. This article introduces a product recommendation whose main purpose is to find a recommendation list by numerical value decomposition combining filter and cosine similarity.*

***Keywords**: Recommender systems, Collaborative Filtering, cold start, Rating, SVD*

INTRODUCTION

In recent years, recommendation strategies, e-commerce sites, social platforms, etc., aim to better present the products they like to users. plays an important role in online services. A popular and effective method used by recommenders is Collaborative Filtering (CF) [1], which learns user preferences for products from previous user data (for example, often using matrix materials). However, the classic CF system can recommend existing products to existing users.

When a new user or product arrives, it cannot be confirmed because this user or product has no history. This problem is called a cold start problem [2].

Cold start issue usually affects recommendation performance and user experience through user recommendations. As such, it has received a lot of attention from the research community and businesses. In general, two main methods have been developed, namely content-based discussion and interview. The content-based approach tries to solve the data gap using information provided by users or products. In general, service information can be used to provide similar restrictions on users (or objects) [3] or transformed into data to create users (or objects) such as represented in [4].

In this article, we propose a novel cold-start recommendation model, which aims to generate effective recommendations for new users.

COLD START PROBLEM

Cold-Start Problem When a new item is added to the RS repository or a new user interacts with the RS, RS encounters a problem in providing recommendations; This issue is known as the first cold start problem [5] in RS. There are two different forms of cold start problems in RSs: (1) new user cold start problem and (2) new item cold start problem. In a new user cold start problem, a new user is introduced to the system, and RS faces a problem in giving recommendations as it has no information about the user. In the new item cold start problem, the system has no ratings for the new item and it faces difficulty in determining a target user for the item. If cold users and cold items can be managed more effectively, then personalized recommendations can be obtained. Most literature treats cold users by telling them about the most popular things [6]. Out of the two kinds of cold-start problems, the new user cold-start problem is more difficult and has been widely studied [7][8]. This paper provides a model to mitigate the cold start problem in RSs.

COLLABORATIVE FILTERING

Collaborative filtering (CF) was first proposed by Goldberg in 1992. [9] Its main idea is to use the interests of interest groups to suggest information that users need. Collaborative filtering algorithms only consider user behaviour to recommend products. They use the information of other people who use the measures for their daily work. Other users' actions and interests are used to promote content to new users [10]. Collaborative filtering is a process where users filter their interests based on similar users.

It works by looking at the crowd and finding smaller customers with similar interests as that customer. He looks at his favourite products and combines them to create a list of recommendations. CF is a new algorithmic method that finds its place in many business applications and has become an important part of consensus [11]. Generally speaking, the CF algorithm has two parts, one is the consensus CF memory and the other is the CF consensus-based model. [12].

Memory-Based CF recommendation

Memory-based CF recommendations use the entire data history to find similar objects. Memory-based collaborative filter suggestions can be divided into product-based collaborative filter suggestions and user-collaborative suggestions. Items based on CF will find product balance based on the similarity of suggested products. It relies on the user's surrounding information to provide recommendations, predictions, and recommendations for the CF user [11]. Community Selection is an important part of the customer-centric CF strategy that selects customers from surrounding competitors based on active users.

Basic Similarity Methods User-based CF is also known as the nearest neighbour-based collaborative filter [13]. It first finds the target user's nearest neighbours and then provides an estimate or best N recommendation for the target user along with the neighbours' preferences. Comparison analysis, which measures the similarity between two users, is the most important feature of KF users. Choosing a similar method can improve the performance of CF users. Three similar methods are as follows:

Cosine Similarity: In this case, two users are considered two dimensions in the object space. The similarities between them are measured by integrating the cosine of the angle between these two vectors. Formally, similarities between users i and j are given [14].

$$sim(i,j) = \frac{I.J}{\|I\|\|J\|} = \frac{\sum_{c\in Item} R_{ic}R_{jc}}{\sqrt{\sum_{c\in Item} R_{ic}^{2}}\sqrt{\sum_{c\in Item} R_{jc}^{2}}}$$

Adjusted Cosine Similarity: The basic cosine ratio has one important drawback the difference in the rating scale between different users is ignored. The adjusted cosine similarity match removes this setback by subtracting the corresponding user rating from each of the two pairs. In the past, the similarity between user i and j is given by [14].

$$sim(i,j) = \frac{\sum_{c\in I_{ij}} (R_{ic}-\bar{R}_i)(R_{jc}-\bar{R}_j)}{\sqrt{\sum_{c\in Item} (R_{ic}-\bar{R}_i)^2}\sqrt{\sum_{c\in Item} (R_{jc}-\bar{R}_j)^2}}$$

where represents the items that user i and j co-rated; denote the average rating of user I and j.

Pearson's Collection Similarity: In this case, the similarity between users i and j is measured by computing the Pearson correlation. To make the correlation computation accurate, we isolate the co-rated cases. The correlation similarity is given by [14].

$$sim(i,j)=\frac{\sum_{c\in I_{ij}}\left(R_{ic}-\overline{R}_i\right)\left(R_{jc}-\overline{R}_j\right)}{\sqrt{\sum_{c\in I_{ij}}\left(R_{ic}-\overline{R}_i\right)^2}\sqrt{\sum_{c\in I_{ij}}\left(R_{jc}-\overline{R}_j\right)^2}}$$

The demerit of CF recommendation algorithms is additionally very obvious, which causes these researchers to make efforts to enhance the algorithm or to mix it with data mining techniques to unravel those problems. CF recommendation algorithm mainly has squint issues.

Sparsity Problem: Due to the tremendous sparsity of the data, collaborative filter recommendation algorithms often lose information when forming the nearest neighbour sets of target users, thus reducing the recommended effectiveness.

Cold Start Problem: When a new item first appears, the CF recommendation algorithm is not able to predict the score because the user is not evaluating the new item. [14]

Model-Based CF recommendation

The model-based CF recommendation often takes advantage of knowledge mining, machine learning, and other techniques. Model-based CF methods include the neural network model, the Bayesian belief network model, and the clustering model [13].

LITERATURE REVIEW

In previous studies, various methods have been developed to solve the cold start problem experienced during the consensus process. Collaborative filtering is one of the commonly used techniques in RS. However, there are some issues with this method such as cold boot issues. In recent years, many methods have been proposed to solve the cold start problem. Some of these methods use other data, such as demographic data or social beliefs, in addition to the CF method.

To solve the cold start problem, Safoury et al. [15] used general information from users to calculate the similarity between users. Cui C et al. [18] In this article, the authors propose a POI recommendation method that includes information about images uploaded and liked by users, and traffic information that the relationship is happy to obtain via chat. The main advantage of this method is to reduce the problem of information sparsity in the POI recommendation by considering different information.

Nguyen et al. [17] use demographic information such as age, occupation, and gender, which are easily found in the user's profile. To this end, they constructed various α-community models for user groups, where α is the user's similarity. In addition, missing α neighborhoods are calculated for new users, which is used by the rule-based induction rule to predict missing objects. D.

Authors Polrier et al. [18] proposed a solution to the cold start problem by using blog data and populating it with users' opinions, and then creating a user evaluation matrix for sharing hand filters and improving suggestions. Lin et al. [19] developed a hybrid model based on the analysis of two modeling approaches. Their research provides a pure water filter integrated with user data to solve the cold start problem.

It uses a variety of combinations such as cascade and hybrid boost, which can be used in application-based recommendations for better accuracy and results. Luo Zhenghua [22] In this paper, the author said that hybrid methods play an important role in collaborative filtering. It provides user-user compatibility and product-product compatibility. The authors discuss a new hybrid approach to the evaluation problem of finding unrated items. This consensus addresses two main issues: consensus, data accuracy, and variance.

C Preisach et al. [23] argued that many data users have anonymous data that could provide important information, especially for cold start problems, and suggested a Correct as a semi-supervisor using anonymous letters. A. N. Raosli et al. [24] developed a new index by combining similar results from video "Facebook" pages. First, the similarity between users is calculated based on the evaluation of the video rating system. Then, data from the interest types of users with similar results are combined as extracted from the "Facebook Page". M. Braunhofer et al. [25] In this paper, the authors present a personalized AI strategy that uses the personal information of LFM-based CF system users. Users write questions to help judge themselves based on binary predictions, choosing relevant items for the match.

METHODOLOGY

The following steps are involved in building a model

(a) This dataset was from an Amazon dataset. Details of attributes are given below:

user-id, product-id, rating, and timestamp

(b) Create a “popularity-based model” and earn points: in a very popular-based recommendation system first, calculate what number of users have rated a product. within the next step, the code divides the database into a training database and a test database using an 80-20 scale.” Stored the number of ratings cherish a respective product in an exceedingly very column and gave it index as “score”. The score described count of the rating users has rated to the particular product”. Then they were grouped in descending order with relevant products and displayed the foremost popular products that had the best ratings which were then recommended to every user. Product predictions are made based on popularity.

(c) Various methods to implement Collaborative filtering

Matrix Factorization using Singular value decomposition

Nearest Neighbour collaborative filtering (User-based and Item-based)

(d) Split whole data into the training set and test set as data frame into the variables rating and rating test. Split whole data randomly into train and test datasets into 80:20 ratio train_data

(e) Train the model and result accuracy are:

- RMSE for the Matrix Factorization using SVD:0.97706
- MAE for the Matrix Factorization using SVD:0.724346
- RMSE for KNNwithMeans using user-user similarity: 1.07981
- MAE for KNNwithMeans using user-user similarity: 0.80585
- RMSE for KNNwithMeans using item-item similarity: 1.19377
- MAE for KNNwithMeans using item-item similarity: 0.845632

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Figure 1 Predictions with SVD

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              ('B001UI2FPE', 4.650686916938439),
              ('B000B6D39I', 4.636352905649753),
              ('B00B588HY2', 4.587451861513724)],
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              ('B003A7CDY6', 4.929597255783729 5)],
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Figure 2 Top Five Predictions

```
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 Prediction(uid='A2F7CSE6KT7NI4', iid='B001W9JMOS', r_ui=4.0, est=4.2582
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```

Figure 3 Predictions KNN with mean

```
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82352941176, details={'was_impossible': True, 'reason': 'User and/or ite
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m is unknown.'}),
 Prediction(uid='A2F7CSE6KT7NI4', iid='B001W9JMOS', r_ui=4.0, est=4.2582
82352941176, details={'was_impossible': True, 'reason': 'User and/or ite
m is unknown.'}),
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```

Figure 4 Predictions KNN with mean item-item similarity

RESULT

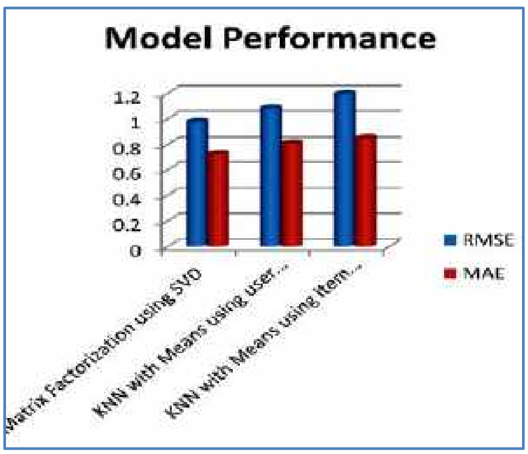

Figure 5 Graphical comparison

A comparative analysis of the model is shown below:

Model	RMSE	MAE
Matrix Factorization using SVD	0.97706	0.72434
KNN with Means using user-user similarity	1.07981	0.80585
KNN with Means using item-item similarity	1.19377	0.84563

CONCLUSION AND FUTURE SCOPE

This recommendation system will help new small-scale industry improve their customer experience on e-commerce and result in better customer acquisition and retention. the advice system, which we've designed relies on a brand new customer's journey from the instant they first visit the business website to their next purchase. Popularity-based could be a vast strategy to focus on the new users with the foremost popular products sold on e-commerce and is extremely useful to cold start a recommendation engine. It's a non-personalized recommender system. The popularity-based algorithm has its use cases when the user would similar to browses the foremost popular items. For a personalized recommender system go with Model Matrix Factorization using SVD, KNN with Means using user-user similarity, and KNN with Means using item-item similarity. To conclude, we suggest going with Matrix Factorization using SVD as the RMSE and MAE for this system are the least in error compared to others. Shortly, the "RMSE" and “MAE” values could be reduced and the performance of this model could be improved. We hope this approach will improve the performance of our algorithm because our preliminary experiment has shown promising results.

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MECHANICAL ENGINEERING DIVISION

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Reimagining Tomorrow: Engineering the Future through Disruptive and Interdisciplinary Technologies

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***Abstract**: Mechanical engineering has always been an interdisciplinary field demanding professionals to have a firm grasp on a variety of subjects like thermodynamics, fluid mechanics and materials science. But the mechanical engineering trends, we are seeing now, are pushing the boundaries of the industry and professionals are under pressure to up skill and help usher in this new era. Going Green with electric vehicles, Giving Customers what they want with 3D printing, Running simulations on Digital twins, handling the Reins to Artificial Intelligence and Revolutionizing Manufacturing with wireless connectivity with the advent of the internet of things (IoT) and 5G networks are engineering the future through Disruptive and Interdisciplinary Technologies.*

***Keywords** Electric Vehicles: 3d Printing: Simulations on Digital Twins: Artificial Intelligence (Ai): Manufacturing With Wireless Connectivity*

INTRODUCTION

Below is the list of future mechanical engineering trends to stay up to date in this ever-changing and competitive industry:

Going Green with ELECTRIC VEHICLES

As global temperatures rise, automakers are under growing pressure to add electric vehicles to their line-ups. Automakers will rely on mechanical engineers to help them transition from internal combustion engines to electric motors. The Advanced Clean Cars, requiring that all new cars and light trucks sold in the India would be electric or hydrogen-powered soon. India will have a solution for two of the biggest problems facing electric vehicles: limited driving range and slow charging. Using a magnetic field to manipulate stacks of nano- sheets, a new type of vertical electrode for lithium-ion batteries that could double the driving range of electric vehicles, a horizontal electrode capable of recharging to 50% in only 30 minutes. Although in its early stages, our team's research is nonetheless promising for the future of electric vehicles.

Giving Customers what they want with 3D PRINTING

For years, industry professionals have talked about the potential and benefits of additive manufacturing, better known as 3D printing. One of the key factors driving growth is the rising demand for mass customization, which will allow for personalized products, such as made-to-order and custom-fitted shoes. 3D printing also requires less energy and fewer resources than traditional manufacturing and with the release of renewable materials, companies will face increased pressure to adopt this sustainable manufacturing method.

Running SIMULATIONS ON DIGITAL TWINS

A digital twin is a virtual model of a real-world object. For example, a jet engine outfitted with various sensors relays real-time data to a processing system to be applied to its digital twin. With our digital twin, we can monitor performance and achieve peak efficiency. We can even run simulations on our jet engine's digital twin to glean insights that'll help us refine our designs. Can be used throughout the automotive, construction, healthcare and manufacturing industries, digital twins could see a big push in future as cloud providers like Microsoft offer expanded capabilities.

Handing the Reins to ARTIFICIAL INTELLIGENCE (AI)

A survey on AI adoption in manufacturing revealed that -majority of companies think AI makes a visible impact with over half thinking that AI projects will bring value to their companies in 2-5 years. AI-powered robots are taking over dangerous, repetitive tasks in warehouses while AI systems handle clerical chores in offices, freeing up mechanical engineers to apply their expertise to more complex challenges.

Revolutionizing Manufacturing with WIRELESS CONNECTIVITY

The muscle behind AI, "big data" enables manufacturers to optimize supply chains, perform predictive maintenance and improve operational efficiency. Collecting, storing and analyzing vast amounts of data hasn't always been easy, but that could all change with the advent of the internet of things (IoT) and 5G networks.

Going Green with ELECTRIC VEHICLES

Advantages of EVs

1. Lower operating costs: Electric vehicles have lower fuel costs and require less maintenance than traditional gasoline-powered vehicles.
2. Environmental benefits: EVs produce zero emissions and can significantly reduce air pollution and greenhouse gas emissions.
3. Energy independence: As more renewable energy sources are used to power EVs, it can reduce dependence on fossil fuels.
4. Improved performance: EVs have instant torque, which means they can accelerate quickly, and have a smoother and quieter ride.
5. Government incentives: Many countries and local governments offer tax credits, rebates, and other incentives to encourage the purchase of EVs.
6. Cost reduction: The cost of EVs is constantly reducing as the technology improves and economies of scale increase.
7. Convenience: Many electric vehicles have the ability to charge at home using a standard electrical outlet, eliminating the need to visit a gas station.

Energy security: EV's use domestic electricity to power the car, reducing the need for oil imports.

Challenges of EVs

1. High initial cost: The upfront cost of EVs is still higher than traditional gasoline-powered vehicles, making it difficult for many consumers to afford them.
2. Limited charging infrastructure: The lack of charging infrastructure makes it difficult for EV owners to travel long distances.
3. Battery technology: The current battery technology still has some limitations, such as limited driving range and long charging time.
4. Limited domestic manufacturing capabilities: India currently lacks the domestic manufacturing capabilities for electric vehicle components and batteries, making it dependent on imports.
5. Lack of awareness: There is still a lack of awareness about the benefits of EVs among the general public in India.
6. Limited Government initiatives: The Indian Government has set ambitious goals for the adoption of electric vehicles, but the lack of concrete action plans and initiatives has been a hindrance.

7. Lack of standardization: The lack of standardization in charging infrastructure and lack of uniformity in regulations across states and union territories is a challenge.
8. Power Grid infrastructure: India's power grid infrastructure is not fully developed and is not capable of handling the high-power demand of EV charging stations.

Giving Customers what they want with 3D PRINTING

3D printing is the process of creating 3D objects wherein raw materials are stacked one after the other in a desired form. A Computer Aided Design (CAD) controls the deposition of these layers. The fabrication of each layer requires a virtual 3D blueprint and other technical specifications. According to these specifications, the CAD software slices the virtual model into different layers. Subsequently, a string to codes are sent to a 3D printer wherein it is explained how to compile the layers of raw materials. The thickness of a layer can be as low as one thousandth of a meter. This way, 3D printing has made its impact as a greatly high precision manufacturing process. It is primarily used to make functional models and prototypes for different applications in various sectors like automotive, hospitality, jewellery making, consumer end markets and many more.

Advantages of 3D printing

3D printing offers numerous advantages across various industries and applications. Some of the key advantages include:

Rapid Prototyping: 3D printing allows for the quick and cost-effective creation of prototypes. This enables designers and engineers to iterate and test their ideas rapidly, reducing the development cycle and time to market for new products.

Customization and Personalization: With 3D printing, it's easy to create highly customized and personalized products.

Complexity is Free: Unlike traditional manufacturing methods, 3D printing doesn't add significant costs for complex geometries. This means that intricate and elaborate designs can be created without incurring additional expenses, making it ideal for intricate and innovative products.

Reduced Material Waste: Traditional subtractive manufacturing methods often produce a significant amount of material waste. In contrast, 3D printing is an additive process, which means it only uses the necessary amount of material, minimizing waste and contributing to more sustainable manufacturing practices.

On-Demand Production: 3D printing allows for decentralized production, which means products can be manufactured closer to the end-users, reducing shipping costs and delivery times.

Low-Volume Production and Mass Customization: 3D printing is well-suited for low-volume production runs, enabling companies to economically produce smaller quantities of products without the need for expensive tooling. This also opens opportunities for mass customization, where products can be personalized for individual customers on a larger scale.

Design Freedom and Innovation: 3D printing offers a level of design freedom that is often limited or impossible with traditional manufacturing methods. This encourages innovation and allows designers to explore new possibilities and push the boundaries of what is achievable.

Tooling and Jigs: 3D printing can be used to create custom tooling and jigs for various manufacturing processes. This enables faster and more efficient production in industries such as aerospace, automotive, and electronics.

Challenges of 3D printing

Despite its many advantages, 3D printing also has some challenges and limitations that are worth considering:

Speed: 3D printing can be relatively slow compared to traditional manufacturing methods, especially when producing large or complex objects. The layer-by-layer additive process takes time, which may not be suitable for high-volume production.

Material Limitations: Although 3D printing can work with a wide range of materials, the selection is still limited compared to traditional manufacturing. Certain specialized materials or high-performance alloys may not be readily available for 3D printing, restricting its use in some industries.

Cost: While 3D printing is becoming more affordable, the initial investment in 3D printing equipment and materials can still be significant, particularly for industrial-grade machines. Additionally, the cost per part can be higher for larger and more complex objects.

Postprocessing Requirements: 3D-printed parts often require post-processing, such as sanding, polishing, or painting, to achieve the desired finish and quality. This additional step can add to the overall production time and cost.

Accuracy and Surface Finish: Depending on the 3D printing technology used, the accuracy and surface finish of printed parts may not be as high as those achieved with traditional manufacturing methods. This can be a concern for certain applications that require tight tolerances or smooth surfaces.

Size Limitations: Most 3D printers have limitations on the maximum size of objects they can produce. Large-scale manufacturing of oversized objects may not be practical with current 3D printing technology.

Complexity in Design and Printing: While 3D printing offers design freedom, creating complex designs for 3D printing can be challenging, especially for beginners. Certain design features may require advanced knowledge of 3D modeling and printing techniques.

Structural Limitations: 3D-printed parts may have different mechanical properties compared to conventionally manufactured parts, which could impact their strength, durability, and performance in specific applications.

Running SIMULATIONS ON DIGITAL TWINS and reshaping manufacturing

In recent years, trends such as digital twins have been reshaping the manufacturing landscape. By bridging the physical and digital realms, digital twins enable manufacturers to optimize processes, enhance productivity, and drive innovation. As advancements in connectivity, data analytics, and AI continue, digital twins are poised to reshape the future of manufacturing, empowering organizations to stay competitive in an increasingly dynamic and demanding market.

Advantages of Digital Twins

Bridging the Physical and Digital Worlds: One of the key technological trends in manufacturing is the concept of digital twins. A digital twin serves as an exact replica or model of the physical world, providing real-time visibility and insights into various processes. By feeding relevant data sets into the digital twin, organizations can simulate different scenarios, optimize processes, and gain valuable insights without the need for physical trial and error. The result is improved cycle time, enhanced quality, and cost reduction. The data incorporated into digital twins can span from environmental factors like temperature and humidity to physical attributes such as weight, dimensions, and even financial data.

Enhancing Agility and Operations with Digital Twins: Digital twins offer significant advantages by increasing agility and bolstering operations in manufacturing. Production line issues can be identified and resolved before physical implementation and potential bottlenecks throughout the product lifecycle, from design to logistics, can be eliminated.

Increasing Flexibility in Production Planning: Production planning is a critical aspect of manufacturing that requires optimization of resources such as labor, machinery and materials. Digital twins provide a powerful tool to determine the optimal output based on desired outcomes, whether it's revenue maximization or quantity optimization. The traditional trial-and-error approach is streamlined, enabling manufacturers to respond more swiftly to changes in demand or resource availability.

Benefits of Digital Twins for Manufacturers: The adoption of digital twins brings several significant benefits to manufacturers. Foremost, it offers unparalleled speed and quality by visualizing outcomes before physical implementation. By identifying potential issues and optimizing processes in the digital realm, manufacturers can drive business growth, increase profitability, and improve cash flow.

Integrating Automation with Human Labor: While automation technologies play a crucial role in driving efficiency and quality, human workers remain integral to the manufacturing process. For instance, simulation and digital twins can guide design changes for manufacturability, but factors such as cost and time-to-market considerations necessitate human involvement.

Challenges in Deploying Digital Twins

The deployment of digital twins comes with its own set of challenges. A successful digital twin deployment must align with business objectives and provide measurable impact. Establishing a functional, real-time digital twin simulation requires a vast amount of data from various processes and sources, demanding a robust data management infrastructure. Significant investments in data collection, connectivity and storage may present hurdles for some organizations, making it imperative to bridge existing gaps in data streams and digitize assets.

The Future of Digital Twins

Looking ahead, the future holds promising advancements as technology continues to be harnessed for better product development, improved employee experiences and enhanced operational efficiency. The integration of cutting-edge technologies such as digital twins, artificial intelligence and machine learning will continue to shape the global manufacturing landscape.

Handing the Reins to ARTIFICIAL INTELLIGENCE (AI)

Like many other sectors, the manufacturing industry is slowly becoming transformed through the use of artificial intelligence. AI is being utilized in many different ways, including predictive maintenance, generative design, and market predictions.

Advantages of AI in the Manufacturing Industry

Here are some of the key reasons why one should consider adopting AI for manufacturing operations.

Predictive Maintenance Means Less Downtime: The predictive maintenance of AI means one can quickly and accurately predict when the next failure of a machine, part, or system will occur. Predictive maintenance uses advanced AI algorithms to formulate asset malfunction predictions.

AI Enables Higher Quality: Manufacturing companies are finding it more and more challenging to maintain high levels of quality and also comply with regulations and standards concerning quality.

Increasing production without addressing quality can lead to defects and product recalls, which can seriously damage a company's brand in addition to being a costly expense. On the other hand, AI ensures the highest quality is maintained throughout the manufacturing process. AI algorithms can notify workers of emerging production faults that could potentially create quality issues.

AI Can Enhance Production Designs: AI is changing the way that products are designed, for the better. For instance, one method is for designers and engineers to define a brief that is then inputted into an AI algorithm. The brief's data would include things like restrictions and parameters for types of materials, available production methods, time constraints, and budget limitations. The algorithm would then explore each possible configuration before returning a set of the best solutions.

AI Helps Manufacturers: Adapt to an Ever-changing Market: AI's use in the manufacturing industry is not limited to design methods and ways of improving production on the machine shop floor. It can also be used to optimize manufacturing supply chains and identify market changes. That gives a manufacturing company a massive advantage as it can move from a responsive mindset to a strategic mindset. AI algorithms formulate predictions of market demands by identifying patterns that link things like location, political status, socioeconomic and macroeconomic elements, and consumer behavior. Armed with such data, manufacturing companies can much better optimize things like inventory control, staffing, the supply of raw materials, and energy consumption.

Challenges of AI in the Manufacturing Industry:

AI Can Be Expensive: Although adopting AI allows to cut labor costs, the initial implementation of AI can be pretty costly, especially for startups and small companies.

However, one lessen the cost of implementing AI by opting for second-hand CNC machines.

AI Needs Skillful Experts: Because AI is continually evolving, an AI expert needed with the relevant skills to provide abilities like sophisticated programming. At present, AI experts are few and in high demand, it means the cost of employing an AI expert will be more expensive than hiring others.

AI Is Open to Vulnerabilities: AI is vulnerable to cyberattacks, and as AI becomes more sophisticated and widespread, cybercriminals will continue to come up with new hacking methods.

If there is even a small breach, it can disrupt your production line. In fact, a small breach can potentially shut down a manufacturing business.

Revolutionizing Manufacturing with WIRELESS CONNECTIVITY

The adoption of wireless standards in industrial automation has had a profound impact on multiple aspects of the industry. Let's explore some key areas where wireless technology has brought about positive change:

Wireless Sensor Networks: Sensors play a crucial role in automation systems by monitoring various parameters and providing real-time data. With wireless standards, the implementation of sensor networks becomes easier and more cost-effective. Wireless sensor networks enable seamless communication between sensors and control systems, allowing for efficient monitoring and control of industrial processes.

Remote Monitoring and Control: Wireless connectivity has enabled remote monitoring and control of industrial processes. Operators can now monitor and make necessary adjustments to equipment and processes from a centralized location. This not only improves productivity but also enhances worker safety by reducing the need for manual intervention in potentially hazardous environments.

Predictive Maintenance: Wireless standards have facilitated the implementation of predictive maintenance strategies in industrial automation. By collecting real-time data from sensors and analyzing it using advanced algorithms, potential equipment failures can be predicted before they occur. This proactive approach to maintenance reduces downtime, enhances equipment lifespan, and optimizes maintenance costs.

Enhanced Safety and Security: Wireless standards have played a crucial role in improving safety and security in industrial automation. Real-time monitoring and control enable the early detection of safety hazards, ensuring prompt actions are taken to mitigate risks. Additionally, wireless encryption protocols provide robust security measures to protect critical data and prevent unauthorized access.

FUTURE POSSIBILITIES

The impact of wireless standards on industrial automation is just the beginning. Here are some potential advancements that may shape the future of industrial automation:

5G Connectivity: The introduction of 5G technology will revolutionize wireless communication in industrial automation. With ultra-low latency and high-speed connectivity, 5G will enable real-time control of automation systems, paving the way for advanced applications such as autonomous robots and remote virtual reality interfaces.

Internet of Things (IoT) Integration: Wireless standards form the foundation for IoT integration in industrial automation. The seamless connection of devices and systems will open doors for intelligent decision-making, predictive analytics, and synchronized operations.

Artificial Intelligence (AI) Integration: By combining wireless standards with AI technologies, industrial automation systems can become self-learning and adaptive. AI algorithms can analyze vast amounts of data collected through wireless connectivity, enabling automation systems to optimize performance, detect anomalies, and make real-time adjustments.

CONCLUSION

The manufacturing industry is engineering its future through Disruptive and Interdisciplinary Technologies and it has seen substantial change over the past few years and is now one of the fastest expanding sectors. The fourth industrial revolution or Industry 4.0, propelled by cyber-physical systems, big data analytics, IoT, cloud computing infrastructure, AI, and 3D printing, has brought about an evolution in manufacturing. To remain competitive on a worldwide scale, the manufacturing sector is also concentrating on technologies like robotics and automation. Disruptive technology is more than an innovation in today's economy. It's a chance to outperform the existing completion and get better. At the end, accepting disruption empowers the business establishments to overcome the potential risks and to stay afloat in the competitive environment.

MC_IEC 2023 TV 014

On Some Aspects of Modern Composites

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Abstract: The field and scope of composites is constantly broadening with introduction of new manufacturing processes and technologies.Unknown properties of different engineering, non-engineering and bio-materials are regularly explored for the development of modern composites that show immense potential for applications in domestic, automotive, defence and aerospace industries. Some fundamental aspects, processing techniques, properties and applications of modern composites are briefly reviewed in the paper.

Keywords : Metal Matrix Composite; Ceramic Composite; Polymer Composite; Nano Composite

INTRODUCTION

Conventional composites havelimited strength, reduced high temperature resistance, low corrosion and wear resistance etc. The pressing need forachieving improved properties of composites has given rise to paradigm shift in their development. Use of non-conventional materials and manufacturing practices has been the highlight of current research in the field of composites. This review paper presents latest developments in the field of metal matrix, ceramic matrix, polymer matrix, laminated and nano composites. Few pertinent fundamental aspects, processing techniques, properties and applications of some important modern composites are briefly presented and discussed in the paper.

METAL MATRIX COMPOSITES

Nano-Structured ODS, Lanthanum Oxide–Tungsten Composites [1,2]

Theory: Tungsten is an important refractory metal renowned for its high strength and corrosion resistance at elevated temperatures thereby making it suitable for high temperature applications viz., fusion reactors. But due to its recrystallization brittleness, it is not possible to use tungsten in high temperature reactors. Carbon-carbon composites are also known to be good heat conductors but higher erosion rates and low sputtering resistance make them unacceptable in high quality and stable fusion reactor applications. However, it is found that nano-structuring of ODS [Oxide Dispersion Strengthened] tungsten alloys could be an effective way to use tungsten within permissible temperature frames and radioactive environment of a fusion reactor.

Process: These composites are fabricated by using wet processing technique which becomes handy in development of nanostructured materials and promises to be a potentially reliable method for fabrication of tungsten based composites with high homogeneity and purity. The sintering of tungsten powder is carried out by Spark Plasma Sintering [SPS] which allows the consolidation of powder materials into fine-grain and high-density sinters at relatively low temperatures as compared to conventional sintering techniques. SPS is a rapid densification process based on three factors namely [i] High mechanical pressure applied in the process [ii] Use of pulsed DC current and [iii] Very high heating and cooling rates. Tungsten powder doped by means of wet chemistry methods is employed for the production of Tungsten-ODS composites by utilizing SPS technique for consolidation.

Properties: It is inferred from the experiments that the distribution of oxide phase in bulk ODS metal is defined by APT [Atom probe tomography] particle size and its distribution in the powder. Sintering of the composite by SPS technique at temperatures significantly lower than those in conventional sintering methods avoids grain growth. It is observed that there is a substantial increase in hardness with finer sub grains due to low angle boundaries.

Applications: These composites have the potential for use in critical nuclear applications.

Carbon Fiber Reinforced Aluminium Matrix Composite [3,4]

Theory: Several challenges such as higher processing temperatures, fiber matrix bonding issues, the ability to produce desired shapes stand in the way of production of Metal Matrix Composite [MMC] castings. However, these issues are resolved and quality castings are manufactured with minimum processing time by using appropriate fiber matrix systems and innovative strategies. Among various techniques available for fabrication of fibrous metal matrix composites, liquid metal infiltration is a special casting technique which combines the advantages of traditional pressure die casting, gravity permanent casting and common forging technology. This process proves advantageous over others in providing 100% casting yield, good dimensional accuracy, high strength to weight ratio and improved wear resistance. Aluminium Matrix Composites [AMC] are produced by liquid infiltration technique using carbon perform-A356 alloy matrix.

Process: Refer **Figure 1**, Liquid metal is injected into the interstices of fiber usually called perform. In the process, it is seen that the liquid metal is pressurized while solidification and hence neat net shapes are produced.

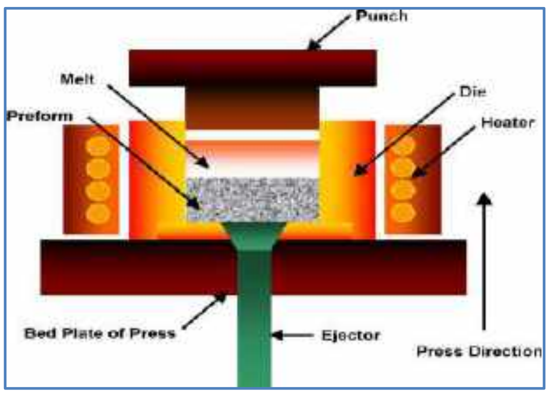

Figure 1 Layout of the squeeze infiltration apparatus.

It is also demonstrated that the metal matrix composites can conveniently be fabricated from carbon fiber preforms and aluminium alloys using squeeze infiltration technique. This process is particularly appropriate for the manufacture of castings incorporating selective reinforcement in critical regions.

Properties: The density of developed AMC [2.47 g/cc] is noticed to be lesser than that of the matrix material [2.7 g/cc]. The process of metal matrix composite production results in enhancement of the hardness and impact energy of the composite than that of pure aluminium alloy. It is found that AMC specimen shows better hardness characteristics both axially and radially. On observing the specimens, alternate layers of fibres within the infiltrated portion of the billet shows good fibre/matrix contact. The Charpy impact test of the composite reveals higher impact energy than that of squeeze cast alloy matrix. This is attributed to easy debonding of the infiltrated carbon fibre layers in the latter.

Applications: AMC are employed in the wide range of aerospace and automobile applications.

TiAl - B_4C Composites [5,6]

Theory: Refractory ceramic metals are best suited for demanding applications owing to their exceptional hardness and stability at high working temperatures. But, the disadvantage of ceramic materials is brittleness coupled with low fracture toughness. Of late, research has proved that Boron Carbide [B_4C] ceramic portrays excellent properties but is difficult to fabricateas sintered body due to covalent bond in its configuration. It is learnt that by adding 4 wt.% amount of Al using pressureless-sintering at around 2100°C under argon atmosphere, the density and mechanical performance of B_4C can be improved. In-situ homogenous Ti-Al alloy and particulate reinforced B_4C composite is fabricated from Ti, Al and B_4C via High Energy Ball Milling and subsequent press sintering. As the Ti-Alloy percentage is increased in the matrix, the relative density increases while there is decrease in the hardness of the matrix. Overall, the composite exhibits good fracture toughness and bending strength.

Process: Refer **Figure 2**. The raw materials Al, Ti and B_4C composition is considered according to necessary percentage and blending followed by subjecting it to dry milling up to 30hrs at the rate of 380rpm in a planetary high energy ball mill with use of 1.27% stearic acid as process control agent. The powders are then sieved and transferred into graphite dies for hot press sintering in the furnace. This process is generally known as High Energy Mechanical Alloying.

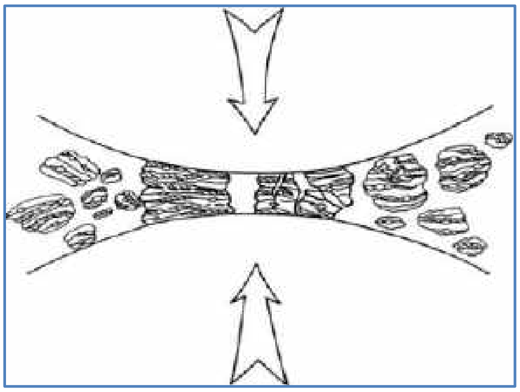

Figure 2 High energy ball milling (Mechanical Alloying) process

Properties: Microscopic studies reveal that the ball milling product is flat and having regular lattice structure of the Ti-Al alloy. Under the pressure of 20MPa and dwell time of 30 min, the liquid phase fills up pore spaces of ceramics while the residual gas diffuses or escapes making the composite more compact. As a result, the relative density of the composite is increased. It is observed that TiAl/B_4C composite promises high fracture toughness and bending strength.

Applications: TiAl/B_4C composites are employed in aerospace structural applications.

CERAMIC COMPOSITES

SiC Nanoparticle Reinforced Al_2O_3–Nb Composite [7]

Theory: Ceramics have been used as an alternative to metal polythene bearing couple in Total Hip Arthroplasty (THA) for a long time now and Al_2O_3 being the most common type is employed for its promising wear reduction behaviour. But, due to the inherent property of brittleness, Al_2O_3 leads to catastrophic failure under load. A ceramicmetal composite consisting of SiC nanoparticles reinforced Al_2O_3 and Niobium[Nb](referred to as SiC/ Al_2O_3–Nb) is therefore explored and evaluated for potential application as a femoral head material in THA.

Process: Dense composite laminates of SiC nanoparticles reinforced Al_2O_3 and Niobiumare prepared by hot pressing and evaluated using SEM, microchemical analysis and mechanical testing techniques.

Properties: It is observed that reinforcing the Al_2O_3 phase with 5% vol.SiC nanoparticles results in marked improvement in the mechanical properties of Al_2O_3-Nb laminated composites without affecting the interfacial bond strength betweenAl_2O_3 and Nb layers. Reinforcement, typically 5–10 vol.%, has also shown to provide a marked improvement in the flexural strength and wear resistance besides resulting in small improvement in hardness and fracture toughness of the composite. Dense laminates of Al_2O_3 and Niobium, fabricated by hot pressing, have flexural strengths of 720±40 MPa, far higher than the flexural strength of dense Al_2O_3 [460±110 MPa].

Applications: SiC nanoparticles reinforced Al_2O_3-Nb composite is a potential material for biomedical implants.

TiN-TiB$_2$ Ceramic Composites[8]

Theory: TiN/TiB_2 ceramic composites possess excellent physical properties like high hardness and strength retention combined with good thermal conductivity, high melting point and chemical stability. All these unique characteristics make this composite ideal for use in aerospace applications. In the referred work, the simultaneous synthesis and densification of TiN/TiB_2 ceramic composites [CC] via Reactive Spark Plasma Sintering [RSPS] is investigated. Usage of these materials leads to enhanced fracture toughness and non-catastrophic failure mode.

Process: These composites are manufactured by Spark Plasma Sintering [SPS] which is also termed as Field Assisted Sintering or Electric Discharge Sintering. The advantages of employing SPS technique are high thermal efficiency, rapid heating up, self-cleaning of the surface particles and enhanced sintering activity which enables fast densification under low temperatures.

Properties: The highest relative density [97.0–97.8%] is obtained for CC containing 36 wt% $TiB_2$and 64 wt% TiN. The modulusof sintered CC varies from 16 to 25 GPa, the fracture toughness varies in the range of 4–6.5 MPam$^{1/2}$. Moreover, the heating rate within the interval 112.5–300 °C/min has no significant effect on the mechanical properties of the sintered CC. The composites containing 36 wt% $TiB_2$and 64 wt% TiN is found to have the most homogeneous nanostructure with average grain sizes of 150–550 nm.

Applications:TiN–TiB_2 ceramic compositesare an attractive option for jet engine parts, armour plates, cutting tools and dies as well as high performing electrical systems.

LAMINATED COMPOSITES

Bio-Inspired Laminated Composites[9]

Theory: The hard outer skeletons of insects or arthropods show outstanding structural properties with different functional capabilities such as supporting of the body weight, filtering chemicals and resisting external loads. The helicoidal structure can be characterized by the stacking sequence consisting of gradual rotation of each lamina in the multi-layered laminated composite. These helicoidal structures can be employed in designing and producing some important practical composites.

Process: The material selected for the model is unidirectional S_2-glass epoxy prepreg (DA409U/S_2glass). The prepreg rolls are formed and stored in a contamination free container at -18^{o}C before processing. Prior to fabrication, each roll is removed from cold storage to allow for stabilization at room temperature followed by wrapping to prevent moisture from condensing on the prepreg. Prepreg rolls are cut into square pieces before being laid up to construct laminated composite plates. All laminates are formed in to stacks of plies using selected sequences corresponding to structural configurations. After curing by vacuum method, plies are attached on both sides of the stacked prepreg to render a smooth finish on the laminates. The whole lay-up system, including the laminate and all the other facilities described above, is finally retrieved from the oven after the curing cycle, finished and then cooled to room temperature.

Properties: The bio-inspired structures show improved mechanical properties when compared to conventional baseline structures. Also, superior residual strength under static load conditions is observed in a bio-inspired composite.

FIBER REINFORCED POLYMER COMPOSITES

Thermoset Composites with Carbon Nanofibers [10]

Theory: The flaming behaviour of thermoset composites is excellent under well-controlled combustion conditions. Multifunctional thermoset composites are made from polyester resin, glass fiber mats and carbon nanofiber sheets. Both the nanofibers and charred materials act as excellent insulators and mass transport barrier, improving the fire retardancy of the composite.

Process: The carbon nanofiber powders are ground with small amount of de-ionized water. After grinding, the mixtureis transferred into a glass beaker and water is added together with few drops of surfactants. The mixture is agitated. The solution is then allowed to settle and suspension is collected. The final mixture is treated in the ultrasonic sonicator for 10 min before being filtered. Resin transfer moulding process is used to manufacture the samples, in which several plies of glass fiber mats are pre-formed in moulds. With the help of vacuum pump, polyester resin flows and finally cures inside the channels of fiber mats and carbon nanofiber sheets.

Recycled Carbon Fiber-PP Composites [11]

Theory: Due to the shortage of raw materials and stringent environmental issues, recycling has assumed importance in composites production. These conditions are forcing material developers to think of recycling even composites. The carbon fiberis one such ingredient which is being used in many composites due of its versatility. These carbon fiber composites are generating lot of waste, and are considered for recycling which of course is complicated due to the complex nature of the composites themselves.

Process: Refer **Figure 3**. In the refereed work, the carbon fibersand polypropylene (PP)used in the preparation of the composite are recycled. The polypropylene is obtained from PURE process technology where it is a scrap product. The fibersare produced by milling of carbon fiber composites, obtained from the production waste generated by the aircraft industry. The fibersare recovered by using pyrolysis at approximately 1200°C. The principles of papermaking are used to obtain preforms with uniformly distributed carbon fibers for subsequent composite manufacturing. Two layers of polypropylene films manufactured by press forming are sandwiched between three carbon fiber perform layers in a stack. The stack is heated and pressed resulting in a new composite plate.

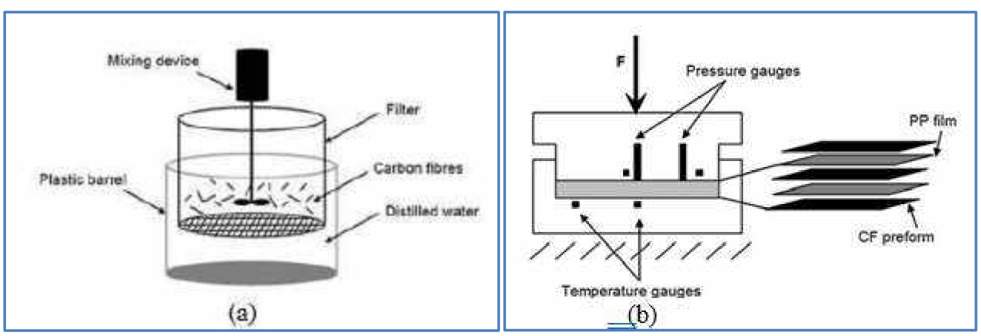

Figure 3 (a) Carbon fibre dispersion and (b) Press forming to form a composite plate

Properties: An increase in tensile strength of the composite is observed as compared to scrap material obtained from the industry. However, increase in strength decreases the elastic modulus. The micro-cracks are responsible for the eventual reduction in elastic modulus. The increase in fracture toughness around the micro-cracks is used as a possible explanation for the measured increase in flexural strength. The stress-strain curves in tension and the strength are sensitive to strain rate which indicates time-dependent behaviour. It is also noted that the development of visco-plastic strains is accompanied with increase in viscoelastic compliance which indicates that damage and visco-plasticity are coupled. The viscoelastic response of the composite is slightly nonlinear.

NANOCOMPOSITES

Al6061– Al_2O_3 Nanocomposites [12,13]

Theory: Aluminum (Al) based MMC's reinforced with nano ceramic particles display better mechanical properties than unreinforced aluminum alloys and are used in automotive industry due to their high ratio of strength/density and better wear resistance. Tribological properties are improved by synthesizing nanocomposite bulk materials where non-metallic nanoparticles are embedded in a relatively compliant metallic matrix.

Process: Al6061 chips are mechanically milled in a planetary hardened steel ball mill in a high purity argon atmosphere up to 30h. The rotational speed of 500 rpm and ball to powder weight ratio of 10:1 is preferred. In order to produce Al6061–3 % vol. Al_2O_3 nanocomposite powder, an ultrasonic treatment is carried for 90 min. Particles which are dispersed ultrasonically are then added for milling. The milled powders are filled in a uniaxial die. Finally, the specimen is heated to 400^oC and pressed at constant pressure of 128 MPa. The duration of hot pressing is 30 min.

Properties: Milling time and Al_2O_3 particle size significantly affect the relative density, hardness and wear rate of the composite. Increasing the milling time of Al6061 and Al_2O_3 nanoparticles simultaneously up to 15h causes a significant improvement in the surface quality of powder particles in addition to uniform distribution of fine alumina particles. The hardness of the composite decreases with increase in porosity. Relative density decreases with increasing Al_2O_3 particulates size.

CONCLUSION

Amini-literature study is undertaken on some fundamental aspects, processing techniques, properties and applications of modern metal matrix, ceramic matrix, polymer matrix, laminated and nano composites that are meant for advanced applications. Latest trends involving usage of newer materials and innovative fabrication technologies are briefly presented.

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The Influence of Plate Fin Heat Sink Orientation under Natural Convection on Thermal Performance: An Experimental and Numerical Study

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Abstract: *Many electronic gadgets now require more power as a result of technological advancements, and in order to prolong their lifespan, they must all be kept thermally stable. To prevent electronic equipment from operating above their safe operating temperature, numerous techniques are used. Due to its low cost and dependable manner of cooling, the naturally cooled heat sink is the most used technology. The goal of the current research is to improve the thermal efficiency of less dense heat sinks by modifying their design and orientation. The aluminium heat sink utilized for the experimental and numerical investigation has the following dimensions: length 120 mm, width 100 mm, thickness 2 mm, height 40 mm, and channel width 12 mm. The cartridge type heater received heat input ranging from 25 W, 50 W, 75 W and 100 w. Under natural convection, the orientation was changed to 0°, 15°, 30°, 45°, 60°, and 90°. By increasing the orientation angle of the heat sink from 0°(horizontal position) for all the heat input, the Nusselt number and rate of heat transfer increases. Due to changes in the flow pattern, the vertical orientation of heat sink found to be transferring heat more quickly than other orientations. According to the study, plate fin heat sinks with circular in-line notches perform thermally better than those without any notches.*

Keywords: *Heat Sink, Natural Convection, Orientation, Notch*

NOMENCLATURE

Nua	Nusselt Number
k	Thermal conductivity
ha	average heat transfer coefficient
Ae	convection area of fin
t	thickness of fin
L	length of heat sink
w	channel width
W	width of heat sink
H	height of fin
Acd	Area of conduction
Q_t	total heat input
T_∞	Ambient temperature
T	Temperature
Qc	convectional heat transfer
Q_R	radiation Heat transfer
Q_{cd}	Conduction heat transfer
V	Voltage
I	Current l Characteristic Length
A_s	Area of radiation ε emissivity
T^∞	Ambient temperature

INTRODUCTION

The Ever-increasing demand for electronic devices with enhanced performance has led to a constant rise in the power densities and heat generation within the systems. Efficient thermal management is imperative to ensure reliability and longevity of these devices. Naturally cooled heat sink most commonly used technique due to low cost and high reliability. The different types of heat sinks are used in many industries for cooling application such as automotive radiator, air conditioning, led lights, power electronic, server, power amplifier, telecommunication [2, 14, 5 ,15]. The geometric optimization of the heat sink by varying the various important parameters such as fin thickness (t) , fin height (h) , channel width (w) was performed by Yu et al [13]. Kim et.al. conducted analytical, numerical and experimental analysis to find out closed form correlation for thermal optimization of plate fin heat sink under natural convention. It was discovered that the optimal fin thickness depends on height, the solid conductivity and the fluid conductivity [24]. Tae Young Kim et.al. carried out experimental study to understand the effect of cross cuts on thermal performance of heat sinks under the parallel flow condition. The following parameters were varied during the tests: length of cross cuts, number of cross cuts and position of cross cuts. Experimental result showed that among all the parameters investigated the cross cuts length had more influence on thermal performance of heat sinks [26]. Dong-kwon Kim et.al. carried out optimization study for the optimization of plate fin heat sink by varying fin thickness in the direction of normal to fluid flow based on volume averaging theory. The thermal resistance of the variable thickness fins with water-cooled arrangement was reduced by 15% compared to the uniform thickness fin [22,23]. Sable et.al. conducted experimental investigation of vertically heated plate by multiple V-fin array to enhance thermal performance under natural convection. The result revealed that V-type fin array gave better heat transfer performance than vertical fin array and 'V' fin with bottom spacing type array [4]. Very few research papers emphasized on understanding the heat transfer performance at the different orientations of the fin heat sinks. This research paper focuses mainly on studying an effect of the orientation of less dense fin heat sink and the circular inline notch on its thermal performance. The effect of circular inline notch is also compared with solid fins. This study aims to examine experimentally and Numerically the influence of orientation on the thermal performance of the heat sink. For the sake of the thermal performance comparison at different orientation, there is a need to use fix fin volume heat sink. It should be noted that the failure rate of electronic components increases exponentially with temperature and any system capable of removing more heat will increase reliability and the life of the components.

EXPERIMENTAL SET UP DETAILS

The experimental set up includes following arrangements: heater, thermocouples, temperature indicators, wattmeter's, fins, spacers and Bakelite covering plates. The layout of the experimental set up is shown in the Fig. 1. The tests were performed on aluminum fins with spacing = 12 mm, thickness = 2 mm, fin height = 40 mm and number fins = 8. The proposed array of fins was tested for different heat inputs which are as follows: 25W, 50W, 75W and 100W. The heat input of different watts (25 W, 50 W, 75 W and 100 W) was generated by using the two cartridge type of the rod heaters (10 mm in diameters). The heaters were placed at the center of the bottom plate of fin heat sink array. The testing was conducted in the open environment (i.e. natural convection). The fin heat sink array was supported by the syporex block at the bottom and its side to minimize the conduction and radiation losses. The K–type of thermocouples were placed at various locations of the fin arrays [Ref. **Figure 1**] to collect the data of the temperatures.

CALCULATIONS

The heat transfer analysis of the Solid and perforated rectangular fins was based on the following assumptions a) Steady heat conduction in the fins b) No heat generation in the fin body c) Uniform ambient temperature d) Uniform heat transfer coefficient all over the fin surface

The rate of heat supplied to the heat sink is calculated by equation (1) :

$$Q_t = V \cdot I \qquad (1)$$

But, Qt is also calculated by equation (2) :

Q t = Qcd) + Qrf + Qc (2)

Conduction heat loss through fin array is calculated by equation (3):

Qcd = k .Acd [(dt/dx) bottom + (dt/dx) side] / 2 (3)

Radiation heat loss through fin array is calculated by equation (4):

Qrf = [ε × σ × AS × (TS4 - T∞4)] (4)

Convection heat Transferis calculated by equation (5):

Qc = Qt - Qcd + Qr (5)

Average heat transfer Coefficientis calculated by equation (6):

ha = [Qc /Ae × (TS - T∞)] (6)

Average Nusselt Number is calculated by equation (7):

Nu a = ha L /k (7)

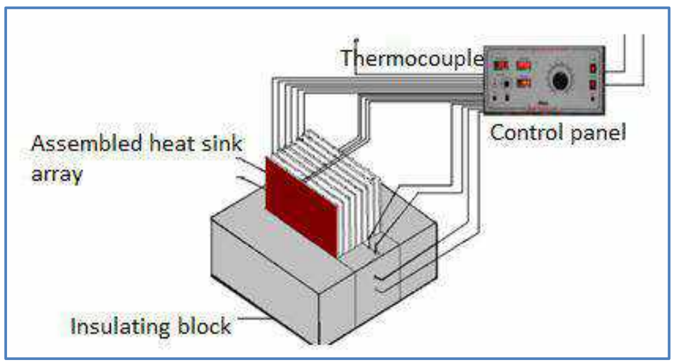
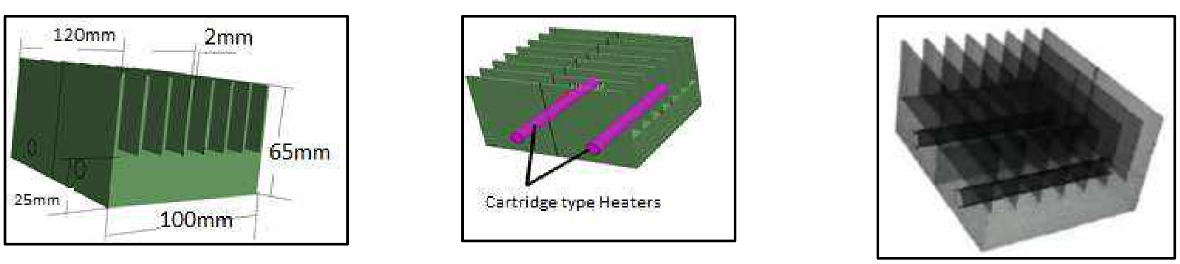


Figure 1 Layout of Experimental Set up

COMPUTATIONAL MODELLING

The present research involves the use of Computational Fluid Dynamic (CFD) software Star- CCM+ to investigate the thermal performance of the fin heat sink array in natural convection. Mainly the convection currents and temperature distribution all over the surface of the fins were observed. The numerical set up details: Geometry and meshing was created in the STAR CCM+ [Ref **Figure 2**]. The prism layer meshing was generated in the software. The different numerical models used were as follows: (a) Air models: coupled flow, gas – air, gradient, ideal gas, laminar flow, steady state conditions and 3-D model, (b) Fin model: constant density, coupled solid energy, gradient, solid, steady and 3-D model, (c) Heater model: constant density, coupled solid energy, gradient, solid, steady and 3-D model.



a b c

Figure 2 Diagram of (a) fin heat sink array, (b) positions of the heater in the base plate, (c) Meshing scene

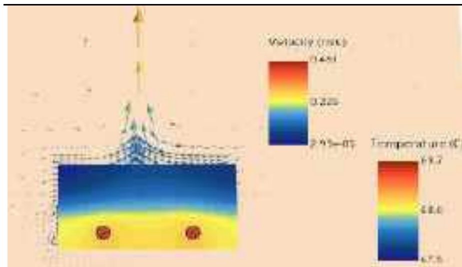
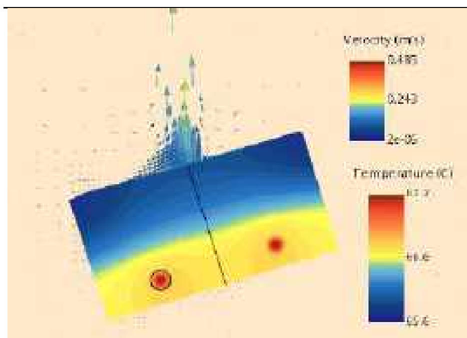
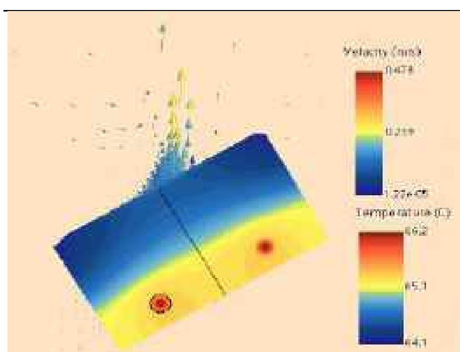
RESULTS AND DISCUSSION

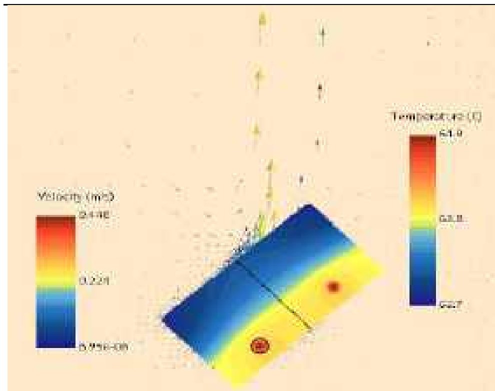
The results and discussion section mainly presents the data of an experimental and the numerical results and their comparison.

Influence of Orientation of Plate Fin Heat Sink

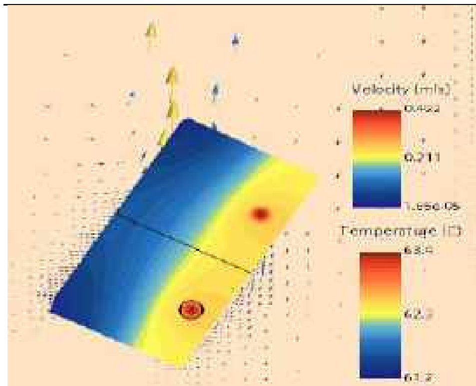
The plate type of fin Heat sinks (without notch) were tested for different orientations to check its thermal performance, the results are mentioned in the data **Table 1**. The temperature contours and air flow patterns for different orientations (such as 0°, 15°, 30°, 45°, 60° and 90°) for 25 watt heater input are presented in **Table 1**. The results showed that the increasing angle of orientation of the fin heat sink improved the airflow patterns which resulted into decreased temperatures of the fin heat sinks. The average temperature was found to be equal to 340 K and 334 K at 0° and 90° respectively. Which showed the signs of improved thermal performance of the fin heat sink at 90°.

Table 1 CFD results for different orientation of the plate fins and at 25 W

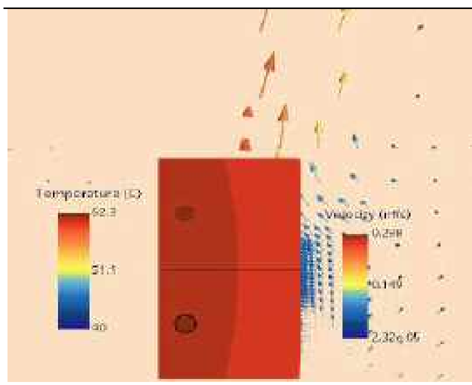
Heat SINK CFD RESULT	**TYPE AND ORINTATION**
	0 Degree
	15 Degree
	30 Degree



45 Degree



60 Degree



90 Degree

The variation of the heat transfer coefficient for different orientations of the fin heat sinks at 25 W is shown in **Figure 3**. The experimental results showed that, as the orientation of the fin heat sink was changed from horizontal (0^o), 15^0, 30^0, 45^0 ,60^0 to vertical (90°), the heat transfer coefficient was found to be increasing in the ascending order of 4.82, 5.03, 5.21, 5.42, 5.78, 6.07 respectively. So, vertical orientation gave the best thermal performance.

The Experimental investigation revealed that an average heat transfer coefficient was found to be increasing with increased heater input [Ref. **Figure 4**]. The Maximum heat transfer coefficient was found to be equal to 7.2 W/m^2 K at 90 degree and for heater input of 100 W. The minimum value of heat transfer coefficient was equal to 4.2 W/m^2K at 0 degree and for heater input of 25 W (Refer **Figure 4**)

The Experimental data was used to calculate the Nusselt number for all the tested conditions and Maximum Nusselt Number (Nu_a) was found to be equal to 10.3 for 100 W and 90 degree. Nusselt Number (Nu_a) was found to be equal to 6.9for 25 W and 0 degree [Refer **Figure 5**]. The Nusselt Number was found to be increasing in ascending order as we are increasing orientation angle from 0 degree to 90 degrees at each heater input i.e., 25 w, 50 w, 75 w, 100 watts [Refer **Figure 5**]

The maximum thermal performance was observed at 90-degree orientation for all the heater inputs. The circular inline notch type of heat sink array showed better performance than the solid/plane heat sink for both 0 degree and 90-degree orientation [Refer **Figure 6**]. The heat transfer coefficient of notch heat sink was observed to be equal to 7.8W/m^2 K at 90-degree orientation which was more (i.e. 6.7W/m^2 K) compared to heat sink without notch [Refer **Figure 6**].

The numerical study showed the variation in the air velocity due to circular inline notch in the fin of heat sink. The convection area was reduced by 15%, because of removal of material in the notch type of the fin array. The notch changes air flow pattern which resulted into increased thermal performance of the heat sink [Refer **Table 2**]

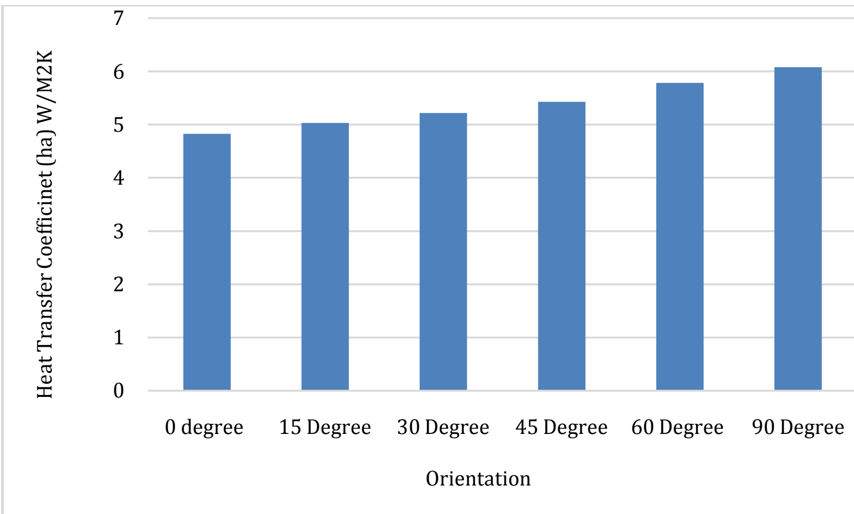


Figure 3 Variation of the heat transfer coefficient for different orientations of the fin heat sinks at 25 W

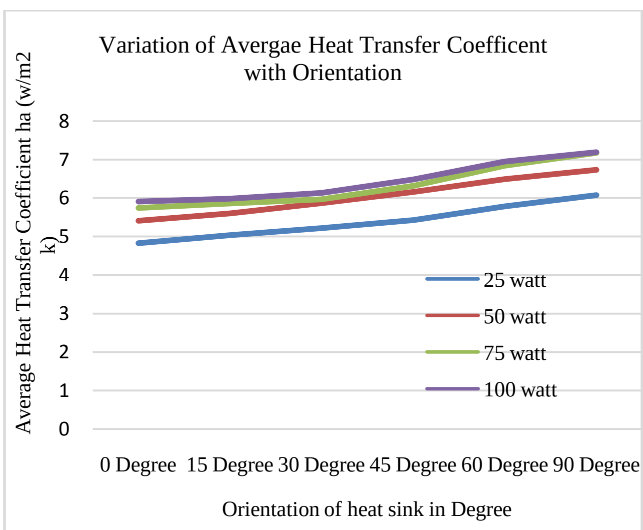


Figure 4 Heat transfer coefficient at different heater Input and Orientation

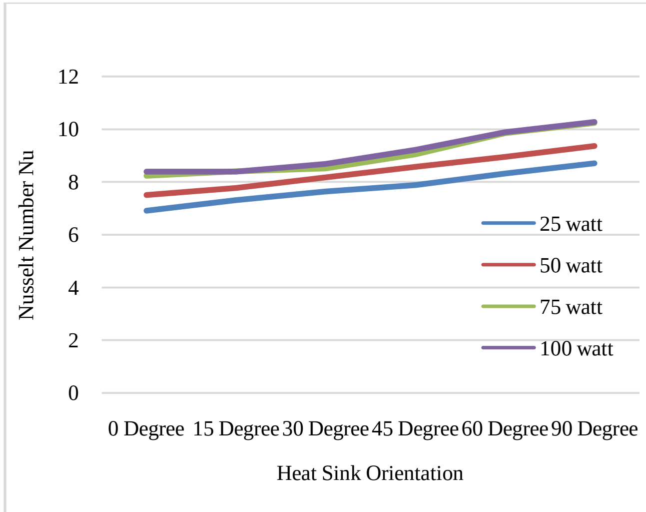


Figure 5 Variation of Nusselt Number (Nu) Vs Orientation angle at different heater Input

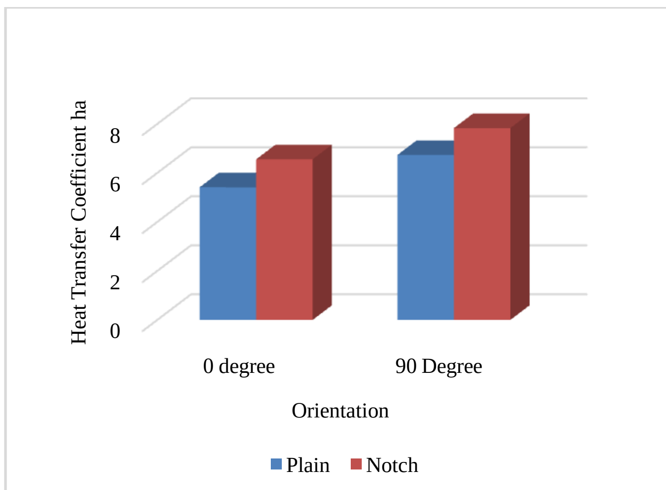
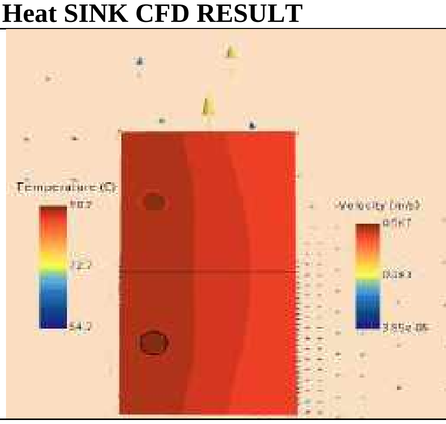
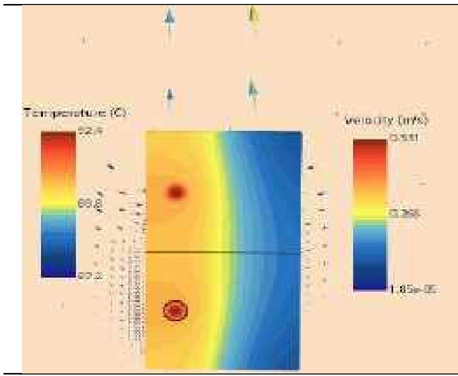


Figure 6 Comparison of heat transfer coefficient of plain and notch heat sink

Table 2 CFD result of Notch heat and Plain Heat Sink at 50 Watt

Heat SINK CFD RESULT	TYPE AND ORINTATION
	90 Degree Notch Heat sink

	90 Degree Plain Heat Sink

CONCLUSION

The use of plate fin heat sink in cooling applications play significant role to bring thermal stability of electronic devices. The experimental and numerical study on fin array provided the following important observations:

- The heat transfer coefficient increased with increasing orientation from 0 degree to 90 degree for all heater inputs. The maximum heat transfer coefficient was found at 90 degrees (vertical position) due to variation in the flow pattern
- The Nusselt Number of plain fin heat sink was found to be maximum at 90-degree orientation at heater input equal to 100 W.
- The minimum Nusselt number was found at 0 degree and 25 W heater input.
- The Numerical study revealed the chimney type of flow pattern for horizontal orientation of fin array whereas flow pattern changed with the orientation of the fin array.
- The circular inline notch type of heat sink array showed better performance than the solid/plane heat sink for both 0 degree and 90-degree orientation

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A Study of Optimization and Analysis of Chassis for Heavy Electric Truck under Different Load Condition

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***Abstract**: The design of heavy electric truck chassis is a critical aspect of developing sustainable and efficient transportation solutions. Heavy electric trucks, which are powered by electric motors and rely on large battery packs for energy storage. the structural integrity and strength of the chassis are of utmost importance. the integration of the battery pack into the chassis is a critical consideration. The chassis needs to accommodate the size, weight, and distribution of the battery pack while ensuring proper thermal management and protection. the unique challenges posed by these vehicles. By considering factors such as structural integrity, battery integration, lightweight materials, and other relevant design considerations and analysis through Ansys software. it is possible to develop efficient and sustainable heavy electric trucks that meet the demands of modern transportation.*

***Keywords** : Heavy Vehicle Chassis, FEM, Stress, Deformation, EV Truck*

INTRODUCTION

On-road vehicles have seen a significant transformation in recent years based on design and other functional factors. Countries that are now still in the process of developing demand speedier, high-load transportation. Heavy load carrying vehicles are being developed by manufacturer to meet these requirements. Even though these vehicles provide faster, more efficient heavy transportation, vehicle safety must be maintained. Vehicle components including the battery, Inverter, motor transmission, tires, axles, assembly, brakes, steering, etc. are bolted to the automotive chassis, which functions as a frame or skeleton. It provides the vehicle with strength and stability in various circumstances. Due to their increased load carrying capacity, ladder frames are frequently employed in heavy commercial vehicles. Automobile frames give the vehicle both flexibility and strength. Every vehicle has a body, which must support both its own weight and the payload. The Electric component weight are more than convention diesel weight. There is major member such as longitudinal, end rail and cross member are some of the components in the chassis of truck. A cross members connect with the parallel to main rails to create a sturdy, box-like structure.

Typically, connection plates are used to join the cross members to the side members. In trucks, the members are jointed with riveted and bolted. In trailers, members are welded. The design of vehicles with a greater payload is the industry's most important problem. Automotive designers must have a thorough understanding of the varied stresses that are present in various chassis work areas. Thus, the discussion of the results is study in the literature of chassis analysis at present work.

COMPARATIVE ANALYSIS OF DIFFERENT CHASSIS CROSS SECTION

For different cars the chassis was modelled considering four different factors: section. i.e., hollow box in rectangular shape, I-shape, and C-shape section. The result was a rectangular box. (middle) part is stronger for steel alloy chassis with the shape of rectangular, I and C bodies technical characteristics of box-shaped (hollow) cross-sectional design. In every scenario, the rectangular box part deflected the least [1].

Table 1 Analysis of different cross section [2]

Type of Cross-section	C shape	I shape	Hollow rectangular shape box
Displacement (mm)	6.153	4.786	2.683
VonMises Stress (MPa)	$3.01*10^2$	$2.34*10^2$	$1.27*10^2$
Max. Stress (MPa)	$1.59*10^2$	$1.24*10^2$	$6.53*10^1$

The dimension of chassis (TATA LP BS4 Bus) Chassis is used for analysing of materials. The material is steel alloys carry the same load on cross section given in **Table 1**. The optimal cross-section, which has least stress and deflection, is I [3], because the head portion of the rolling chassis is arriving. Due to its lowest stress and deflection values, the stress and deflection result for the I cross-section is preferred.

METHODOLOGY

Two categories are included in methodology: quantitative and qualitative. A method is then selected. It is based on a project-specific methodology. Quantitative methodology requires: Significant amounts of data are needed to draw conclusions, and statistics are needed to verify them. While qualitative methodologies involve developing hypotheses, qualitative methodologies use a moderate amount of data and Behaviour analysis to create theory [4]. This study's major goal is to improve low-cost design through design. The safety value's significance is altered, and the results of the final analysis such as the maximum stress and deflection are then contrasted with those that were really measured. Choose a security whose analytical value is close to but does not exceed the theoretical value. The general research process is shown in **Figure 1**.

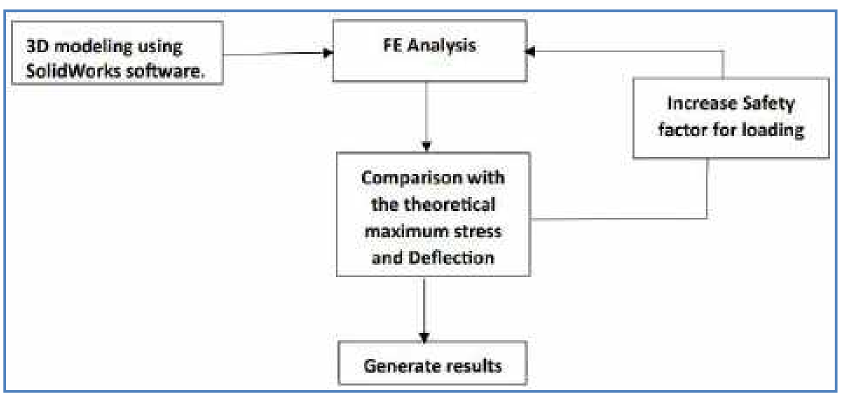

Figure 1 Process flow and analysing [5]

The chassis of numerous large vehicles have been examined by numerous researchers. Using the finite element approach, Abd Rahman et al. explored the stress analysis of heavy truck chassis [6]. The finite element method's conclusion is that when the chassis opens and touches the bolts, the crucial value is stress points. So, it's crucial to lower the voltage in that area. The maximum deflection of a simple beam under uniform loading and the preceding FEA corresponds nicely. diversified power. Ebrahimi and others. The components of a hay trailer model were dissected [7]. Egg by Sane et al. A light commercial vehicle chassis underwent a stress study using an iterative stress reduction process. [8] Koszalka and co. The FEM approach was used to do a stress analysis on a semitrailer structure [9]. Two frame design alternatives were examined, with a focus on the most stressed beam portions.

MATERIAL SELECTION

The first step in choosing structural components and mechanical pieces is material selection, which is also the most crucial choice a designer must make. Steel and iron are thus the most crucial components of large structure. Most vehicle are constructed from low-cost components.

Material Failure

Roadside durability testing of the chassis at the testing facility. The longitudinal stringers were seen to fail during testing. Durability tests revealed that these stringers had cracks before they had reached the end of their intended lifespan. **Figure 2** illustrates how these cracks widened and led to the component's failure.

Figure 2 Longitudinal cracks

Tensile test results of the steel used [10, 11]. Different type of material shown in **Table 2** for manufacturing of the heavy vehicle chassis.

Table 2 Analysis of different cross section [12]

Sr. no.	Material name	Bulk modulus (GPa)	Poisson's ratio	Modulus of elasticity (GPa)	Tensile ultimate strength (MPa)	Tensile yield strength (MPa)	Shear modulus (GPa)
1	Austenitic	166	0.25	193	579	290	77
2	ASTM A710 Steel Grade A and B [13]	170	0.3	206	630	590	85
3	AL 360	62	0.33	71	317	170	26.5
4	AISI 1018	159	0.29	205	440	370	80
5	St 52 [14-15]		0.31	210	500	355	
6	AISI 4130 [16-17]	150	0.396	206	741	465	85

ELECTRIC COMPONENT

Heavy duty trucks will initially have 5 or 6 battery packs. The total energy of each battery pack is 90 kWh, which means a total of 450 kWh or 540 kWh of energy. The weight of each battery is 505 kg. Heavy duty trucks will initially have 5 or 6 battery pack. The total energy of each battery pack is 90 kWh, which means a total of 450 kWh of energy. The weight of each battery is 505 kg. for 6 batteries pack the total weight is 3030 kg, this weight is subjected to side members of chassis. [18,19].

For modification of diesel engine vehicle to electric vehicle for heavy truck are shown in below tables

Diesel	
Component	**Mass (Kg)**
Engine	1400
Transmission	360
Intake	25
Exhaust	75
Fuel tank + pump	50
Fuel 150 US Gallons	500
Miscellaneous parts	100
Total ICE specific	**2510**

Electric	
Component	**Mass (Kg)**
Battery Pack	4400
Inverters	75
Moter + Transmission	360
DC-DC	25
Total EV specific	**4860**

4860 kg -2510 kg = 2350 kg (2.5t)

The overall weight of Electric Component is 4860 kg and acting on a chassis and marge in gross vehicle weight. In the Tata1612 truck chassis has four wheels at the rear axle and two wheels are front at the front axle. The location of the electric motor is very important in large electric vehicles due to their weight. Basically, each motor weighs about 120 kg. The Tesla Semi has three electric motors, one on the first rear axle that is switched on continuously via a single-speed gearbox. Meanwhile, two other electric motors are used on the rear axle to drive the left and right wheels separately. The Nikola One has a motor at each wheel, the Hyundai XCIENT has a motor on the rail between the wheels, the Freightliner eCascadia has a motor at the end of the axle, and the Mercedes-Benz GenH2 truck has two electric motors. The motor is in the truck's power trains. The BYD 8TT is a Class 8 heavy-duty truck with an electric motor. The motor is in the tractor unit for the semi-trailer are shown in **Figure 3**.

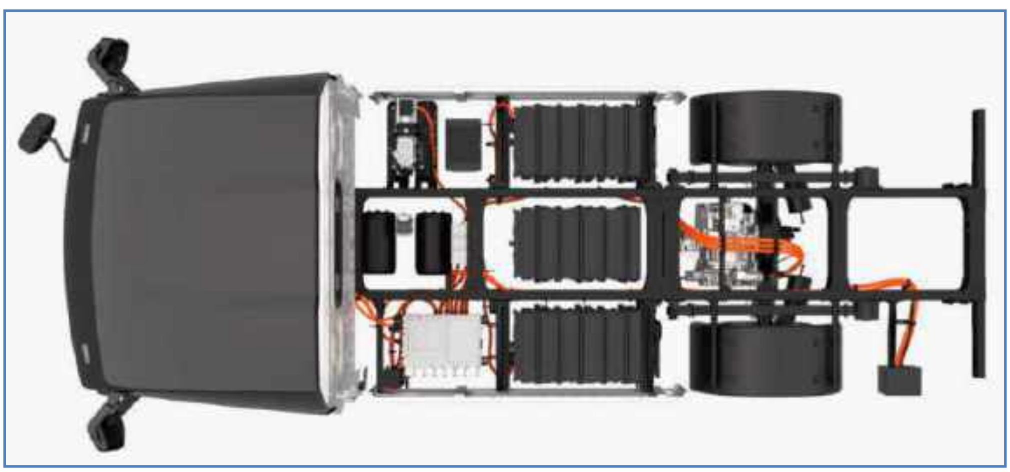

Figure 3 Arrangement of electric component of BYD 8TT

OBSERVATION AND DISCUSSION

FE Outcomes for a Typical Chassis

The chassis FE result has no electric component. FE outcomes for a typical chassis to calculate deformation and corresponding voltage, FE simulations are run on the chassis. Near the stabilized ends are the side member sections that are: **Figure 4** illustrates the greater equivalent voltage. The midsection of the stressed chassis possesses high voltage. Accordingly, under additional loading situations, both the chassis' centre and its edges may sustain damage. There could be chassis failure.

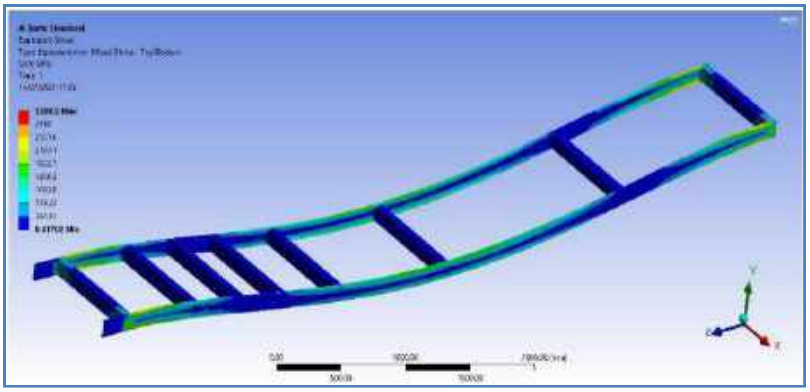

Figure 4 Equivalent stress.[20]

Figure 5 displays the chassis deformation diagram. At the middle/medium length on the chassis, there is the greatest distortion. The smallest cross elements are found towards the end, and deformations are minimized. To increase the chassis' response to such situations, we must improve it.

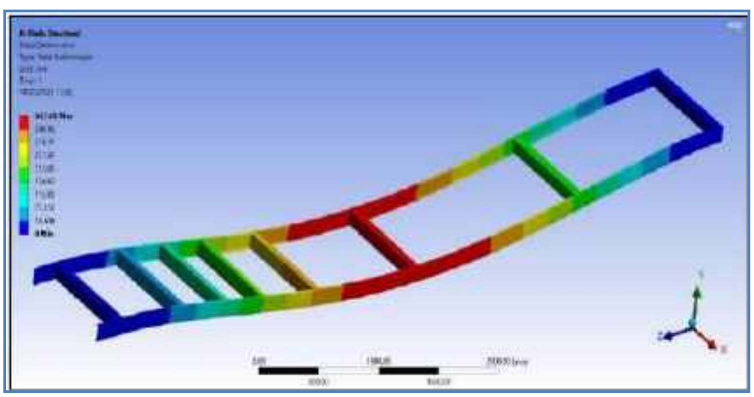

Figure 5 Deformation plot.[20]

EXPECTED OUTCOME

In this work we get a chassis with strength and stability. The length of the chassis has a great impact on the load-carrying characteristics. Chassis Reducing weight means lower production and equipment costs. There are many other factors that can be considered to improve vehicle chassis design with Electric component. By moving the cross members or altering the orientation of the cross members, the truck chassis design can be enhanced. Additionally, the strength and longevity of the heavy vehicle chassis construction should be enhanced while using lightweight materials to optimize weight. This may significantly affect the chassis' power-to-weight ratio.

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Vertical Axis Wind Turbine for Domestic Applications

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***Abstract**: Currently the domain of design and installation of Vertical Axis Wind Turbines (VAWT) is in a developing phase and contemporary researches propose various methods to develop a VAWT. This system is showing a potential solution of domestic energy need. A review of current researches is required to proceed further towards a better understanding of VAWT for small requirement. The development of a VAWT is an interdisciplinary work that involves the core knowledge of various branches of engineering. This review work aims to assess the various processes and methodologies to design and install vertical axis wind turbine for efficient energy generation in urban and small-scale settings. A thorough literature survey is done to fulfil the objective of the review. This work also holds significance as it addresses the need for innovative solutions in smart renewable energy generation. The outcomes of this study will provide guidance towards a better understanding of recent trends of development of VAWT and scope of further work to make the technology more efficient and smart.*

***Keywords:** Vertical Axis Wind Turbine (VAWT); Renewable Energy; Sustainable development; Smart Technology; Domestic Energy Need*

INTRODUCTION

Renewable energy in various forms like solar, ocean waves, wind, biomass, hydrogen, geothermal and in other forms altogether is presently is aiming to form about 30% of the total energy consumption in the year 2022 globally[1]. Wind energy being an increasing popular choice, presently wind power shares almost 6% of the global electricity demand an average[2].

Projection made by Global Wind Energy Council (GWEC) is reporting that this year of 2023 is going to be the very first year to exceed 100GW power generation globally [3]. India is one of the major contributors of onshore wind energy production and shares fourth in the world. Wind energy is found to be the maximally environment friendly, with an optimal mix of social impacts as compared to other sources of renewable energies [4] [5]. The generation of wind energy is dependent upon the wind speed, which is a variable depending upon location and time [6]. A vertical axis wind turbine (VAWT) is a type of wind turbine in which the main rotor shaft is kept vertically, in contrast to the more common horizontal axis wind turbine (HAWT) in which the main rotor shaft is set horizontal. Vertical Axis Wind Turbines (VAWTs) come in various designs, each with its own advantages and disadvantages. The main types of VAWT are Darrieus wind turbine, Savonius wind turbine, Helical (Screw) wind turbine and Hybrid type VAWT.

VAWTs are available in a variety of designs, each with pros and cons [7]. Some emerging technological advancements in VAWT designs are making these more efficient and applicable as a reliable source of energy. Researchers are experimenting on the different design of VAWTs with the intension of testing and analysing these designs and implementing them in real world scenarios [8] [9]. Mathematical models are being developed to analyse the performance and aerodynamic changes of these designs based on different critical operational parameters like speed, wind power etc. [8] [9] [10]. Extensive research has shown the impact of these parameters on the final power generation and other crucial aspects of the turbines. Numerical analysis using advanced computational tools like Computational Fluid Dynamics (CFD), Large Eddy Simulation (LES) based on dynamic SGS is being done and compared with experimental results to gain a sophisticated understanding of this technology and take it to new levels of advancement in the near future [8] [10] [11] [12].

The emerging technology of VAWT in various sectors is reimagining tomorrow by shaping the future through disruptive and interdisciplinary technologies.

DARRIEUS VERTICAL-AXIS WIND TURBINE

An inventive and striking method of utilizing wind power is the Darrieus Vertical Axis Wind Turbine. In the recent years, various different designs of Darrieus turbines are being made and tested by engineers in order to find an affordable and efficient clean energy source. Engineers have tested with common and easy to work with materials like wood to successfully fabricate small scale wind turbines [13]. A novel technology on a passively self-starting Darrieus wind turbine for the generation of electricity has been patented in recent times [14]. A special type of Darrieus turbine, three bladed Giromill turbines are being designed and fabricated by using affordable materials like steel, aluminium and wood [15] [16]. Work has been done by researchers on utilizing QBlade and Matlab Simulink to analyze giromill-type vertical axis wind turbine design parameters for enhanced power [17]. Results show a D-shaped airfoil with low aspect ratio and odd blade numbers significantly improves energy efficiency, surpassing high aspect ratio turbines.

Several works investigates the impact of design parameters on a Giromill vertical axis wind turbine (VAWT). The first study notes significant effects of pitch angle, turbine radius, and chord length on the power coefficient [18]. The second project employs a three-dimensional simulation and experimentation on a Giromill VAWT with NACA 63618 airfoil, analyzing parameters such as angle of attack and number of blades [19]. The third paper estimates the aerodynamic performance of an H-Darrieus wind turbine suggesting the use of the NACA 1418 airfoil for fixed blades [20]. Another paper provides a pioneering review of concepts aimed at improving the low wind speed performance of Darrieus turbines, evaluating them based on economic, reliability, complexity, and commercialization criteria [21]. While most solutions enhance performance in limited tip speed ratios, their effectiveness in low wind speed conditions is demonstrated. Recommendations are offered, emphasizing the need for further critical research to make Darrieus turbines more suitable for low-speed environments. In a separate study, the efficiency of a H-rotor design Darrieus Vertical Axis Wind Turbine (VAWT) is analyzed using Computational Fluid Dynamics (CFD), focusing on factors such as blade profile, wind velocity, and blade pitch angle [22].

In an experimental study on a small vertical axis wind turbine (VAWT), the impact of flow uniformity on vibration and power generation was investigated [23]. Using the operating deflection shape (ODS) technique, the turbine's vibrations were analyzed under various speeds with and without a flow conditioner. The results showed a significant impact on vibration (up to 30% difference) but a minimal effect on power generation (approximately 2% difference). Another study compared ANSYS Workbench and Gambit meshing tools for Darrieus rotor numerical modeling, concluding that the ANSYS Workbench meshing accuracy improves with the SST K-omega model, achieving higher efficiency with new airfoil shapes [24]. Researchers explored efficiency enhancement in a vertical axis wind turbine (VAWT) by incorporating an upstream deflector, optimizing a two-dimensional model through computational fluid dynamics (CFD) simulations, achieving 19.101% efficiency in an open rotor design, and validating results through wind tunnel experiments despite challenges in correlating numerical and experimental outcomes [25].

SAVONIOUS VERTICAL-AXIS WIND TURBINE

Known for its straightforward but efficient design, the Savonius Vertical Axis Wind Turbine (VAWT) is a notable wind energy generating device.

Studies have provided valuable insights on the structural design and enhancement of performance of Savonius wind turbines for engineers [26] [27]. The studies highlight the importance of ongoing research in optimizing parameters like aspect ratio, overlap ratio, and blade number etc. for improved performance, acknowledging the challenge of balancing complexity and efficiency in Savonius rotor designs. Engineers are focusing on designing and analyzing a cost-effective Savonius wind turbine for electricity generation, aiming to enhance efficiency at low maintenance costs [28] [29]. The simple construction of the vertical axis Savonius turbine allows it to rotate at low wind speeds, maximizing power output. The generated energy is stored in batteries for relevant applications

Several experimental studies are being done by engineers and researchers to assess the effect of different variables on the performance and power generation capability of different Savonius wind turbines under laboratory conditions. One such study investigates the impact of the number of blades on a Savonius wind turbine's performance [30]. Results show that a three-bladed Savonius model exhibits the best performance at high tip speed ratios. Another experimental study explores the efficiency and wake characteristics of a drag-driven, helical-configured Savonius turbine under varying inflow conditions [31]. From the experimental results it is concluded that the efficiency is highly dependent on the Reynolds number, with increased turbulence mitigating Reynolds number effects. Experiments are being conducted on conventional and modified Savonius turbines to study the impact of the addition of multiple layers at specific positions [32]. Results demonstrate a 17.6% increase in power coefficient with the addition of multiple layers, enhancing Savonius turbine performance.

Reseachers are using fluid simulation tools to solve complex numerical problems to improve the performance of Savonious wind turbine [33] [34]. One of these work investigates the aerodynamic performance of Savonius wind turbines, specifically exploring the impact of the number of blades on torque and power coefficients at different tip speed ratios [33]. Numerical simulations indicate the optimum conditions of the variables, demonstrating significant improvements in torque and power coefficients with increasing free-stream velocity. The second work introduces a novel technique to enhance Savonius wind turbine performance using an upstream deflector and downstream baffle [34]. Optimized through a genetic algorithm, the modified configuration significantly improves the power coefficient, nearly doubling the power coefficient of the standard Savonius turbine. This enhancement is attributed to favorable aerodynamic interactions and the generation of larger turning torque, encouraging future applications in small-scale wind energy projects.

Scientists are reviewing methods of improving the low-power performance of Savonius turbines, categorizing improvements into interior and exterior designs [35]. By studying various works it has been found that structural changes and external additions significantly increase the power coefficient values, with exterior design modifications showing a very big impact (up to 64% increase). However, it is observed that the exterior additions may compromise the turbine's omni-directional wind reception, requiring an additional sensor mechanism. Interior designs maintain the turbine's ability to receive wind from all directions without the need for supplementary sensors.

HYBRID VERTICAL-AXIS WIND TURBINE

Researchers and engineer are working restlessly on hybrid technologies containing the advantages of both Savonious and Darrieus turbines. A paper outlines the design of a small-scale VAWT, combining characteristics of Savonius and Darrieus models to meet the energy needs of remote residential areas [36]. Another hybrid VAWT was designed incorporating both rotor designs, demonstrated substantial improvements in self-starting ability and coefficient of power, achieving a 92% increase in Cp values compared to a conventional straight-bladed H-rotor VAWT at higher wind speeds [37]. Another study focuses on the impact of the radius ratio between Savonius and Darrieus rotors on turbine performance, revealing significant influences when altering the radius ratio [38].

Through extensive research, a novel configuration combining a 2-bladed modified Savonius Bach-type rotor and a 3-bladed Darrieus turbine was modeled and analyzed using computational fluid dynamics (CFD) to determine characteristic parameters [39]. The generated geometry was employed in CFD Meshing for further analyses, evaluating the hybrid VAWT's overall performance. Among other contemporary researches a work introduces a unique approach, testing a Savonius wind turbine with dimple structures on its blades to assess its impact on efficiency [40]. The study explores experimental validation of a converging ducted structure's effect on single and double stage configurations of the Savonius wind turbine, also comparing performance with and without endplates. Another work focuses on free and forced vibration analysis of H-type and hybrid vertical axis wind turbines (VAWTs) [41]. In a different investigation, conducted in a wind tunnel, a researcher delves into the detailed performance characteristics of H-Darrieus and Savonius-type VAWT configurations [42]. Another research created and 3D printed a CAD wind turbine model, incorporating a combined Darrieus and Scoop Harmony rotor to investigate its impact on tip speed ratio, torque, and power coefficient (CP) under varying wind speeds [43].

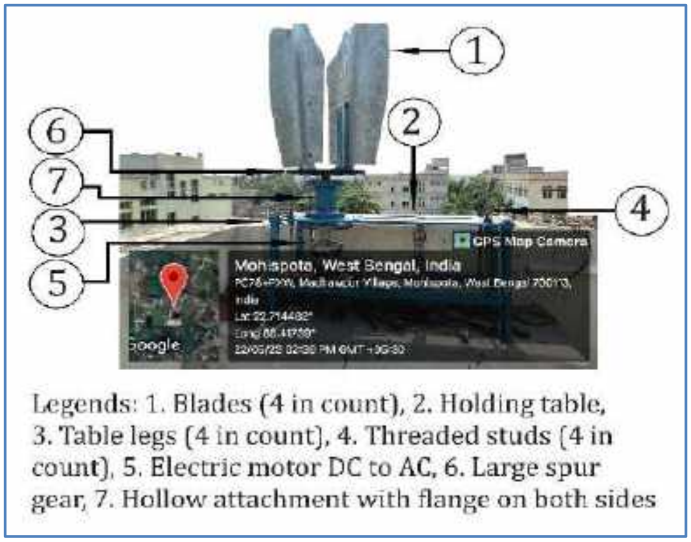

Figure 1 A hybrid type VAWT installed at rooftop for domestic energy requirement

Figure 1 shows a typical hybrid type VAWT installed on rooftop for domestic energy requirement. This project is done by the authors at the rooftop of Elitte College of Engineering.

CONCLUSION

In conclusion, this extensive review underscores the promising role of Vertical Axis Wind Turbines (VAWTs) in addressing domestic energy needs. In comparison to traditional horizontal-axis turbines, VAWTs present distinct advantages such as compactness, adaptability to varying wind directions, and applicability in urban environments with limited space. The ongoing evolution in VAWT design and installation methodologies represents a collaborative effort across multiple engineering disciplines, essential for fulfilling the energy requirements of households. The review meticulously assesses diverse processes and methodologies aimed at augmenting VAWT efficiency within urban and small-scale settings.

Crucially, VAWTs emerge as potential alternative energy sources, contributing to a reduction in reliance on conventional fossil fuels and mitigating carbon emissions. The study accentuates the significance of innovative solutions in fostering smart renewable energy generation. The ultimate goal is to enhance the efficiency and practicality of VAWTs, making them more viable and reliable contributors to the global transition toward sustainable energy solutions. This collaborative endeavor between researchers, engineers, and the broader scientific community is poised to play a pivotal role in shaping the future landscape of domestic energy generation.

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Evaluation of Fitness for Service and Remaining Life Assessment of a Corroded Coke Oven Gas Pipeline in an Integrated Steel Plant

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Abstract: *Fitness for Service (FFS) evaluation is a methodology to determine fitness or integrity in continued service for in-service equipment, structure, piping and pipeline, which are subject to susceptible to erosion and corrosion, in oil & gas, power, metallurgical or other industrial plants, using standardized methods and criteria. It forms a rational criterion for defining the limits of acceptance of flaw caused by erosion and corrosion in the course of prolonged operation/service of the plant components, and guides the engineers and managers to differentiate between acceptable and unacceptable flaws and damage. Accurate evaluation of FFS for plant piping and pipelines is an integral part of plant asset integrity management, and is a useful tool to not only determine the current fitness of the piping system, but also helps to predict the remaining life of the piping or pipeline. A major portion of plant piping or interplant pipelines can continue in service despite having small flaws, and a minimum repair or replacement to repair or replace can aid in continuation of the piping system in operation, without leading to any catastrophic failure, thus avoiding equipment unnecessary capital expenditure. In addition, needless repairs can do more impairment than good and may cause safety hazards in many cases. Remaining life assessment (RLA) studies for the piping systems are closely associated with fitness for Service (FFS) evaluation, and have a crucial role in CAPEX planning for the owners of industrial facilities. Coke Oven Gas (COG), produced in Coke Oven Plant, is used in many units of any integrated steel plant as fuel gas, and is conveyed through interplant pipelines to different units. Due to its high corrosive nature, the conveying piping/pipelines get corroded over long period of operation. This paper captures the study made in an integrated steel plant in India, wherein the COG pipeline of more than two (2) km got substantially corroded due to continuous operation for more than ten (10) years, leading to reduction in pipe wall thickness and localized failure of some weld joints. In order to evaluate the fitness and integrity of pipeline in continued service and predict the remaining life of pipeline, as well as to recommend measures of improvement, pipe stress analysis as per ASME B31.3 and 31.8 and FFS and RLA studies as per API 579/ASME FFS-1 and ASME B31G had been carried out, outcome of which are depicted in this paper.*

Keywords: *Plant, Piping, Pipeline, FFS, RLA, Stress*

INTRODUCTION

With prolonged usage, industrial equipment, structures, piping & pipelines, particularly in the oil & gas, petrochemical and metallurgical industries, are subjected to various forms of degradation and damage that can affect their structural integrity and life. Most of the Codes and Standards pertaining to structural, equipment and piping components do not adequately address the issues of degradation and damage, nor they do provide information on acceptance criteria for the degradation, damages, integrity and remaining product life. As such, performing a fitness-for-service (FFS) assessment is recommended to make run-repair-replace decisions of an in-service component that may be flawed or damaged. [1] For plant piping and pipelines, a fitness-for-service (FFS) analysis is a multidisciplinary analytical method in which damaged constructions are assessed for integrity and safety; during the design phase, often the specific failure mechanisms and their perpetual effect on the integrity of the installation are not taken into account, because in many cases, the conditions during operation vary widely from the design conditions. An FFS analysis combines the knowledge associated with strength related technical design aspects, stress analysis, fracture mechanics, metallurgy, corrosion and other degradation mechanisms, welding and other joining techniques, fabrication, inspection including destructive and non-destructive examination, installation and construction methods, operation and failure behaviour respectively failure consequences. As the failures propagated by corrosion, fatigue or creep lead to reduction in strength of the installation, FFS provides a quantitative measure of structural integrity of a component containing defects or flaws. The intent of an FFS analysis is to arrive at a decision about WHETHER or NOT to continue the piping or pipeline system in operation. [2]

Remaining life assessment or residual life assessment (RLA) study is another mode of analysis in continuation to FFS study wherein the intent is to determine an inspection interval and/or set the pathway for necessary changes to the system/installation and/or operating condition(s) in order to predict the further remaining working life of the subject system/installation taking into account the physical condition as on date. [2]

BACKGROUND OF THE STUDY

A leading Manufacturer of hot rolled coils, having their integrated steel plant at Western India, had been experiencing repeated failure of circumferential weld joints on the Coke Oven Gas (COG) pipeline, originated from Gas Holder in the adjacent premises of Iron Making Unit under same corporate group and routed to the subject plant premises for supplying coke oven gas to different consumers as a fuel gas. The plant authority sought the consultancy service from the authors for a sustainable remedial measure. Accordingly, the authors visited their premises and participated in discussion with plant personnel, inspected the physical installation of the pipeline visually and studied the drawings, documents and plant operational data, in order to assess the nature and extent of the problem. The plant authority, along with request for providing solution to the problem, also had a wish to carry out a fitness-for-service (FFS) study along with a prediction for remaining life assessment (RLA) for the existing coke oven gas pipeline.

Figure 1 Failure of Circumferential Weld Joints of COG Pipeline

Process/service parameters & physical properties of COG pipeline

a. COG line length – More than two (2) km
b. COG line size – DN 550 (Outer Dia. – 558.8 mm)
c. Piping Material – Carbon Steel, Spiral Welded, as per API 5L Gr. B
d. Pipe Thickness: 6.6 mm at the time of installation; 5.77 mm (average), and 5.5 mm (minimum) available from survey carried out by plant authority through external agency
e. Flow of COG at Gas Booster Outlet –
    - 7000 Nm^3/hr (minimum)
    - 10000 Nm^3/hr (average)
    - 12600 Nm^3/hr (maximum)

f. Line Pressure of COG at Gas Booster Outlet –
    - 700 mm WC (g) (minimum)

- 1200 mm WC (g) (minimum)
- 1500 mm WC (g) (minimum)

g. Line Temperature of COG at Gas Booster Outlet – 45°C (average)
h. Maximum recorded ambient temperature at site – 47.5°C
i. Year in which COG pipeline was erected – 2012

OBSERVATIONS FROM VISUAL ROUTE SURVEY AT SITE, STUDY OF DRAWINGS & DOCUMENTS AND DISCUSSION WITH PLANT PERSONNEL

During joint site visit by plant personnel and authors, it had been observed that circumferential weld joints eighteen (18) nos. of locations (two (2) which are shown in **Figure 1**) are failing repeatedly, even after re-weld. Plant personnel were enquired about the status of manufactured spiral weld joints of pipe spools, and it was informed that there had been no issues on those joints. Inspection of pipe support welding status were done throughout zone at which weld joints had been failing, and it has been found that saddle bottom plates are welded on pipe rack structural member, but pipe is laid free on curved saddle plate. There had not been any issues on circumferential weld joints after the COG pipeline starts from Coke Oven Gas Holder up to the takeover point of the plant in subject, as well as after it enters the plant premises, as well as in the branch towards Captive Power Plant of same corporate group.

Primarily, it had been ascertained that in the portion of COG pipeline wherein the circumferential weld joint failures occurred, there had been around 900 m of pipeline having a straight route, thus restricting the inherent flexibility and increasing operating stress beyond allowable limit, particularly subject to solar radiation, thus raising the pipe metal temperature to as high as 80°C. It had also been observed that saddle supports were not properly installed during erection of the pipeline, thus imparting a possibility of lifting off pipe from saddle plate, during any thermal upset.

Also, from the report of pipeline thickness verification carried out by external agency (done in 2019), it was observed that in seven years of operation, COG pipeline had been corroded significantly, to the tune of 13% to 17% at different zones.

STRESS ANALYSIS OF COG PIPELINE

As the zone of COG pipeline experiencing circumferential weld joint failure had no inherent flexibility in layout, pipe stress analysis was performed using Hexagon CAESAR II, under provisions of two (2) separate piping and pipeline codes, viz. ASME B31.3 (ASME Code for Pressure Piping – Process Piping) and ASME B31.8 (ASME Code for Pressure Piping - Gas Transmission and Distribution Piping Systems).

Design considerations as indicated in **Table 1** had been used in stress analysis.

First, pipe stress analysis has been performed for the existing configuration of the pipeline. It has been found that the thermal stress in corroded thickness condition in the zone of weld failures was substantially high, as the profile of pipeline in that zone lacks inherent flexibility. Also, uplift due to thermal expansion had been observed in many saddle support locations, as there had been no axial stops, lateral guides and upward stops in the pipe support locations. Next, the pipeline is re-analyzed considering fifteen (15) nos. Single Bellow Metallic Expansion Joints (Axial type), having flanged ends, to be installed in the piping system near the locations of weld failures, along with consideration of axial stops, lateral guides and upward stops at strategic support locations, without adding any additional/new support. This reduced the lateral thermal movements of pipe as well as stress in sustained, thermal and occasional load conditions within the allowable limits of ASME B31.3 & ASME B31.8 Code requirements.

Figure 2 shows the stress model of COG pipeline after installation of Expansion Joints (one of which shown typically in enlarged view). Although this retrofitting would reduce the stress of the system substantially, another serious matter of concern is reduction of pipe thickness around 13% - 17% (may be more in locations where readings are not available) from the value of 6.6 mm at installed condition.

Table 1 Design considerations for pipe stress analysis

Process/Service Conditions		
Operating Temperature of COG Line (T1)	45°C	
Design Temperature of COG Line (T2)	80°C (under solar radiation)	
Ambient Temperature (Max.)	48°C	
Ambient Temperature (Min.)	8°C	
Installation Temperature	21.1^{O}C	
Operating Pressure of COG Line (P1)	1200 mm WC (g), i.e. 0.12 bar (g)	
Operating Pressure of COG Line (P2)	1500 mm WC (g), i.e. 0.15 bar (g)	
Fluid	Coke Oven Gas	
Fluid Density (at above condition)	Negligible	
Material of Construction for COG Piping	API 5L Gr. B	
Restraint Friction Coefficient	0.3	
Corrosion Allowance	1.5 mm	
Special Condition	Fully corroded in all load cases	
WIND LOADING CONDITIONS AS PER IS 875 PART 3		
Basic Wind Speed at Plant Location	44 m/sec	
Wind Zone Number	3	
Risk Factor K1	1.07	
Terrain Category	Category 4	
Equipment Class	Class C	
Topography Factor	1.36	
SEISMIC LOADING CONDITIONS AS PER IS 1893 PART 4		
Design Horizontal Seismic Coefficient Ah = (Z/2) x (Sa/g) x (I/R) = 0.046875 $\underset{\sim}{}$ 0.05		
where		
Z = Zone Factor	0.10 (For Zone II)	
Sa/g = Site Specific Spectral Acceleration Coefficient	2.5	
I = Importance Factor	1.5 for Category 2 Structures	
R = Response Reduction Factor	4.0 for steel frame with concentric braces	
Design Vertical Seismic Coefficient	2/3rd of Ah = 0.033	
MECHANICAL PROPERTIES OF PIPE MATERIAL		
	As per ASME B31.3	As per ASME B31.8
Density of Piping Material	7830 kg/m^3	7830 kg/m^3
Modulus of Elasticity at Installation Temperature	2.0339 x 10^8 kPa	2.0339 x 10^8 kPa
Modulus of Elasticity at Operating Temperature	2.0156 x 10^8 kPa	2.0165 x 10^8 kPa
Modulus of Elasticity at Design Temperature	1.9939 x 10^8 kPa	1.9923 x 10^8 kPa
Poisson's Ratio	0.2920	0.3
Allowable Stress / Yield Stress* at Installation Temperature	137895 kPa	241316.5 kPa*
Allowable Stress / Yield Stress* at Operating Temperature	137895 kPa	241316.5 kPa*
Allowable Stress / Yield Stress* at Design Temperature	137895 kPa	241316.5 kPa*
Coefficient of Thermal Expansion at Installation Temperature	11.5 x 10^{-6} mm/mm - °C	11.25 x 10^{-6} mm/mm - °C

In **Table 2** samples of pipe thickness verification carried out by external agency in the year 2019 for few chainage points are presented.

Fitness-for-service (FFS) analysis of COG pipeline

As mentioned in earlier sections, the plant authority had a serious concern over reduction in pipe thickness significantly in just seven (7) years of operation. Coke oven gas (COG), being highly corrosive in nature, have the potential of corroding the conveying piping system in a prolonged period of operation. Therefore, the plant authority had a wish to ascertain whether the COG pipeline is fit enough for to be continued in service even after retrofitting of expansion joints are done, and what would be the remaining life of the installation as per code provisions, in case the corrosion propagates in the prevailing rate or even faster. Accordingly, fitness-for-service (FFS) analysis was undertaken.

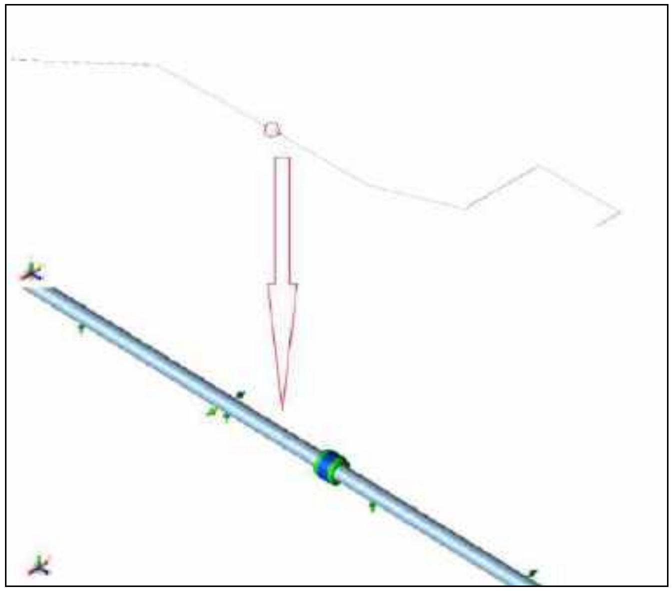
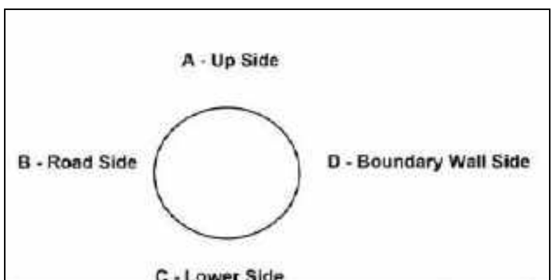


Figure 2 Pipe stress analysis model of COG pipeline, showing typical expansion joint installation

Table 2 Recording of pipe thicknesses at a few Chainage points



Chainage No.	Point A	Point B	Point C	Point D
1	5.6 mm	5.7 mm	5.7 mm	5.7 mm
2	5.7 mm	5.7 mm	5.6 mm	5.6 mm
3	5.7 mm	5.6 mm	5.7 mm	5.7 mm
4	5.6 mm	5.6 mm	5.6 mm	5.6 mm
5	5.7 mm	5.7 mm	5.6 mm	5.6 mm
6	5.6 mm	5.7 mm	5.7 mm	5.6 mm
7	5.6 mm	5.7 mm	5.6 mm	5.6 mm
8	5.6 mm	5.6 mm	5.6 mm	5.7 mm
9	5.8 mm	5.6 mm	5.7 mm	5.8 mm
10	5.6 mm	5.7 mm	5.6 mm	5.6 mm
11	5.6 mm	5.6 mm	5.7 mm	5.5 mm
12	5.7 mm	5.8 mm	5.7 mm	5.7 mm

Corrosion is an electrochemical process, and a mechanism depending on time as well as chemical properties of conveyed fluid and local environment within or adjacent to the pipeline. It usually appears as either general corrosion or localised (pitting) corrosion. There are many different types of corrosion, viz. galvanic corrosion, microbiologically induced corrosion, corrosion due to differential soils, differential aeration and cracking. Corrosion causes metal loss on internal and/or external surfaces of the pipe, at base material, seam weld, girth weld, and/or associated heat affected zone (HAZ). Together, internal and external corrosion form one of the major causes of pipeline failures. Corrosion in pipelines may be challenging to characterise. Typically, it would have an irregular depth profile and extend in irregular pattern in both longitudinal and circumferential directions, and may occur as a single defect or as a cluster of adjacent defects separated by un-corroded material with full thickness, with no clear definitions of different types of corrosion defects. [6] Impact of defects/flaws caused by corrosion on piping system components that causes pipe leakage and rupture under line pressure is investigated using nonlinear finite element (FE) analysis, leading to a simple analytical expression for estimating the retained pipe strength. Uncertainties & gaps in predicting leakage or rupture are linked with in-situ measurement of flaw size (including measurement uncertainty and sampling error), pipe geometry, pipe material properties, operating pressures, and corrosion model parameters in the exposure environments. These uncertainties are included in a probabilistic analysis of the reliability of the pipeline over the expected lifetime of interest. Finally, a set of simple and practical reliability-based evaluation tools are presented for pipe safety assessment. Uncertainties in loads, material and geometric shape/layout of the pipe, corrosion defect geometry, and in situ environment can cause significant deviations of the actual pipe performance from those intended. With numerous uncertainties that might impact the performance of a pipe that is susceptible to corrosion, probability-based structural reliability principles provide powerful means for integrating these uncertainties into decision making tools for evaluating pipeline safety, remaining service, and maintenance plan. [3]

There are different literatures, standards and guidelines for FFS study, among which API 579-1/ASME FFS-1, developed jointly by American Petroleum Institute (API) and American Society of Mechanical Engineers (ASME), contains the most acceptable evaluation criteria to assess the fitness of installation based on the types of damages and flaws present on the in-service component, with detailed assessment and analysis to determine the structural integrity of the component to identify possible flaws or damage, offering a complete evaluation so that decision makers can determine accurately on whether to maintain operation, or repair equipment/piping, or replace it altogether. [1]

In 2000, the American Petroleum Institute (API) published API RP 579, a Recommended Practice for FFS assessment, primarily intended for refining and petrochemical plants; however, getting widespread acceptability in a wide range of industries. This standard covers a wide range of flaws and damage mechanisms, including local metal loss, pitting corrosion, blisters, weld misalignment, crack-like flaws and fire damage, with appendices that provide guidance on analysing fracture toughness and weld residual stress distributions. Procedures outlined in API 579 utilize the design and construction rules and methods in the ASME Boiler and Pressure Vessel Code, Section I and Section VIII, Divisions 1 and 2, ASME B31.1 and B31.3 piping codes, and API 650 and 620 storage tank standards, as well as guidance on adopting its procedures to equipment/piping complied to non ASME/API codes and standards. [4] In 2007, together with American Society for Mechanical Engineers (ASME), API 579-1/ASME FFS-1 emerged as an updated document, which, is a Standard rather than a Recommended Practice, contains several improvements and explicitly addresses industries beyond refining and petrochemical. [7].

All FFS assessments can be performed at different levels of complexity, known as Level 1, 2 and 3 analyses.

- Level 1 assessments: Also called ‘simplified assessment’, Level 1 assessments provide conservative screening criteria requiring least magnitude of inspection and component information, and generally do not require extensive calculations. This level is applicable for Type A components subject to internal pressure (pressure vessel cylindrical and conical shell sections, spherical pressure vessels and storage spheres, formed heads – spherical, elliptical and torispherical, cylindrical atmospheric storage tank shell courses, straight pipes and elbows not having structural attachments). Either inspectors or plant engineers can conduct a Level 1 assessment.
- Level 2 assessments: Also called ‘normal assessment’, Level 2 assessments involve a more detailed evaluation of components and generally need precise measurement of flaws or damage. This is applied if Level 1 does not provide satisfactory results, and combines less conservative criteria with more detailed results. Data requirement in this level is similar to Level 1, but precise calculations and evaluations are performed. This level is applicable for Type A components subject to internal pressure and supplemental loads and Type B Class 1 components (pressure vessel cylindrical and conical shell sections and piping systems not classified as Type A). Most Level 2 assessments require calculation of the required component thickness or stress, and be done by either plant engineers or engineering specialists.
- Level 3 assessments: Also called ‘ductile tearing instability’, Level 3 assessments are more sophisticated analyses and need in-depth evaluation of components, and are considered when the Level 1 and Level 2

assessment results are not satisfactory. Compared to two previous levels, Level 3 provide least conservative and most detailed method of evaluation. The analysis in this level is based on experimental and inspectional techniques. Flaws or damages on component must be accurately determined, and calculation methods often involve numerical analysis such as the finite element method. Level 3 assessments calls for the involvement of engineering specialists experienced in advanced stress analysis, materials science, fracture mechanics, computer simulation, finite element analysis (FEA) or computational fluid dynamics (CFD). [1] [2] [4] [7] Figure. 4 shows the technology triad for FFS assessment.

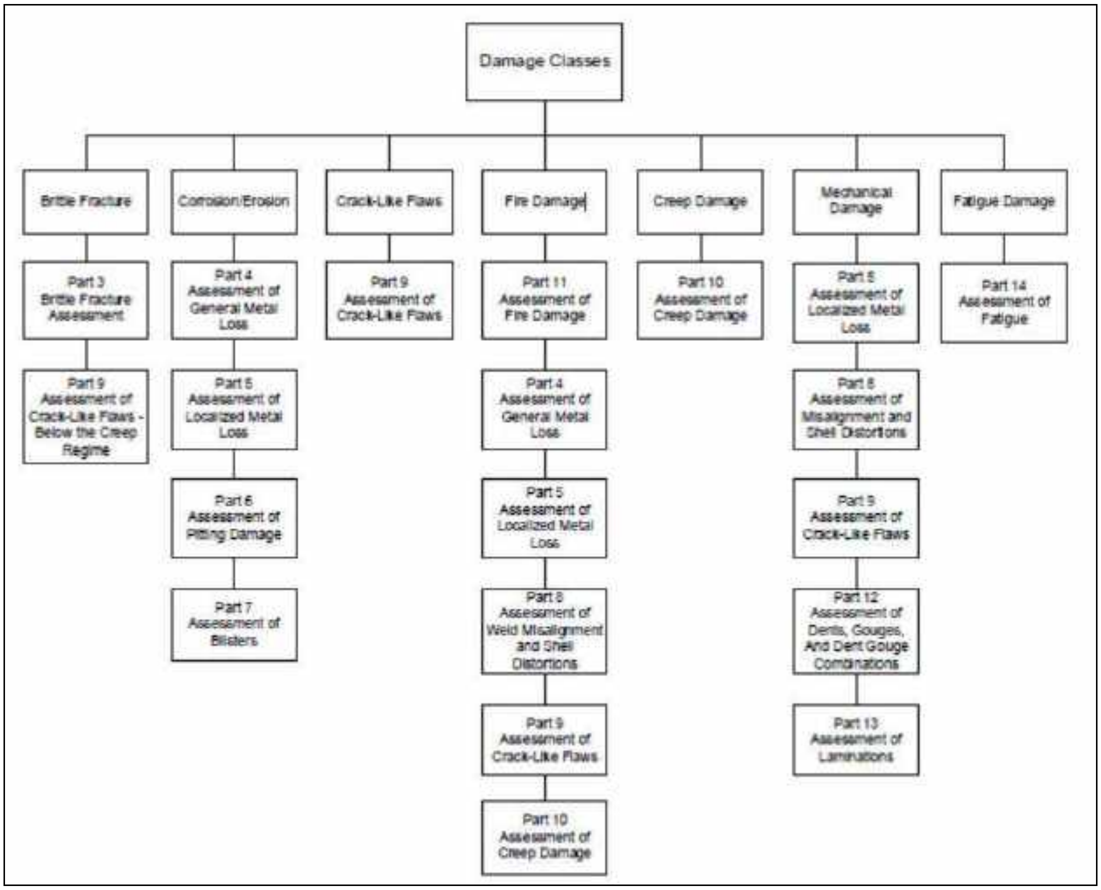


Figure 3 Framework of FFS Analysis as per API 579-1/ASME FFS-1 [11]

These three assessment levels hold a balance between simplicity and accuracy. Assessment procedures which are simplified are necessarily more conservative than more sophisticated engineering analyses. In some cases, the component under evaluation may fail a Level 1 assessment but pass a Level 2 or Level 3 assessment due to conservative simplifying assumptions in the former. In some situations, API 579-1/ASME FFS-1 does not permit Level 1 assessment, e.g., for pressure equipment subject to significant supplemental loads, viz. dead loads, wind loads, thermal expansion loads, and seismic loads. [7]

Fitness-for-services assessments on pipes related to corrosion requires attention to many things, such as internal and external corrosion, where the effect is caused by a metal loss that occurs on the outside and inside of the pipe. Internal and external corrosions can be measured using ultrasonic testing thickness to determine the remaining wall thickness of the pipe, and using pit gauges, respectively. It is also necessary to provide attention to whether the damage mechanisms that occur are uniform or localized corrosion because the effect of pitting on localized corrosion has a different assessment, namely by measuring the depth of the pit. [5]

Few pictorial representations of various types of defects and their extents ae shown in **Figure 5**.

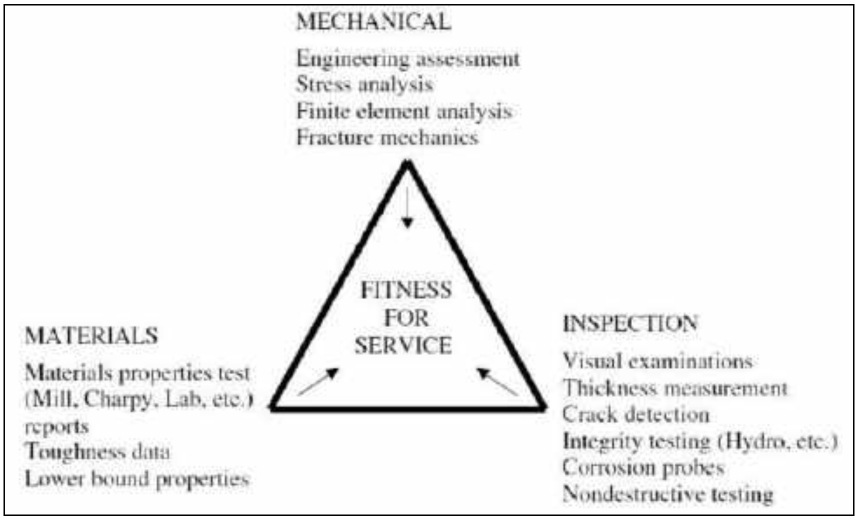


Figure 4 Technology triad required for FFS assessment [17]

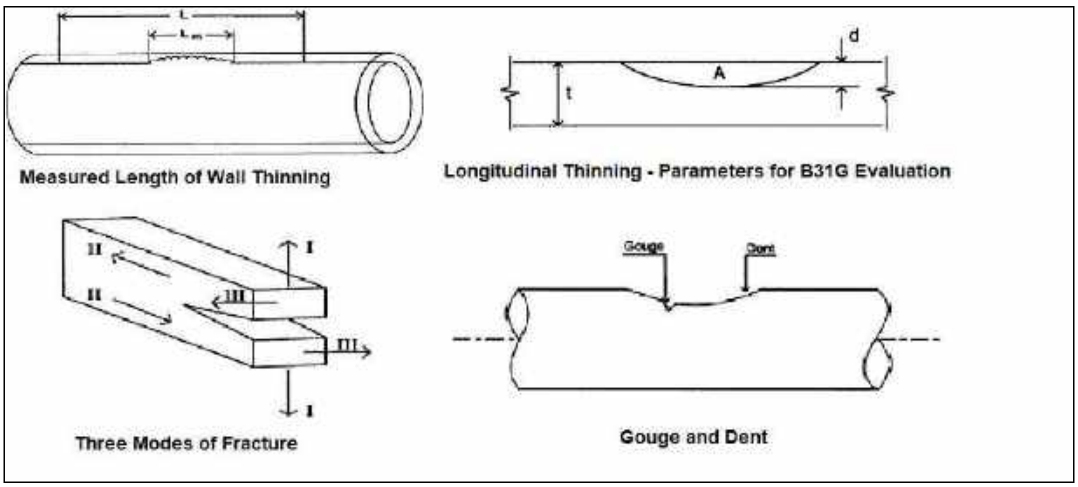


Figure 5 Various Types of Defects and Their Extents (Typical) [15]

Outcome of a fitness-for-service assessment for piping system or pipeline is a decision to run as is, repair, re-rate, alter, or retire the system. A remaining life assessment may also be performed as part of the assessment, which can be used to set future inspection intervals and to budget for capital expenditures when existing equipment is to be retired. [7] FFS assessment cover both present integrity of the component given an existing state of damage and projected remaining life. If results of the assessment indicate that the system is suitable for the expected operating conditions, it can be continued in operation these conditions, as long as a suitable inspection program is established. If results are not favourable, calculation methods are provided in API 579-1/ASME FFS-1 to rerate the component, which can be used for pressurized components (e.g., pressure vessels and piping) to find a reduced maximum allowable working pressure and/or associated temperature. In short, remaining life calculation is used to establish an appropriate inspection interval in conjunction with relevant in-service inspection code, provide information for an in-service monitoring plan, or to establish the need for remediation. API 579-1/ASME FFS-1 accentuates the need for remediation where remaining life cannot be established; may be in form of altering the process condition, or isolating the fluid from the component by installation of a coating or lining, or putting weld overlay. It also emphasizes the need for monitoring and inspection to validate the assumptions made about continuing damage. [8]

Life extension in ageing facilities depends on ageing process, including material degradation and organizational issues. The degradation process, assets data in real conditions, and evaluation methods guide to an implementation strategy for extended life. Main accelerating factors causing degradation in facilities are operating conditions, extreme environment, design integrity, quality of welding joints, and lack of consistency in inspection and assessment. [5]

FFS analysis should be done with validated software only, wherein input data and results must be verifiable, by presenting the results in a format that can be confirmed against applicable code(s)/standard(s). Software to be used should preferably be agreed upon in advance by authority in charge with the appraisal. [2]

ANALYSIS & RESULTS

Fitness-for-service Analysis

In order to perform the FFS analysis for subject COG pipeline, TWI Global IntegriWISE developed by The Welding Institute (TWI) has been used.

The evaluation procedure is done in eight steps:

1) Damage type determination
2) Applicability and limitations of procedure
3) Data requirements
4) Assessment techniques and acceptance criteria
5) Remaining life assessment
6) Remediation
7) In-service inspection
8) Documentation

Following seven (7) studies have been done, and the outcomes are tabulated in **Table 3**.

Table 3 Results of FFS analysis in TWI Global IntegriWISE

Assessment	Results
Assessment to API 579 Part 3: Brittle Fracture	DO NOT indicate any matter of concern right now
Assessment to API 579 Part 4: General Metal Loss. Point Thickness Readings	DO NOT indicate any matter of concern right now
Assessment to API 579 Section 4: General Metal Loss. Thickness Profiles	DO NOT indicate any matter of concern right now
Assessment to API 579 Part 5: Local Metal Loss	In this assessment, pipe thicknesses measured by External Agency by Ultrasonic Thickness Tester have been used. The Level 1 Assessment indicates that the longitudinal extent of the flaw is ACCEPTABLE for operation at the MAWP, and the circumferential extent of the flaw is UNACCEPTABLE. Thus, the Level 1 Assessment is UNACCEPTABLE. The Level 2 Assessment indicates that the longitudinal extent of the flaw is ACCEPTABLE for operation at the MAWP, and the circumferential extent of the flaw is UNACCEPTABLE. The Level 2 Assessment is UNACCEPTABLE
Maximum Allowable Working Pressure	DO NOT indicate any matter of concern right now
Nominal Membrane Stress	DO NOT indicate any matter of concern right now
Minimum Required Wall Thickness	DO NOT indicate any matter of concern right now

REMAINING STRENGTH ASSESSMENT (RSA)

Acceptance of wall thinning in accordance with ASME B31G signifies that the thinned wall would be able to withstand a hydrostatic test at a pressure that would bring the nominal wall right to yield.

ASME B31G is applied under the following conditions: [16]

1) Metal loss contains no cracks.
2) Metal loss may be external or internal.
3) Metal loss may be caused by corrosion or by grinding of a defect.
4) Metal loss has a smooth contour, with no stress risers.
5) There are no dents or gouges.
6) Material is ductile.
7) Integrity of pipeline is governed by pressure hoop stresses, with minor contribution from bending, shear, or tension.
8) Rules apply to straight pipeline sections and long bends.

Remaining strength assessment (RSA) of the COG pipeline has been carried out as per provisions and procedure of the code ASME B31G-2023: Manual for Determining the Remaining Strength of Corroded Pipelines, with the help of Hexagon's CAESAR II software, and the results are presented in **Table 4**. [12]

Table 4 Remaining strength calculation as per ASME B31G

CAESAR II Analysis Report: Pipeline Remaining Strength Calculations (B31G)	
Pipe Nominal Diameter ....(mm.)	558.800
Pipe Wall Thickness ....(mm.)	6.600
Design Pressure ....(KPa)	15.000
Material Yield Strength ....(KPa)	241316.500
Material Specified Min Yield Strength .....(KPa)	245000.000
Flaw Length ....(mm.)	250.000
Measurement Increment ....(mm.)	50.000
Factor of Safety (Fs)	1.390
Design Factor (F)	1.000
Measurements are (P)its or (T)hicknesses	T
Measurement 1 ....(mm.)	5.600
Measurement 2 ....(mm.)	5.700
Measurement 3 ....(mm.)	5.700
Measurement 4 ....(mm.)	5.600
Measurement 5 ....(mm.)	5.700
Measurement 6 ....(mm.)	5.600
Measurement 7 ....(mm.)	5.600
Measurement 8 ....(mm.)	5.600
Measurement 9 ....(mm.)	5.800
Measurement 10 ....(mm.)	5.600
Measurement 11 ....(mm.)	5.700
Measurement 12 ....(mm.)	5.700
Measurement 13 ....(mm.)	5.600
Measurement 14 ....(mm.)	5.600
Measurement 15 ....(mm.)	5.700
Measurement 16 ....(mm.)	5.600
Measurement 17 ....(mm.)	5.800
Measurement 18 ....(mm.)	5.800
Measurement 19 ....(mm.)	5.800

Measurement 20 ....(mm.)		5.800	
OUTPUT:			
METHOD	FAILURE STRESS (kPa)	FAILURE PRESSURE (kPa)	MAX ALLOWED DEFECT LENGTH (mm.)
1 B31G (.67dL)	248866.375	3886.025	272.068
2 Modified (.85dL)	284744.313	4839.024	36.355
3 Exact Trapezoid	281511.219	4784.080	79.795
4 Equivalent Area	281705.875	4787.388	84.537
5 Effective Area	278208.250	4727.949	74.113

* NOTE, revised pressure cannot exceed design pressure.

Results do not indicate any matter of concern right now.

Remaining Life Assessment (RLA)

Table 5 Remaining Life Assessment (RLA) AS PER API 570 & API 574

API 570/API 574 Pipe Inspection Calculations - SI Units

Minimum Pipe Wall Thickness for Specified Design Pressure

1. Pressure Design Wall Thickness, t_p			
Pipe Material			= API 5L GR B
Allowable stress of Pipe Material (Source: ASME B31.3 Appendix A)	S =		138000 kPa
Design Fluid Pressure	P =		16 kPag
Pipe O.D.	D =		558.8 mm
Longitudinal Weld Joint Quality Factor (Source: ASME B31.3 Table A-1A or Table A-1B	E =		1
Weld Joint Strength Reduction Factor (Source: ASME B31.3 Para. 302.3.5(e) and Table 302.3.5)	W =		1
Coefficient (Function of Pipe MOC & Op. Temp.) (Source: ASME B31.3 Table 304.1.1)	Y =		0.4
Corrosion Allowance	CA =		1.5 mm
By Barlow Formula	t_1 =	PD/2SE + CA	= 1.531 mm
By ASME B31.3 Eq. 3a	t_1 =	PD/2[(SE+PY)]+CA	= 1.531 mm
Selected Pressure Design Pipe Wall Thickness	t_1 =	Greater of above	= 1.531 mm
2. Structural Minimum Pipe Wall Thickness, t_s (Source: API 574 Table-7)			3.1 mm
3. Required Min. Wall Thickness	t_m =	Greater of t_p & t_s	= 3.1 mm
4. Selected Wall Thickness	t =		6.6 mm
5. Calculation of Remaining Life			
Long Term Corrosion Rate			
Pipe Wall Thickness during installation	t_i =		6.6 mm
Pipe Wall Thickness as observed	t_a =		5.5 mm
Time between t_i & t_a	LT =		7 yrs
Long Term Corrosion Rate	CR_{LT}	$=(t_i - t_a)/LT$	= 0.15716 mm/yr
Short Term Corrosion Rate			
Pipe Wall Thickness as observed at start of period	t_s =		5.8 mm
Pipe Wall Thickness as observed at end of period	t_e =		5.5 mm
Time between t_s & t_e	ST =		1.5 yrs
Short Term Corrosion Rate	CR_{ST}		= 0.2 mm/yr
Calculation of Remaining Life			
Pipe Wall Thickness as observed at end of period	t_a =		5.5 mm
Limiting Pipe Wall Thickness (= t_s x 1.3)	t_{lim} =		4.03 mm
Remaining Life of Pipe (= No. of years to corrode to t_{lim}) (based on Long Term Corrosion Rate) = $(t_a - t_{lim})/CR_{LT}$	L_{LT} =		9 yrs
Remaining Life of Pipe (= No. of years to corrode to t_{lim})	L_{ST} =		7 yrs

Remaining strength assessment of the COG pipeline has been carried out as per provisions and procedure of of the codes API 570-2023: Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems, and API 574-2016: Inspection Practices for Piping System Components, in a spreadsheet developed in Microsoft Excel, and results are presented **Table 5**. [13] [14]

Based on Long Term & Short Term Corrosion Rates, the remaining life of the pipeline are calculated as 9 years & 7 years respectively. Thus, the probable remaining life of the pipeline is 7 years. As such, there is no immediate concern envisaged with respect to fitness-for-service, remaining strength and remaining life.

CONCLUSIONS

It is obvious that safety is an important goal of any ethical organization. While enhanced safety is a clear benefit of fitness-for-service assessment, there are substantial economic benefits associated which are less apparent, e.g., unplanned shutdowns are exceptionally expensive in terms of lost production. Fitness-for-service assessments done on key assets during a planned shutdown can greatly reduce the probability of unplanned outages. When flaws or other damage are detected, the decisions on how to deal with such imperfections have massive economic repercussions. If flaws are found during normal operation, FFS assessment can guide whether it is safe to operate the system or not until next planned shutdown. If the outcome of assessment is favourable in such a case, then a costly unplanned shutdown van be avoided. Even during a shutdown, whether planned or not, it is desirable to evade or postpone repairs, provided the FFS study shows that the system can be safely operated until next planned outage. Unscheduled withdrawal of components can be very expensive, as long lead times for delivery of replacement parts can lead to extensive delays in production. FFS assessments provide a coherent basis to decide whether or not a damaged component can be in operation until a replacement is arrived. A lesser-known but significant economic benefit of FFS study is that it can lead to improved revenues, as if the rate of life reduction of component can be accurately quantified, a plant can be operated more aggressively between shutdowns. Even if components are replaced more frequently due to accelerated life reduction, the increased output may generate significantly higher net profits for the organization. [7] Localized failures accelerated by pitting corrosion depth and crack propagation are major risks to the integrity of transmission systems, pipelines and safe transport of process fluids. [9] Metal-loss due to corrosion compromises the pressure containment capacity (burst capacity), of pipelines conveying corrosive fluids and poses a direct threat to integrity and safety of pipelines. [10] However, cost of FFS assessment tends to increase with complexity, gradually from Level 1 to Level 3. Moreover, Level 1 assessments may need less tedious inspection requirements than higher-level evaluations. However, if a complex engineering analysis lets a plant to avoid a catastrophic failure or an unplanned shutdown, then it is certainly a good investment when compared with the potential savings, and the cost of an assessment, even at Level 3, is often insignificant.

ACKNOWLEDGMENT

Authors acknowledge Mr. Asok Kumar Basu, Former General Manger (Mechanical), Development Consultants Private Limited, Kolkata, India, and Mr. Mahendra Pandya, Principal Mechanical Engineer, Richards Design Services, Houston, Texas, USA for their practical advices and guidance on the subject.

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A Numerical Analysis to Understand the Behavior of Flow Over a Body at Variable Velocities

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***Abstract**: It is known that when a body is kept across a flow, the wake will form and it will extend to some distancedependinguponthewidthofthebodyandvelocityoftheflow.Thepresentstudycarried out is to find the wake formation (no flow zone) distance behind a vehicle and also in front of the second vehicle. The problem considered in the present investigation is that two vehicles are moving in a line and the work is to find the necessary distance to be maintained by the 2nd vehicle which is behind the first vehicle. This paper helps to understand the behavior of the flow between the two vehicles and the analysis has been done using CFD for the purpose, flow is generated and 1/7th power law has been established for developing the boundary layer. The results also indicate the attachment distance, all the results shows in the present investigation carried out at their different inlet velocities shows that there is not much variation observed in the re attachment distance.*

***Keyword**: CFD; Velocity Gradient; Re-Attachment; Flow Separation; Recirculation*

INTRODUCTION

The external flow past an object is a formidable topic for the study and application of fluid dynamics. This is due to the large variety of flow patterns that occur as the principal control parameter, the Reynolds number (Re), is changed. Both in nature and technology, a very wide range of Re can be encountered. Flow over a bluff body is a fundamental fluid mechanics problem of practical importance. Taking a cylinder as an example the flow field over it is symmetric at low values of Reynolds number. As the Reynolds number increases, flow begins to separate behind the cylinder causing vortex shedding which is an unsteady phenomenon. You can apply either a steady state or an unsteady (time dependent) solver to capture these effects, as appropriate. Drag forces acting on the walls of the cylinder are highly dependent upon Reynolds number. So the effects of viscosity and flow separation upon pressure distribution can be observed.

This investigation reports the computational analysis of fluid flow behavior flowing over two bodies placed, one behind another in a straight line with a fixed distance taken from 2 sec rule used for safe distance[3] which is equivalent to the length of the vehicle moving behind. The approach flow follows the velocity profile satisfying 1/7th power law shown in Chart [1]. The boundary conditions at inlet are taken by considering common speed ranges. The body at front is a regular size load truck behind which a biker is travelling. CAD model of truck and biker has been created with an rough overview of a regular size vehicle dimensions shown in Fig.1.Three different velocities has been taken for the steady state simulation i.e. at 40, 60, 100 kmph, accordingly inlet and outlet boundary conditions are calculated as shown in table[1]. The discretization, defining physics model, boundary conditions, solving and post processing are made by gambit & CFX codes.

MODEL SETUP & BOUNDARY CONDITIONS.

The scenario is dealing with atmospheric boundary layer flow for which Fluid models used for heat transfer is Total energy and for turbulence is shear stress transport. Boundary conditions are defined for three values of speed considering that both the vehicle are moving with same speed i.e. 40, 60, 100 km/hr. Wall is taken as no slip. The boundary conditions are taken in terms of total and static pressure at inlet and outlet as shown in **Table 1**, using the hypothetical formulae's

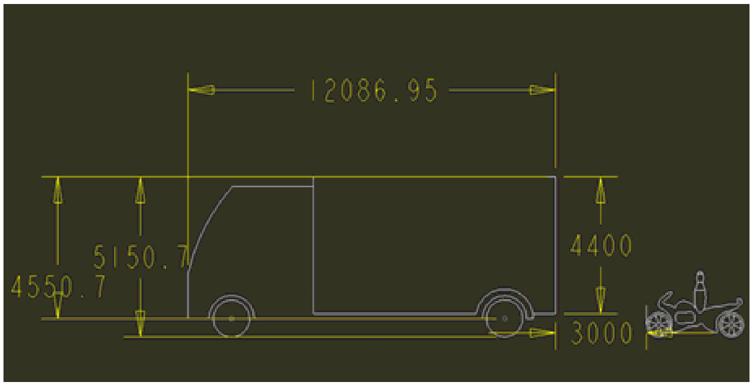


Figure 1 Model with Dimension (mm)

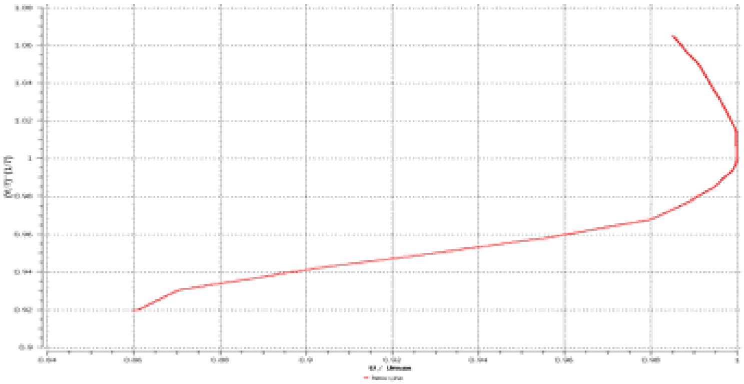


Chart 1 Atmospheric BL Curve Using 1/7th Power Law

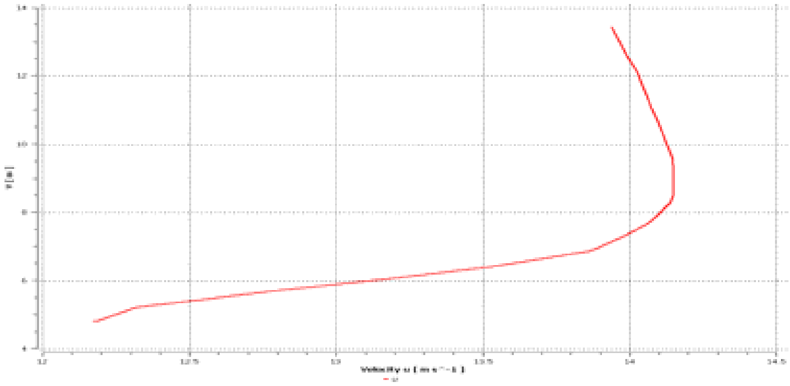


Chart 2 Simulation Velocity Profile

Table 1 Details of boundary condition

Boundary Condition	Velocity [Kmph]	Inlet [Pa]	Outlet [Pa]
CaseA	40	101433	101325
CaseB	60	101604	101325
CaseC	100	101761	101325

METHODOLOGY

Considered place for analysis is the space behind the front body and in front of second body. In the model X shows the horizontal axis Y shows the vertical and Z shows the depth. Section X0 is End of the front body and X2 is the point at which the velocity gradient du/dy=0 i.e. reattachment point and X1 is the intermediate point. Contours are plotted on two plane namely X-Y (Vertical Plane) at Z=0, Z-X plane is the horizontal plane at Y= 1.2 m. Charts are plotted for 15 line section i.e. 5 points in Z direction for each X coordinated. The above position is shown in **Figure 2**.

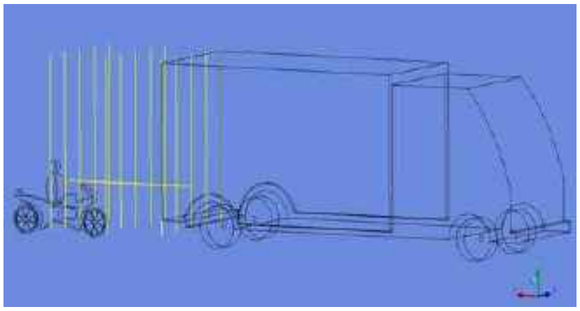


Figure 2 showing coordinates taken under consideration between the two bodies

RESULTS AND DISCUSSION

Results are plotted in form of vector, contour and chart for all the three case A, B & C

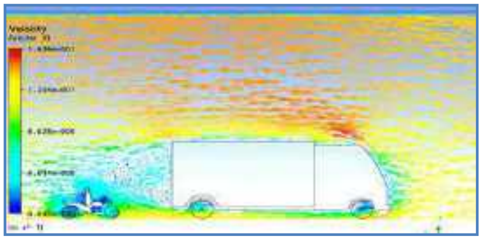


Figure 3 (A)

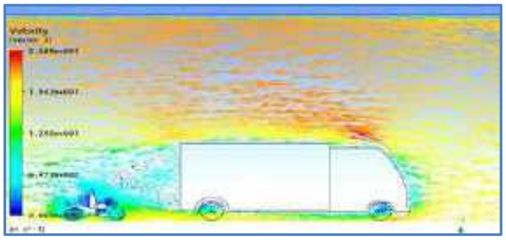


Figure 4(B)

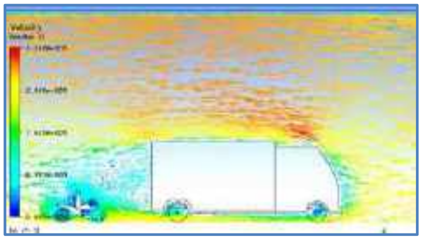


Figure 5(C) Velocity Vector on XY plane at Z=0

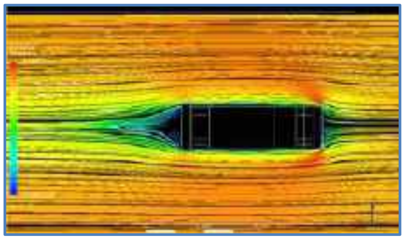


Figure 6 shows streamlines at 1.2 m ZX plane

Figure 3, 4 & **5** shows the velocity vectors in the X- Y symmetry plane and **Figure 6** shows wake streamlines on Z-X plane. The shear layers originate on the upper and lower edges of the model. A strong reversed flow region is formed behind the model which is bounded by these two shear layers. The overall length of the recirculation region is estimated. However, there is a strong lower recirculation region. Practically it will have rapid upward deflection of underbody flow and strong upsweep, which can be observed in the simulations with fineness of grid in the boundary layers[2].

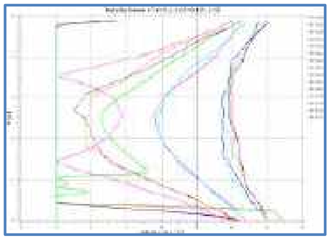


Chart 3 Velocity profile for (A)

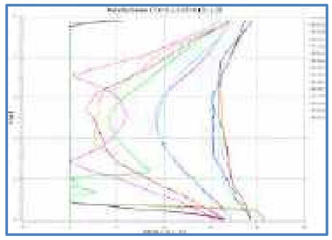


Chart 4 Velocity profile for (B)

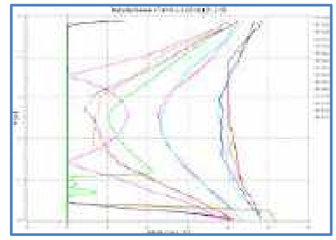


Chart 5 Velocity profile for (C)

Chart 3, 4 & 5 shows the velocity profile plotted in the space between the two bodies for all the three velocities. It shows a quantitative comparison of the mean stream wise velocity profiles at various axial locations in the symmetry plane of the model i.e. behind the first body. It holds a good agreement with the hypothesis regarding reversed velocity curve in the recirculation zone or no flow zone.

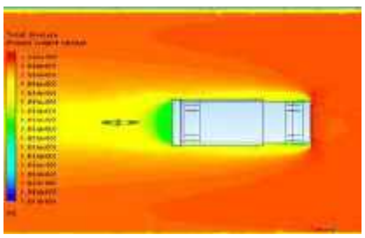


Figure 7 Pressure Contour on ZX plane at Y = 1.2m

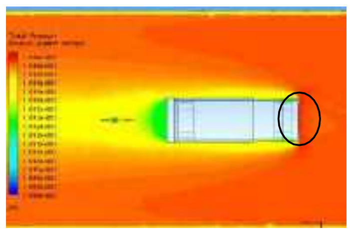


Figure 8 Pressure Contour on ZX plane at Y = 1.2 m

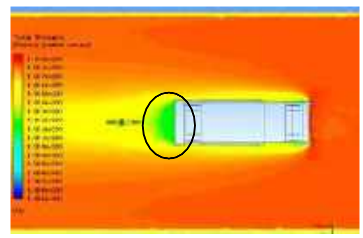


Figure 9 Pressure Contour on ZX plane at Y = 1.2m

Figures 7, **8** & **9** are the contours on the symmetrical plane showing pressure distribution, the wake behind the body and the stagnation zone.

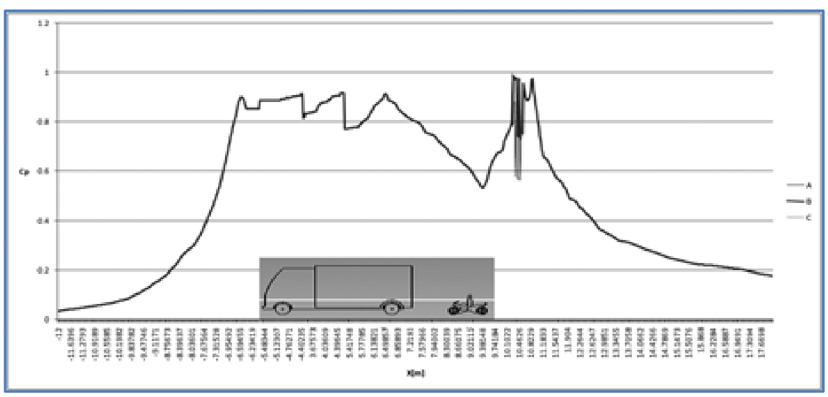
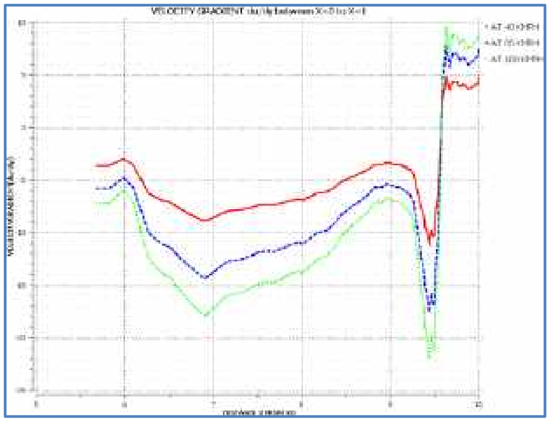


Chart 6 showing Coefficient of pressure Cp vs. direction of flow x

The variation of static pressure coefficient (Cp) on the centerline of the X-Y plane against stream wise distance is plotted in **Chart 6** for all the three case. The results reflect the typical stream wise mean pressure distribution fore and aft of the model. Upstream of the model, the increase of positive Cp reflects increasing stagnant flow due to the presence of the frontal surface. Downstream of the model, the results show two distinct features of the flow field, namely a wake and the attachment of the local flow[5].



Reattachment point is estimated by plotting velocity gradient $\frac{du}{dy} = 0 vs$ the direction of flow between X_0 and X_2. Velocity gradient shows negative value in the circulation zone and further it shows significant change in the value which crosses the zero this shows that the flow is reattached. The reattachment lengths for the three case are shown in **Table 2**. Which concludes that reattachment point does not shows high variation.

Table 2 Reattachment length for all three cases A, B & C

S.No	Case	ValueofX
1	CaseA	9.57344m
2	CaseB	9.57373m
3	CaseC	9.57383m

Figure 10 shows the recirculation zone formation behind the body at Reynolds number equals to 2e+7 for all the three case A, B & C. It establishes a good understanding of vortex formation in all the three velocities, that the zone of vortex formed, is near about same.

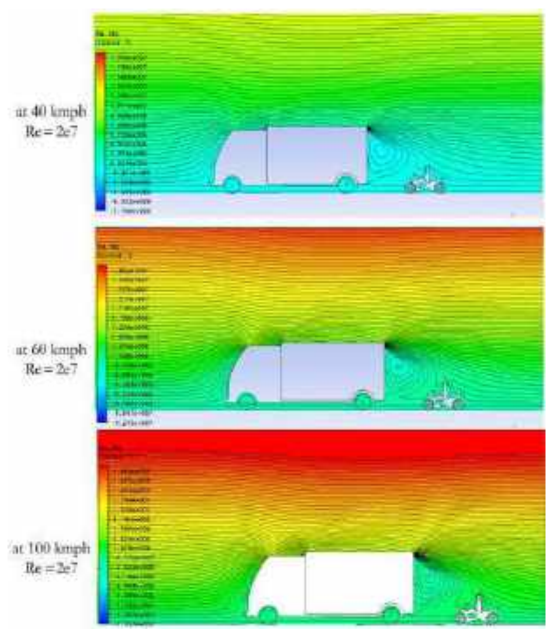


Figure10 shows Reynolds number distribution over the vertical symmetrical plane

Figure 11 shows the values of reduced drag force on second body with an increase in the inertia. These values are plotted to show the significant change in drag force and jump in the inertia on the second body when it moves in the no flow zone.

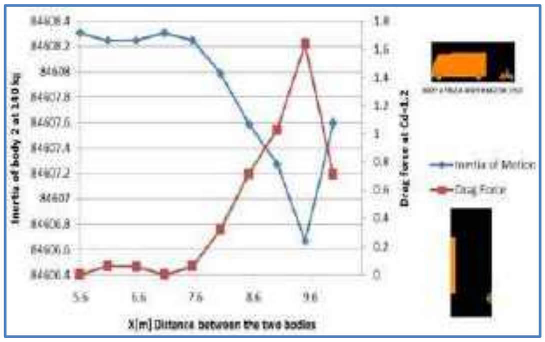


Figure 11 shows the values of drag force and inertia on & of the second body

CONCLUSION

The result helps to have a good understanding of the flow across the body. It satisfies the hypothetical understandings of flow dynamics of bluff bodies.

Reattachment length in all the three velocities is near about same, which justifies the use of 2 second rule for keeping safety distance.

The accuracy of the results can be improved by taking high density mesh with LES model which gives a very clear understanding of vortex shedding. It might help in understanding the effect of vortex zone on air breathing vehicles working .

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Advanced Composite Materials for Industrial Applications

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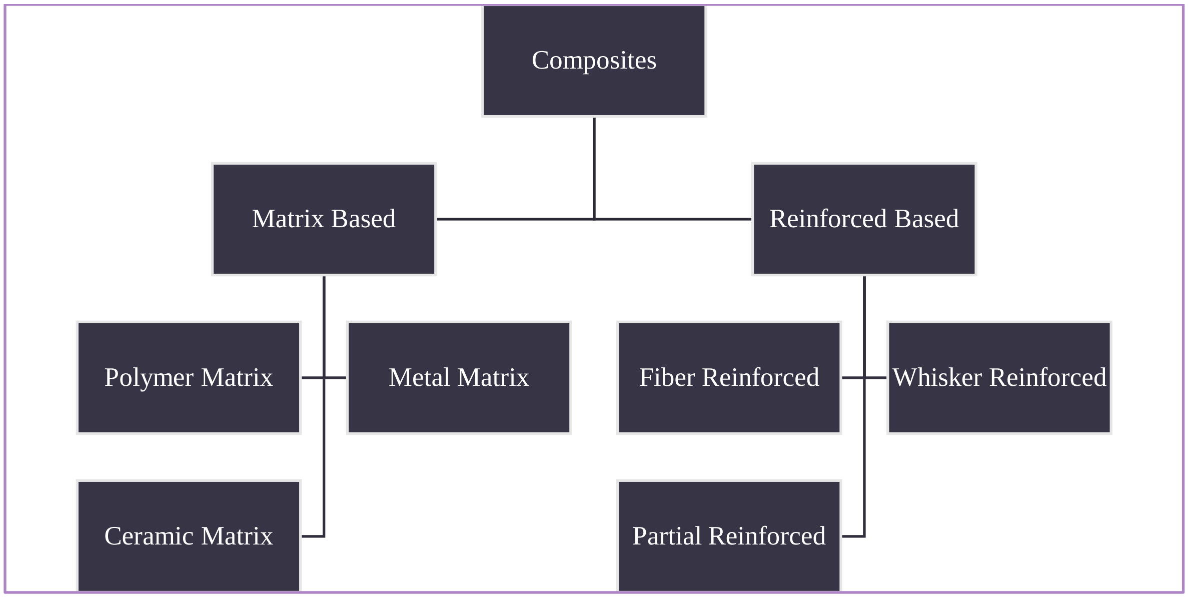
Abstract: *Various technology programmes in world are concerned with preparing for future propulsion technologies to minimize the costs and increase the life time of components for liquid rocket engine components. One of the key roles to fulfil the future requirements and for realizing recyclable and robust engine components is the use of modern and innovative materials. One of the key technologies which concern various engine manufacturers worldwide is the development of fibre reinforced ceramics – CMC's (Ceramic Matrix Composites). The advantages for the developers are recognizable – the low specific weight, the high specific strength over a large temperature range, and their good damage tolerance compared to monolithic ceramics make this material class extremely interesting as a construction material. Different kind of composite materials are available and produced by EADS ST, the standard material SICARBON® (C/SiC made by Liquid Polymer Infiltration) and the new developed and qualified composite materials SICTEX® (C/SiC made by Liquid Silicon Infiltration) and CARBOTEX® (C/C made by Rapid Chemical Vapour Infiltration). The composites are based on textile techniques like weaving, braiding, stiching and sewing to produce multiaxial preforms, the SICTEX material is densificated by the cost effective Liquid Silicon Infiltration (LSI). Over the past years, EADS Space Transportation (formerly DASA) has, together with various partners, worked intensively on developing components for air breathing and liquid rocket engines. Since this, various prototype developments and hot firing-tests with nozzle extensions for upper and core stage engines and combustion chambers of satellite engines were conducted. MBDA France and EADS-ST have been working on the development of fuel-cooled composite structures like combustion chambers and nozzle extensions for future propulsion applications.*

Keywords*: Ceramic Matrix Composites, Fibre, Low Specific Weight, High Specific Strength*

INTRODUCTION

New materials created by combining two or more constituent materials on a macroscopic scale are named composite materials. In order to provide new thermal and mechanical behavior regarding to the complex loading systems of working conditions, two or more materials are mixed together as composite materials. Composite materials are now more popular in the aerospace and automotive industries due to their excellent qualities, such as high strength-to-weight ratios, high specific stiffness, corrosion resistance and low coefficient of thermal expansion (CTE) in certain directions. Chemical compatibility, wettability, adsorption properties, and the creation of complicated stress states arising from changes in heat and moisture expansion are all unknown features of composite materials.The composite materials have exceptional mechanical and structural qualities, including a high strength-to-weight ratio, resistance to fire, chemicals, corrosion, and wear, as well as low manufacturing costs In order to provide new thermal and mechanical behaviour regarding to the complex loading systems of working conditions, two or more materials are mixed together as composite materials.As a result, advanced materials by considering the applied mechanical and thermal loads of working condition are produced as composite materials which are specially designed to carry out a certain function, such as becoming stronger, lighter, or electrically resistant. Also, stiffness and strength of produced composite materials can be enhanced in terms of composite designing process using combination of different materials. To provide superior mechanical and thermal qualities than original materials, composite materials should be designed to resist such events as impact loading, vibrational loading, delamination, cracking, and fatigue. Each composite material attribute must be evaluated and measured, preferably in real time and in a real-world setting, although this is not always practicable.

Classification of composite materials is shown below:



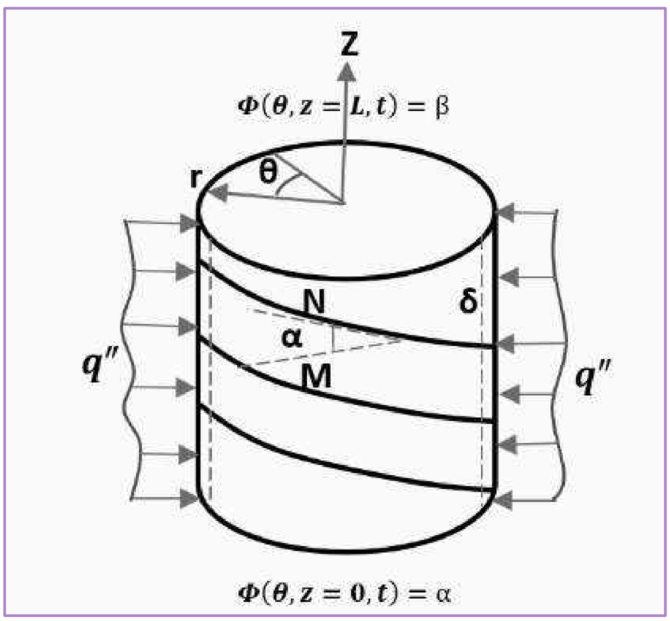
Mechanical Properties of Composite Materials:

In the fiber reinforced composites which are composed of fibers embedded in matrix material, the effects of length and directions of the fibers on the mechanical properties of the campsites can be numerically investigated. As a result, the new kind of composite materials regarding the different working conditions can be generated. The process of polymer composite reinforcements by using fibers, fabrics particles or whiskers to increase mechanical capacities of new composites can be numerically analyzed to increase the efficiency in the process. The orientation as well as volumes of the fiber in the polymer matrixes reinforcements process can be analytically analyzed to increase the strength and flexibility of new generated composites. So, the optimized process of polymer composite reinforcements can be numerically obtained in terms of quality enhancement of produced composites. To prevent part failure due to the fatigue crack propagation in the composite materials and structures produced by additive manufacturing processes, the numerical methods can be implemented.

THERMAL PROPERTIES OF COMPOSITE MATERIALS

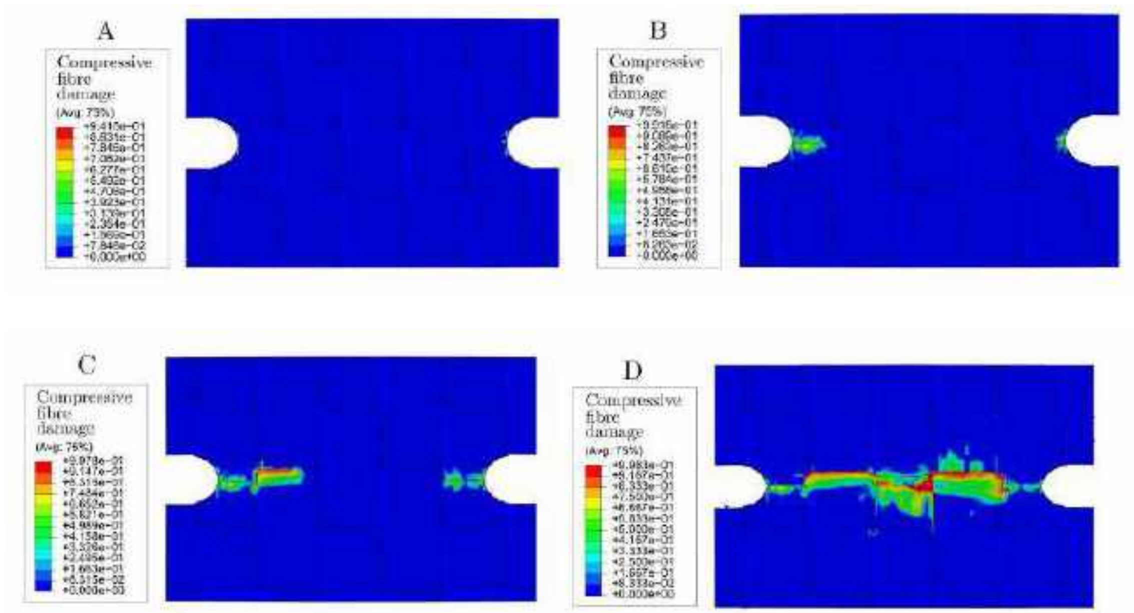
Effective thermal conductivity reflects the ability of a material to conduct heat in terms of applied thermal loads to the composite structures. The rate of thermal energy storage and conversion is an important factor of composite designing process to decrease the possibility of thermal failure of composite components in actual working. "The geometry and boundary conditions of composite cylindrical vessel" conditions. So, the thermal stability and melting behavior of composites can be determined by analysis of thermal properties of composite materials using differential equations. The problem of heat conduction in the metal matrix composite of Titanium, Aluminum and magnesium materials can be analytically investigated in order to analyze the temperature distribution in the composite components. Thus, the thermal fractures of composite parts in actual working condition can be prevented to increase safety and reliability of produced components using composite materials. The geometry and boundary conditions of composite cylindrical vessel. The fractional change in length of a body when heated or cooled over a certain temperature range is known as linear thermal expansion which usually presented as coefficient per unit temperature of the materials. To provide an accurate designing procedure for thermal conductivity of composite materials, the thermal coefficients of the designed composite materials should be obtained. The Rosen and Hashin as well as Chamberlain differentials equations are presented to accurately obtain the thermal expansion coefficients of composites using numerical methods.

Mechanical Behavior of Composite Structures:



The effects of cracks and imperfections on the impact strength of polymer components affect the idea of fracture of polymeric materials, and the critical length of a crack is a major determinant in fracture strength. The fracture toughness of a material is determined by two factors in failure concepts: the first is stress intensity, and the second is energy [122]. The effects of cracks and imperfections on the impact strength of polymer components affect the idea of fracture of polymeric materials, and the critical length of a crack is a major determinant in fracture strength. The fracture toughness of a material is determined by two factors in failure concepts: the first is stress intensity, and the second is energy [122].

Fiber compressive damage and crack propagation is shown:



The failure process of composites with homogeneous isotropic materials is different because they are non-isotropic. In fact, failure in non-isotropic materials can be caused by different states of stress. In the study of the failure of composites, the behavior of each layer is investigated. Whenever the stress distribution causes a layer to fail, the failure calculations continue by removing that layer. Many factors are involved in studying the failure of composites, the most important of which are the thickness of the composite, the direction of the fibers, the composition of the layers, its mechanical properties and its thermal properties.

Delamination problems of composite materials:

In the aerospace and automotive industries, composite laminate is widely used. As a result, delamination, one of the most common and difficult failure modes, has prompted much study and the fast development of both modeling and experiment methods. Damage from the development of such delamination causes a reduction in strength, toughness, and fatigue life. Low velocity caused delamination of composite structures, which is one of the key issues in the safety analysis of the composite structures. Matrix cracking, bending fractures, and shear cracks all contribute to delamination. Selection process of the best geometrical bumper beam concept to fulfill the safety parameters of the defined product design specification using the bio-composite material is presented by Davoodi et all Effects of various parameters on strength and ductility of Biomimetic layered fiber-reinforced Ti–Al composites through finite element analysis is presented by Chen and Hao to simulate and enhance specific bending strength and fracture bending strain under the complex loading system. The stress strain curve, plastic strain, and damage variable of the L-3LFR composite structure is shown.

Stress concentrations in composite materials:

A stress concentration factor is a dimensionless metric for determining how concentrated the stress is in a mechanical component. It's the difference between the greatest stress in the component and a reference stress. All known structural components have stress concentrations.

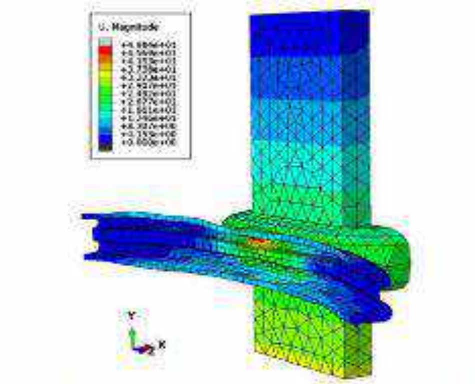


Fig. 5- Displacement profile of double hat profile after impact [142].

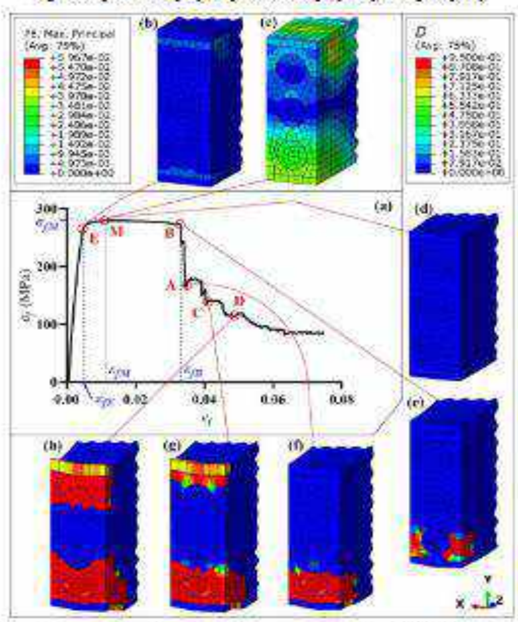
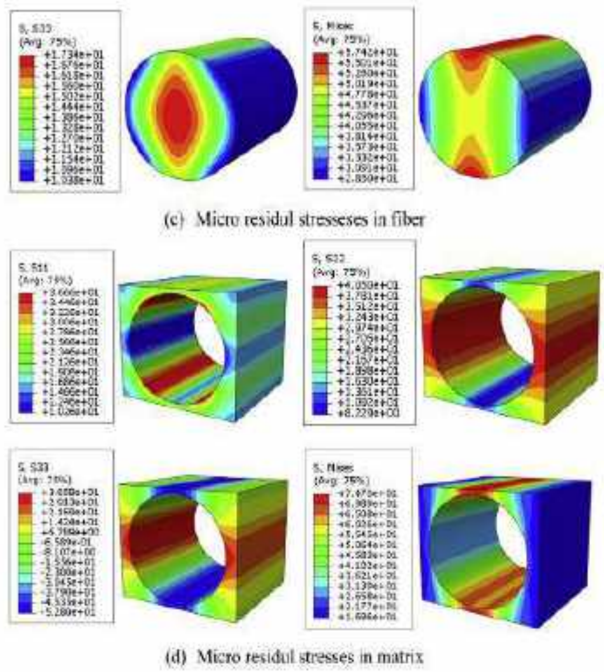


Fig. 6- The stress-strain curve, plastic strain and damage variable of the L-3LFR composite structure [143].

Simulation and fatigue performance of short fiber reinforced polymer composites due to the stress concentration factors is reviewed to increase safety factors in the composite joints. Methods for predicting failure of composite multi-bolt joints using characteristic length measuring method is presented to decrease the effects of stress concentration in the composite structures.

Numerical Simulation of Composite Structures using Finite Element Method:

To simulate the mechanical properties of composite materials such as young modulus and standard deviation, strength and flexibility, instability, rigidity, toughness, and ability to repudiate creep during working conditions can be simulated by using the numerical simulation. The mathematical equations of thermal as well as mechanical properties of the composite materials can be used in the finite element simulation of the composite pipes under internal pressure and bending moments. Also, fatigue life as well as fatigue crack propagation in composite materials due to repeated or varying loadcan be accurately predicted using numerical methods to increase the working life of produced parts from composite Materials.An improved inverse finite element approach for multi -layered composite and sandwich structure movement and stress management is presented to provide the sophisticated composite structures with precise form and stress sensing.A pheon-numerical modelling technique for predicting process-induced distortions is developed to accurately predict and minimize the distortion in the composite structures in composite manufacturing.



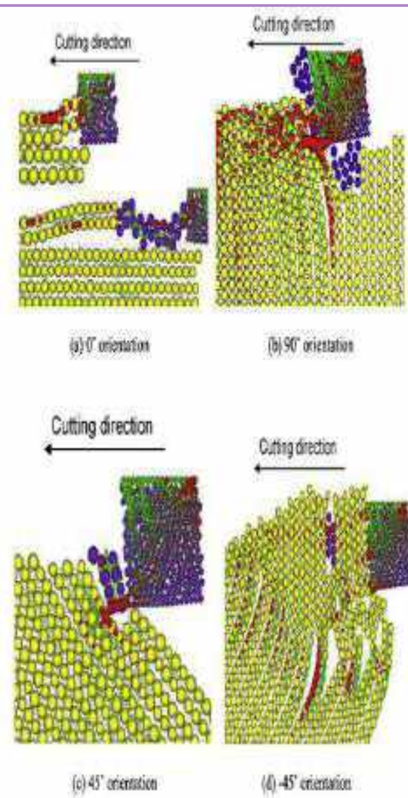


Fig. 8- The formation of a chip during orthogonal cutting using discrete element simulation for various fiber orientations [158].

CONCLUSION AND FUTURE RESEARCH WORK DIRECTIONS

A composite material is made up of two components that have distinct physical and chemical properties. When the materials are mixed, new materials are created which are specialized to perform a specific task, such as becoming stronger lighter, or more resistant to electricity. The numerical solutions can obtain the closed form of exact solution for the generated nonlinear differential equations of thermal and mechanical properties of composites. Then, the obtained exact solutions of the advanced nonlinear differential equations can be used in terms of designing and developing the applications of composites in different industries. Delamination problems of composite materials can be studied by using the mathematical modeling to decrease the failure rate in the composite structures. To increase the safety level as well as performance. Numerical simulations of composite materials using FEA have improved in accuracy and efficiency analysis to predict and prevent the crack development in elastic composites. As a result, the strength of the elastic composite structures can be enhanced using the FEA analysis of applied complex loading systems in virtual environments.

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Vibration Characteristics of Submerged Plates and Panels

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Abstract: *In this communication studied the vibration behavior of fully and partially submerged composite laminate plates and flat panels using a finite element method, formulation is based on first-order shear deformation theory. Here, author employed the sixteen node degenerated shell element using mixed interpolation tensorial component approach (MITC). It is observed from results that added mass of water reduces the vibration frequency of structures. In this article author studied the effect of span-to-thickness ratios, radius-to-span ratios.*

Keywords*: Submerged; fluid-structure interactions; plates; panels*

INTRODUCTION

The knowledge of dynamic behavior of plate and flat panel structures submerged in water is required for better design of structures like ships, submarine hulls andunderwater structures which are subjected static and dynamic loads. The fluid pressure in general reduces the natural vibration frequencies of structures. This fluid pressure may be considered as equivalent to “added mass” of the structure. The evaluation of the added mass meight be a complex problem for irregular geometry of the structures and of the water interfaces.

Several researchers investigated the vibration characteristics of cantilever plates through experimental and analytical approaches [1-3] in the air, totally orpartially immersed in water, and compared the measurements with the theoretical predictions. The classical plate theory was used to model the plate, while, the fluid is assumed to incompressible and non-viscous.

Moreover, Muthuveerappanet al. [4] used the finite element method to solve the fluid structure interaction problem of submerged plates and obtained the vibration frequencies of a cantilever plate immersed in water.Fu and Price [5] investigated the dynamic behavior of fully submerged horizontal plate and partially submerged horizontal plate based on a linear hydro-elasticity theory. Rao et al. [6] studied the free vibration frequencies and mode shapes of the submerged stiffened plate by using finite element method.Ergin and Ugurlu [7] employed finite element method to obtain the in-vacuum dynamic properties of the plate and the fluid–structure interaction effects are considered in terms of the generalized added-mass values by the use of a boundary integral equation method.

From the review of literature, it is observed that the dynamic characteristics of submerged isotropic panels have been studied mostly considering the fluid to be incompressible and non-viscous. However, the studies on the dynamic characteristics of submerged composite panels are limited in the literature. Recently, [10-13]investigated the free vibration response of laminated composite cantilever plates in the air and in water medium by experimental, analytical and numerical approach and observed that the natural frequencies of composite plates are 50-70% lower when submerged in-water than in-air. The behavior of submerged composite panels with relatively light weight will be different from those of isotropic panels and requires more study. So, here investigated the vibration characteristics of dry and wet cantilever plates.

PROBLEM FORMULATION

A sixteen-noded degenerated isoparametric finite element plate element (schematically shown infigure 1) having five degrees of freedom per node (u_1, u_2, u_3, α_k and β_k) is employed to model the composite laminated submerged pre-twisted cantilever plate.

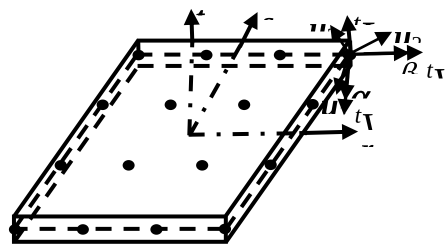

Figure 1 Geometry of 16-noded plate element

Geometry of submerged pre-twisted cantilever plate is presented in Figure 2. The governing equations of motion (1) for the submerged plates are expressed here, considering the following assumptions to model the dynamic behavior of the fluid-structure interaction problems.

(a) The amplitude of the vibration is small, the response of the plate is governed by the Eq. (1):

$$[M]\{\ddot{u}\}+[K_L]\{u\}=\{P_{fluid}\} \qquad (1)$$

Where, u is the displacement of the plate from its static equilibrium position.

The hydrodynamic pressure of fluid is perpendicular to the plate surface, it appears only in z- direction as an applied load $\{P_{fluid}\}$ in Eq. (1) can be represented as:

$$\{P_{fluid}\}=[M_a]\frac{\partial^2 u}{\partial^2 t}=[M_a]\{\ddot{u}\} \qquad (2)$$

Where, $[M_a]$is the added mass and dependent on fluid modeling and fluid-plate interface conditions. Added mass $[M_a]_M=\int_0^a \rho_F A dx=\frac{\pi}{4}\rho_F b^2 a$ and added mass moment of inertia $[M_a]_J=\int_0^a \rho_F \frac{\pi}{8}\left(\frac{b}{2}\right)^4 dx=\frac{\pi}{128}\rho_F b^4 a$.

Here, A is a cross section area, a andb are length and width of the plate and ρ_F is the fluid density.

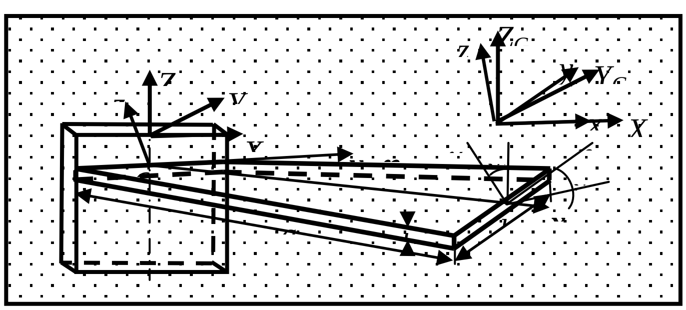

Figure 2 Geometry ofsubmergedtwisted plate

(b) The density of fluid ρ_F is assumed to be homogeneous, incompressible, inviscid and fluid motion is irrotational. Therefore, the fluid pressure P satisfy the Laplace's equation, given by:

$$\nabla^2 P = 0 \tag{3}$$

The governing equation for two dimensional (2-D) problem in acoustic mediumis:

$$\frac{\partial^2 P}{\partial x^2} + \frac{\partial^2 P}{\partial y^2} = 0 \tag{4}$$

(c) We assume no-penetration condition, however transverse force is zero. Therefore hydrostatic force on the fluid particle in x, y and z direction are:

$$\frac{\partial P}{\partial x} = -\rho_F \ddot{u}_1 \; \frac{\partial P}{\partial y} = -\rho_F \ddot{u}_2 \; \frac{\partial P}{\partial z} = -\rho_F \ddot{u}_3 \tag{5}$$

Therefore; $$\frac{\partial^2 P}{\partial x^2} + \frac{\partial^2 P}{\partial y^2} = -\rho\left[\ddot{u}_{1,x} + \ddot{u}_{2,y}\right] = -\rho \frac{d^2}{dt^2}\left[u_{1,x} + u_{2,x}\right] = -\rho \frac{d^2}{dt^2}\left[\varepsilon_{xx} + \varepsilon_{yy}\right] \tag{6}$$

Bulk modulus: $$B = -\frac{P}{dV/V} = -\frac{P}{(\varepsilon_{xx} + \varepsilon_{yy})} \Rightarrow \varepsilon_{xx} + \varepsilon_{yy} = -\frac{P}{B} \tag{7}$$

Hence: $$\frac{\partial^2 P}{\partial x^2} + \frac{\partial^2 P}{\partial y^2} = -\frac{\rho}{B}\ddot{P} \Rightarrow \nabla^2 P + \frac{\rho}{B}\ddot{P} = 0 \tag{8}$$

Where, P is a fluidpressure rise above the static pressure, the boundary conditions for flow analysis are:

1.The Fluid-structure interfaceis: $\frac{\partial P}{\partial n} = -\rho_F \ddot{u}_3$ alongz = 0

Where n is the outward normal from the plate at the fluid-plate interface.

2. Clamped edge: $u_1 = u_2 = u_3 = \alpha = \beta = 0$ and $\frac{\partial P}{\partial n} = 0$ along x = 0

3. Free edge: P= 0, along x = a, y = ±b/2 and far away from the plate.

Hydrostatic fluid pressure:

$$P = \rho_F g u_3$$

and

$$u_3 = \frac{P}{\rho_F g}$$

$$\frac{\partial P}{\partial z} = -\frac{1}{g}\ddot{P}$$

Hence, the fluid pressure acting on the plate will be considered as added mass of the structure. Governing equation of motion with added mass $[M_a]$ is represented by equation (9). When gravitational effects, as well as material and fluid damping effects are ignored.

$$[M + |M_a]\{\ddot{u}\} + [K_L]\{u\} = 0 \tag{9}$$

The natural frequency of the submerged plate is given by:

$$\omega_F = \sqrt{\frac{K_L}{M + M_a}} \text{ or } \omega_F = \omega_V \sqrt{\frac{1}{1 + \frac{M_a}{M}}} \tag{10}$$

Where, ω_F is the natural frequency of the plate submerged in fluid.The non-dimensional quantity M_a/M in equation (10) is defined as added mass factor (AMF) which can be expressed by equation (11) which depends on geometry of the structure.

$$AMF = \frac{M_a}{M}\frac{\rho}{\rho_F} \Rightarrow \frac{M_a}{M} = AMF\frac{\rho_F}{\rho} \tag{11}$$

The added mass, which is different from the structural mass, depends on the direction of motion and orientation. For each cross-section of the plate, the sectional added mass is higher for pure bending than for pure twisting motion. As shown by Kramer et al. [10], the fluid-to-vacuum frequency ratios, based on two-dimensional potential flow theory for added mass and strip theory for the plate in pure bending and pure twisting modes, can be expressed as follows:

$$\omega_F\big|_{bending} = \omega_V \sqrt{\frac{1}{1 + \frac{\pi}{4}\frac{\rho_F}{\rho}\frac{b}{h}}} \tag{12}$$

$$\omega_F\big|_{torsion} = \omega_V \sqrt{\frac{1}{1 + \frac{3\pi}{32}\frac{\rho_F}{\rho}\frac{b}{h}\left(\frac{b^2}{b^2 + h^2}\right)}} \tag{13}$$

RESULTS AND DISCUSSION

The vibration behavior of submerged cantilever isotropic plates is investigated here. The efficacy of the element is now assessed by studying the resonant vibration frequencies of submerged plates for which results are available in the literature. The material properties and geometric properties ofthe isotropic platesare:

Isotropic: E = 207 GPa, $\mu = 0.3$, $\rho_{solid} = 7827$ kg/m^3, $\rho_w = 1000$ kg/m^3, $\rho_a = 1.225$ kg/m^3

Boundary conditions are: $u_1 = u_2 = u_3 = \alpha_k = \beta_k = 0$ along y-axiasat x = 0

Table 1 Comparison of resonant frequencies (in Hz) of an isotropic cantilever plates (a = 0.4025 m, b = 0.2032 m and h = 0.00266 m when aspect ratio a/b = 2, and a = 1.0160 m, b = 0.2032 m and h = 0.00484 m when aspect ratio a/b = 5).

Aspect ratio	**Fluid medium**	**References**	**Modes**				
			1	**2**	**3**	**4**	**5**
a/b = 2	Dry	Motley et al. [11]	13.86	59.11	86.38	192.5	-
		Present Study	13.980	59.618	87.101	194.216	244.304
	Wet	Motley et al. [11]	5.45	31.34	36.83	105.1	-
		Present Study	4.749	30.289	29.589	98.674	82.95
a/b = 5	Dry	Motley et al. [11]	3.96	24.76	39.08	69.46	-
		Ergin and Ugurlu [7]	3.94	24.66	39.07	69.24	119.47
		Exp. (Ret. Ergin and Ugurlu[7]) air	3.84	24.20	39.10	68.10	121.0
		Present Study	3.945	24.692	39.305	69.271	120.221
	Wet	Motley et al. [11]	1.83	11.74	24.43	34.55	-
		Ergin and Ugurlu [7]	1.82	11.68	24.0	34.31	73.91
		Exp. (Ret. Ergin and Ugurlu[8]) water	1.78	11.50	24.20	33.50	75.26
		Present Study	1.7279	10.815	24.475	30.340	74.862

Table 2 Comparison of natural frequencies (in Hz) for isotropic plates (b = 8.0) with numerical and experimental and related numerical results.

b/h	a/b	F.M.	References	Modes					
				1	2	3	4	5	6
16.367	3	Dry	Liang et al. [3]	28.37	173.0	177.1	-	497.9	544.1
			Exp. (Ret. Liang et al.[3])	27.3	172	171	-	478	537
			Abaqus (Ret. Liang et al.[3])	28.2	172	176	-	494	539
			Present study	28.218	172.495	176.006	-	492.847	540.945
		Wet	Vacuum	28.2483	172.563	176.193	-	493.370	541.159
			Liang et al. [3]	18.30	140.0	114.3	-	321.2	440.2
			Exp. (Ret. Liang et al.[3])	17.8	133	166	-	335	417
			Abaqus (Ret.Lianget al.[3])	17.4	135	108	-	304	424
			Present study	17.376	135.841	108.383	-	303.489	425.998
42.017	3	Dry	Liang et al. [3]	11.03	67.34	68.89	-	193.7	211.8
			Exp. (Ret. Liang et al.[3])	10.8	67.7	66.9	-	188	211
			Abaqus (Ret. Liang et al.[3])	11.0	67.9	68.8	-	193	213
			Present study	10.985	67.894	68.619	-	192.701	213.164
		Wet	Vacuum	11.015	67.963	68.806	-	193.226	213.382
			Liang et al. [3]	5.15	43.91	32.15	-	90.37	138.1
			Exp. (Ret. Liang et al.[3])	5.1	41.6	33.3	-	98.9	131
			Abaqus (Ret. Liang et al.[3])	4.83	42.3	30.2	-	84.7	133
			Present study	4.822	42.3069	30.123	-	84.594	132.829
76.335	3	Dry	Liang et al. [3]	6.06	37.04	37.85	-	106.4	116.5
			Exp. (Ret. Liang et al.[3])	6.2	40.3	38.7	-	109	126
			Abaqus (Ret. Liang et al.[3])	6.06	37.4	37.9	-	106	117
			Present study	6.0343	37.394	37.699	-	105.907	117.423
		Wet	Vacuum	6.0641	37.464	37.885	-	106.4302	117.640
			Liang et al. [3]	2.21	19.93	13.82	-	38.84	62.69
			Exp. (Ret. Liang et al.[3])	2.3	20.6	15.4	-	46.5	65.7
			Abaqus (Ret. Liang et al.[3])	2.06	19.0	12.2	-	36.2	59.8
			Present study	2.060	19.037	12.8724	-	36.162	59.778

*Ret. represents here retrieved.

In this article, authors validated the present numerical results compared with available published results of thin cantilever isotropic ($\mu = 0.3$) plates (a/b = 2, 5 and b/h = 42 and 76, respectively) results of Ergin and Ugurhu [7] and Motley et al. [11] as presented in **Table 1**. It is observed that present results have very good match with published experimental and numerical results having percentage of error is 3%.

Thereafter, compared the numerical results of rectangular (a/b = 3) moderately thick (b/h = 16.367) and thin (b/h = 42.017, 76.335) cantilever plate results with Liang et al. [3] for dry and wet plates as given in Table 2. It is noticed that percentage of error is less than 1 % for various cases.

CONCLUSION

In this article author studied the vibration behavior of fully submerged cantilever plates using finite element method based inhouse FORTRAN code based on first order shear deformation theory.

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Study of Design Process Decision Makings Using Hands on Experience of Design of Ground Coupled Central Panel Cooling System (GC-CPCS)

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Abstract: *The nature of design was initially understood as a rational problem solving tool. Later it was observed that this definition of design was not precise to capture the very nature of the actual design situation. Many efforts have been done to model the design activity/process to understand the inherent nature of design methodology. Many general design concepts, unique to any design situation, evolved during such efforts. This paper elaborates some of them. Needless to say, that these concepts give useful insight to capture the actual design situations. These concepts are further tested by analyzing a practical design situation. There is resemblance among the design concepts developed and the practical design situation; the actual design activity. The design concepts are further applied to an actual research work done by the author while designing a system to cool the solar panels.*

Keywords: *Modeling of Design Process; Rational Problem Solving; General Design Concepts; Ill-Structured Vs. Well-Structured Problem; Bracketing; GC-CPCS*

INTRODUCTION

There has been query to what a design process is? What does a designer do? What is the thinking process of a designer? How does design differ from any other problem solving activity? The nature of design was initially thought to be a rational problem solving activity. However with experiences garnered during design teaching and design practice this definition of design was found to be inadequate. It could not capture the very nature of design. It is well taken that a design situation differs from any rational problem solving. If the role of design is restrained to just problem solving then it is bound to miss the important aspects of design activity.

There have been efforts to find an alternative framework for describing design. However due to dearth of any other model other, the Simon’s, rational problem solving approach survived. Later on various efforts have been made to model the design process setting aside the rational problem solving approach. While developing these models various characteristics were discovered which are special to any design situation be it a software design or a bridge design. These characteristics are termed as general design concepts. These general design concepts, distinguishes any design situation / design activity from any other rational problem solving. Design effort is futile in the absence of these general design concepts.[1] [2]

The objective of this paper is to discuss various general design concepts to elaborate their significance. Further to ascertain authenticity of these general design concepts, design cycle of a design project is analyzed by using phenomenological approach. At each stage of design the relevance of general design concepts is evaluated. The design project taken up is a solar panel cooling system nick named as GC-CPCS (Ground-coupled central panel cooling system).

GENERAL DESIGN CONCEPTS

The general design concepts are the distinctive features of a design situation/environment which distinguishes it from a rational problem solving activity. These concepts are drawn from the various efforts done to model design activity / design situation by different researchers.

Ill-structured problem vs. well-structured problem

The concept of ill-structured problem and well-structured problem was envisaged by Simon. The problems can be categorized as ill-structured and well-structured. Simon suggested that design may be understood as solution to ill-structured problem or alternatively design is a process to convert an ill-structured problem to a well-structured problem, But how well can the problems may be treated as ill-structured or well-structured is not clear. Later it was felt that the line between ill-structured and well-structured is thin. It came out that the ill-structuredness of the problem depends upon the lack of tools available to solve it. This means that ill-structuredness depends upon the capability of the problem solver. If the problem solver is equipped with the correct tools then an otherwise ill-structured problem may well be treated as a well-structured problem. [3] [4]

THE DESIGN PROBLEM IS NOT KNOWABLE AT ANY SPECIFIC POINT IN THE DESIGN PROCESS[1]

The design problem cannot be defined as a whole at the beginning of the design or any specific point during the design process. A very pertinent example to explain this attribute is the game of chess. In a game of chess the problem space undergoes continuous change throughout the course of the game. The reasons why the design problem is not knowable at any specific point of time are the following.

(i) The concept of bracketing
(ii) Design situation culminates in the expansion of the initial concepts
(iii) Use of memory and subjective interpretation

CONCEPT OF BRACKETING

The reason why design situation cannot be defined as a whole during any specific point of design process can be understood through the concept of bracketing which is a philosophical technique put forward by phenomenologist Edmund Husserl. Design problem is initially defined deceptively simple. The major objectives of the design are bracketed. This is done to enable the problem solver to be able to solve the design problem by applying practicable amount of computation. If all the objectives of the design problem are taken up in one go then it is practically impossible for the problem solver to handle the abnormal amount of information and the huge amount of computation required to solve the problem. [5]

Bracketing may also be understood as the unpacking of phenomena like peeling away the layers of an onion until the thing itself as meant and experienced remains. Such phenomenological reduction allows the problem solver to handle the design activity by applying practicable amount of computation. However the judgment, the final design specification, is suspended till all the aspects are analyzed.

DESIGN SITUATION CULMINATES IN THE EXPANSION OF THE INITIAL CONCEPTS

Any design problem is hard to identify as it evolves during the design process. There can be different methods to solve a problem. Therefore imagination is applied during the initial stages of framing the design situation. Consequently, design activity leads to the expansion of the initial concepts to which the design situation is initially framed. This is special to any design situation contrary to any problem solving effort. [1]

Use of memory and subjective interpretation

Design is a process of multiple step decision making. New interpretations are based upon the interpretations that have already been taken place in the earlier steps of solving the design problem. This can take the design problem in completely different direction. Therefore use of memory and sound ability of subjective interpretation are the key attributes of a designer. This undermines the very idea of having one knowable problem at the start of tackling a design problem. [1]

Simultaneous Learning and Knowledge from another Space

A problem solving approach may not readily allow introduction of new resources and knowledge from another space. However a design can be easily contemplated if the designer is allowed to use knowledge in another space. Suppose a pair of computer table and chair has to be designed then mere material selection, size, strength considerations and production processes will not be enough. Knowledge from another space viz. technology, statistics, manufacturing technology, material technology, human anatomy, ergonomics, and interior etc., are required to reach the design goals.[1]

Design is a Social Process

Social interactions are very much essential for the materialization of design activity. While understanding the social interactions is of utmost importance the designing of social interactions is equally important. Ability to perceive the type and nature of social interaction required to capture the design situation and get the desired input for the progress of design is the additional attribute a designed need to have. [1]

Method of Paradoxes and Discourses [1]

This design concept is propounded by Kees Dorst. A design discourse is a chain of statements which can be interpreted as a need statement, goal or a requirement. A design paradox is a conflict between two or more unavoidable discourses. When a designer struggles to resolve number of conflicting discourses then the designer has to search a solution that connects all the discourses and is acceptable to all the discourses.

CHRONOLOGY OF DEVELOPMENT OF GROUND-COUPLED CENTRAL PANEL COOLING SYSTEM (GC-CPCS) AND HOW THE GENERAL DESIGN CONCEPTS CAME INTO PLAY

Conversion efficiency of solar PV panels decreases with increase of panel temperature. Cooling of solar panels is of significance as it helps to enhance the conversion efficiency of solar panels. Ground coupled central panel cooling system (GC-CPCS} is designed for cooling of solar Photovoltaic panels.[7] In this section stage wise illustration of the design of GC-CPCS is given along with the general design concepts encountered.

Stage: Vague definition of the design problem

Table 1 Stages of design: <u>Vague definition of the design problem</u> of GC-CPCS; The general design concepts encountered at this stage are italicized and underlined

<u>Discourse</u> [Section 1.5]	Action / <u>design paradox</u>[Section 1.5] / solution / general design concepts encountered
To design a cooling system for solar PV panels [6] [7]	Method of cooling is absent in the <u>discourse</u> though the objective is stated. Hence literature survey was done to find a suitable cooling method. It indicates the relevance of the general design characteristic – <u>The design problem is not knowable at any specific point in the design process.</u> [Section 1.2]

Stage: <u>Ill structured</u> description of the design problem [Section 1.1]

Table 2: Stages of design: <u>Ill structured description of the design problem</u> of GC-CPCS; The general design concepts encountered at this stage are italicized and underlined

<u>Discourse</u> [Section 1.5]	Action / <u>design paradox</u>[Section 1.5] / solution / general design concepts encountered

To design the cooling system which works on the principle of forced convection; ambient air cooled through ground coupled heat exchanger being the working fluid [6] [7]	The solar panel cooling system was supposed to be tried out at the Thin-Film Solar PV panels installed at Energy Park of Rajiv Gandhi Proudyogiki Vishwavidyalaya (RGPV), Bhopal, India. The decision to select a particular cooling system was made after taking into account the resources available with. Discussions were made with experts and experienced persons before taking this decision. Hence it can be very well concluded that design is a social process. [Section 1.4] However at this stage the design is still a ill structured one.[Section 1.1]

Stage: To develop a well structured problem [Sectoon 1.1]

Table 3 Stages of design: To develop a well structured problem of GC-CPCS; The general design concepts encountered at this stage are italicized and underlined

Discourse [Section 1.5]	Action / design paradox[Section 1.5] / solution / general design concepts encountered
To attempt for mathematical modeling of the system such that the various components and their specifications are established [7]	Analysis of the system was done for development of mathematical model. Various basic concepts of engineering viz. fluid mechanics, heat transfer, turbo machinery as well as solar radiation fundamentals were used to develop the model. Therefore simultaneous learning and knowledge were several distinct spaces [Section 1.3] were used to solve the design problem.

Stage: To make the system cool multiple solar panels

Table 4 Stages of design: To make the system cool multiple solar panels of GC-CPCS; The general design concepts encountered at this stage are italicized and underlined

Discourse [Section 1.5]	Action / design paradox[Section 1.5] / solution / general design concepts encountered
Can the concept of centralized cooling be applied for cooling of solar panels [7]	Most of the experiments for the cooling of Solar photo voltaic panels have been done using a single solar photo voltaic panel. The current system was supposed to be installed on the Solar PV plant already operational and having nine Solar PV panels. Hence the system was designed analogous to the centralized air conditioning systems which serve multiple spaces from one base installation. Hence the situation encountered served as the catalyst for a new innovative design concept. Hence it is evident that the design situation culminates in the expansion of the initial concepts. [Section 1.2.2]

Stage: To justify the use of input energy to the GC-CPCS

Table 5 Stages of design: To justify the use of input energy to the GC-CPCS; The general design concepts encountered at this stage are italicized and underlined

Discourse [Section 1.5]	Action / design paradox[Section 1.5] / solution / general design concepts encountered
The objective of installing GC-CPCS is to cool the solar PV panels and increase the conversion efficiency, which gets depleted due to high panel temperature. This system requires input energy to operate. This input energy should be just a fraction of the increase in the output of solar PV	After design of the system energy requirement to run the GC-CPCS was estimated by theoretical calculations which are equal to the head losses. The initial diameter of the pipe was assumed to be 20 mm for the sake of calculation. The energy requirement to run the GC-CPCS was found very high and it nullified the benefits of increase in the conversion efficiency of the solar panels. It was felt that the system is not viable and hence it should be shelved. [5] During this skepticism idea evolved to try different pipe diameters. When the diameter was increased there was drastic reduction in the head losses. A graph

panels. This point could have been considered earlier but it was not taken up then. Here is where the concept of bracketing comes into play. [Section 1.2.1] [7]	was drawn between the total head losses and the corresponding diameter. It was found that there were considerable decreases as the diameter is increased up to 50 mm. It was found that further increase in pipe diameter results in negligible decrease in the total head loss. Therefore pipe diameter was taken as 50 mm to be optimum solution. Hence it is evident that design is a process of multiple steps which requires use of memory and subjective interpretation. [Section 1.2.3] This design phase also used the concept of optimization. Hence simultaneous learning and knowledge from another space did help in tackling the design situation. [Section 1.3]

Stage: Design of support frames for pipeline

Table 6 Stages of design: Design of support frames for pipeline of GC-CPCS; The general design concepts encountered at this stage are italicized and underlined

Discourse [Section 1.5]	Action / design paradox[Section 1.5] / solution / general design concepts encountered
To design a fabricated frame to support the pipeline with ease of assembly [8]	The support frames were made in two halves for ease of assembly. The two halves formed a sliding pair. The sliding arrangement is provided to make room to rotate the pipe such that the nozzles are directed towards the rear surface of panels and adjustment of height if required. When the project was started then design of support frames was the last thing on the mind. Hence the design situation culminated in the expansion of the initial concepts.

Stage: Design and manufacturing of the nozzles

Table 7 Stages of design: Design and manufacturing of the nozzles of GC-CPCS; The general design concepts encountered at this stage are italicized and underlined

Discourse [Section 1.5]	Action / design paradox[Section 1.5] / solution / general design concepts encountered
Total 180 nos. nozzles were supposed to be used. As the quantity is large enough it was imperative to find a cost effective way of making the nozzles. [8]	Design of nozzle was initially made as per the calculation of the governing equations. It was required to find out the raw material and cost effective manufacturing technology. Copper tubes used in air conditioning equipments were found to have matching diameter to the dimensions of required nozzles. Therefore copper tubes were used as raw material also owing to its ease of brazing on the pipe. They were straightened and cut to length. The shape at one end was made by inserting a die in the cut tube and hammering suitably. After making the shape the die was removed. Hence it proves that simultaneous learning and knowledge from another space did help in design and manufacturing of nozzles.

Stage: Achieve stream lined flow at the rear surface of the solar PV panels

Table 8 Stages of design: Achieve stream lined flow at the rear surface of the solar PV panels of GC-CPCS; The general design concepts encountered at this stage are italicized and underlined

Discourse [Section 1.5]	Action / design paradox[Section 1.5] / solution / general design concepts encountered

After the assembly was made and system was run no effect was felt. Perhaps streamlined flow could not be developed. It led to the thought of shelving the project [8]	Cover at the rear surface was provided to facilitate a passage for development of streamlined flow between the rear surface of the solar PV panels and the cover. The cover was provided by using sheets of transparent PVC flexible sheet of 1 mm thickness. After that when the system was run the flow was felt and hot air was coming out at the other end of the nozzles. The system was successful. Hence design is a process of multiple steps. Further simultaneous learning and knowledge from another space help to achieve the design objective, [Sections 1.2..3 & 1.3]

Stage: On site testing of the system on an actual solar PV power plant

Table 9 Stages of design: On site testing of the system on an actual solar PV power plant of GC-CPCS; The general design concepts encountered at this stage are italicized and underlined

Discourse [Section 1.5]	Action / design paradox[Section 1.5] / solution / general design concepts encountered
Most of the experiments to test the solar PV panel are done under Standard Test Condition (STC). However in practice the solar PV panels are seldom used under STC[8]	Unlike most of the experiments done for the cooling of solar PV panels which are conducted in laboratories the experimental set up made for GC-CPCS is on site and it is put on a fully fledged solar PV power plant. Therefore it is tantamount to the real world condition. The test is done under actual solar insulation. Therefore the data generated is of considerable interest. Needless to say that the design situation prompted to take such observations. Thus it can be concluded that the design situation culminates in the expansion of the initial concepts.

Stage: Testing of the system by using the Smoke flow visualization technique

Table 10: Stages of design: Testing of the system by using the Smoke flow visualization technique of GC-CPCS; The general design concepts encountered at this stage are italicized and underlined

Discourse [Section 1.5]	Action / design paradox[Section 1.5] / solution / general design concepts encountered
Can the flow of working fluid be physically examined as it is vital for the desired performance of GC-CPCS? [8]	The basic working principle of GC-CPCS is to collect ambient air, cool it by passing it by through ground coupled heat exchanger and then distributing it to cool the solar PV panels. To observe whether this is being done a technique, Smoke flow visualization, which is widely used in fluid mechanics and aerodynamics for flow visualization is used. Smoke flow visualization was conducted and it was found that air is distributed at all the solar PV panels. Thus simultaneous learning and knowledge from another space helped to establish the performance of the system.

Stage: Validation of the system by using statistical tools

Table 11 Stages of design: Validation of the system by using statistical tools of GC-CPCS; The general design concepts encountered at this stage are italicized and underlined

Discourse [Section 1.5]	Action / design paradox [Section 1.5] / solution / general design concepts encountered
The sole objective of installing the GC-CPCS is to increase the conversion efficiency of the solar PV panels. Therefore the output data solar PV power plant with	Statistical analysis is done to validate the causal effect of GC-CPCS. Statistical technique, Analysis of variance (ANOVA), is used to establish the causal effect. Here two-way ANOVA is technique is used. This technique is used when the data are classified on the basis of two factors. The ANOVA analysis proved that the GC-CPCS was effective at 5% level of significance.

GC-CPCS running and with GC-CPCS turned off needs to be compared. [8]	Hence simultaneous learning and knowledge from another space helped to establish the design. [Section 1.3]

CONCLUSIONS

The study of chronology of design of GC-CPCS clearly indicates that design is different from any problem solving methodology. To capture the design situation different temperament is required. The general design concepts definitely help in distinguishing a problem solving effort to a design effort. A study of general design concepts definitely will help develop aptitude for design for a beginner.

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Future Prospects of Heavy Placer Mineral to Recover Valuable Products in India

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Abstract*: This paper deals with an attempt to discuss on different types of deposits of placer mineral concentration with the aid of flowsheets for pre-concentration and recovery of industrial heavy minerals. This paper also focuses on how the recovery process changes with mineralogy of the deposits. In the present study, recovery of individual heavy minerals with material balance is also discussed with particular reference to Indian mineral industry context. The present suggested technology is not only economical but also can be implemented in the existing and upcoming industries.*

Keywords*: Beach sand, WHIMS, Ilmenite, total heavy minerals (THM), Flotation*

INTRODUCTION

A beach usually consists of placer sand which contain heavy minerals such as ilmenite, magnetite, garnet, zircon, sillimanite, rutile, cassiterite, chromite, monazite, rare earth and precious metals occur in many parts of the world. These heavy mineral products are input to the commercial manufacture of a wide range of end product applications, as diverse as pigments, paints and coatings, metal and specialist alloys, ceramics and a range of chemical and specialty applications, which have both industrial and end consumer applications. The placer deposits of beach and inland sand exhibit a considerable variation in mineralogy depending on the location. In general beach placer deposits contain the valuable industrial minerals such as ilmenite, leucoxene, rutile, zircon, sillimanite, garnet, monazite etc. Red sediments of badlands topography are also a potential resource for industrial placer heavy minerals. These minerals possess difference in specific gravity, magnetic and electrical properties as well as surface chemical properties. Because of the complex in physical characteristics of minerals and variation in mineralogy of different deposits, the preconcentration methods followed in mineral sand plants and overall flowsheet for their beneficiation are varying. The World’s larger producers of heavy minerals are Australia, South Africa, USA, USSR, India and Malaysia.

To recover total heavy minerals from beach sand different gravity concentrator units are used, such as Reichert cone, conventional jig, spiral concentrator and gravity table etc. Among all, spiral concentrators are proved to be the most efficient gravity concentrator to recover total heavy minerals from beach sand. Spiral concentrators are relatively inexpensive devices (with non-mechanical moving parts) for the separation of heavy minerals from an ore, offering a relatively high throughput per unit of installed capacity and plant space requirement. The heavy minerals after pre-concentration are subjected to different unit operations such as electrostatic separator, magnetic separator and flotation to recover individual heavy minerals. The plant practices to recover heavy minerals in some leading heavy mineral producing countries are discussed below.

Australia

The typical wet concentration plant flowsheet of Iluka Resources Limited, Australia is shown in **Figure 1** (Iluka, 2011). Recovery of heavy minerals from the primary ore is carried out wet, utilising sizing and specific gravity difference between heavy minerals, clay and quartz. The objective of wet concentration is to produce a high-grade

(85%-98%) heavy mineral concentrate retaining valuable minerals and minimising gangue within the concentrate. Ore that passes through the primary scrubbing and screening plant is slurried and then pumped to a hopper at the Wet Concentration Plant (WCP). Separation of heavy minerals from the quartz sand occurs through spiral concentrators.WCP spiral circuits generally consist of following stages:

- Primary or rougher spiral stage
- Middlings spiral stage
- Cleaner spiral stage
- Re-cleaner and/or upgrade spiral stage
- Scavenger spiral stage

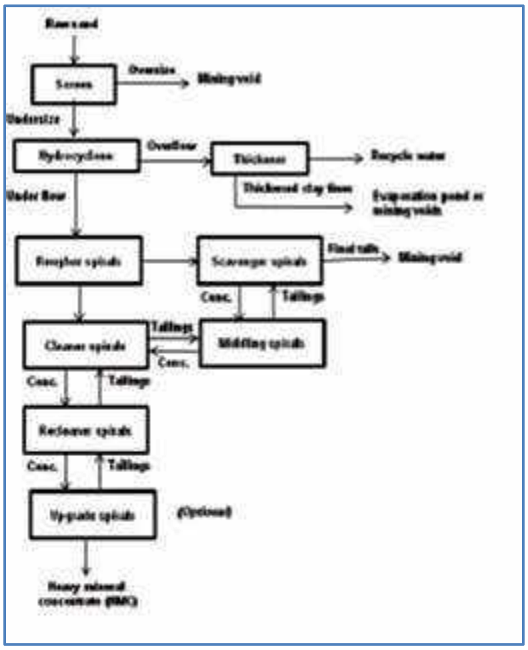

Figure 1 Typical wet concentration plant flowsheet of Iluka Resources Limited, Australia

Intermediate THM from each spiral stage passes to the next stage to be further concentrated, spiral middlings are usually recirculated, and tailings are scavenged to collect unrecovered heavy minerals. WCP sand tailings are pumped to the mining pits for backfilling.

South Africa

The typical wet concentration plant flowsheet of Corridor Sands, South Africa is shown in **Figure 2** (Taylor et al., 2003). The run of mine feed contains 8-17% silt and 13-24% THM. The oversize of raw sand was reduced by using suitable equipment and 85% of the heavy minerals associated with lumps were recovered. The oversize materials from trommel were subjected to crushing and classification. Oversize from classifier was stockpiled and undersize was subjected to trommel again. Trommel undersize fraction was subjected to desliming and screening. The undersize fraction was again subjected to hydrocyclone and hydrocyclone underflow was collected as heavy mineral concentrate and subjected to mineral separation plant for individual mineral beneficiation.

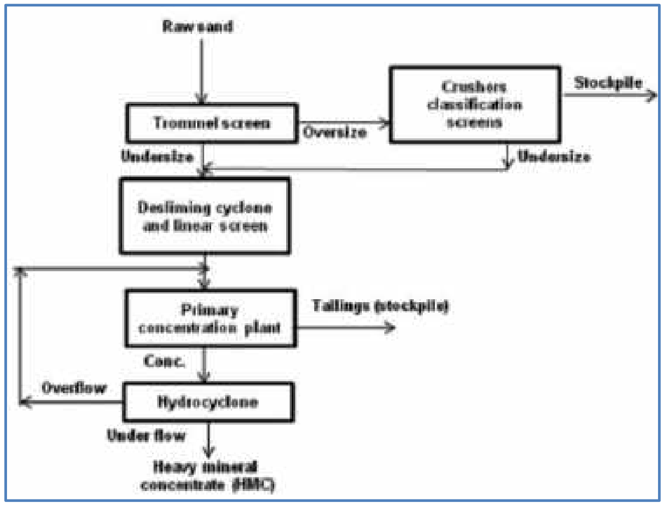

Figure 2 Typical wet concentration plant flowsheet of Corridor Sands, South Africa (Taylor et al. 2003, modified)

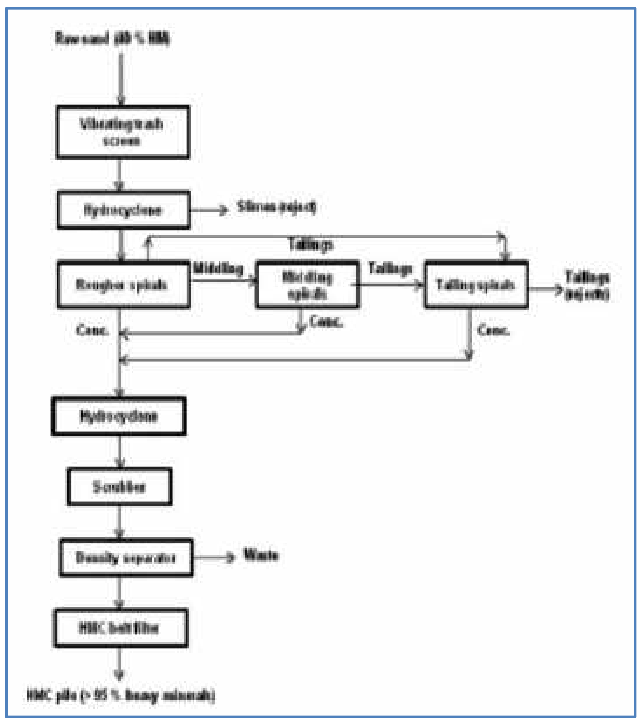

Figure 3 Typical wet concentration plant flowsheet of Orc Coos Bay mineral sands deposit in Oregon, USA (Outotec, 2011, modified).

United States

Typical wet concentration plant flowsheet of Orc Coos Bay mineral sands deposit in Oregon, USA is shown in Fig. 3 (Outotec, 2011). The run of mines sand contains ~40% heavy minerals. The mineralogy of the bulk sample shows the percentage of different minerals such as: epidote 20.6%, chromite 13.9%, garnet 4.7%, zircon 1.2%, staurolite 0.7%, ilmenite 1.7%, leucoxene 0.5%, rutile 0.3%, magnetite 0.2% and miscellaneous light heavies 1.5%. The slime content (< 63 µm) is 12.6% and the oversize sample accounts to 7%. The spiral circuit consist of rougher, middlings cleaner, and tailings cleaner stages. The circuit allows concentrate from all three stages to go to final gravity concentrate and tailings from both middling and tailings circuits to go directly to final tailings without recirculation, resulting in a streamlined and simple to manage gravity circuit. The concentrate from the rougher spirals subjected to hydrocyclone, scrubber, density separator and filter before it produce a heavy mineral concentrate of 95% heavy minerals.

India

India, endowed with a coastline of over 6000 km, hosts some of the largest and richest shoreline placers. The beach and dune sands in India contain heavy minerals like ilmenite, rutile, garnet, zircon, monazite and sillimanite. Out of total world deposit of about 2500 million tons, India has a share of about 270 Mt (i.e., about 10%-11% of world reserve). The Indian resources of heavy mineral are: 463 million tons (Mt) of ilmenite, 150 Mt of garnet, 29Mt of zircon, 10 Mt of monazite and 190 Mt of sillimanite. Indian resources constitute about 35% of world resource of ilmenite, 10% of rutile, 14% zircon and 71.4% of monazite. India meets about 10% of the world requirement of garnet (AMD, 2011). There are six beach sand plants operating in India. Out of six plants, Indian Rare Earth Limited (IREL), Government of India owns three plants. The Government of Kerala owns one plant i.e. Kerala Minerals and Metals Ltd. (KMML), Kerala. The remaining two plants, i.e. Trimex Industries Pvt. Ltd and Trans World Garnet are run by private entrepreneurs. M/s. Beach Minerals Company India Limited, Chennai has mining leases for beach sand and selling of heavy minerals and VV Minerals, Tirunelvali, Tamilnadu have mining leases for beach sand and selling of garnet, ilmenite, rutile and zircon. The details of processing for Beach Minerals Company India Limited and VV Minerals for recovery of these minerals are not known. Process flowsheet for IREL plants in India is presented in Fig. 4 (IREL, 2011).

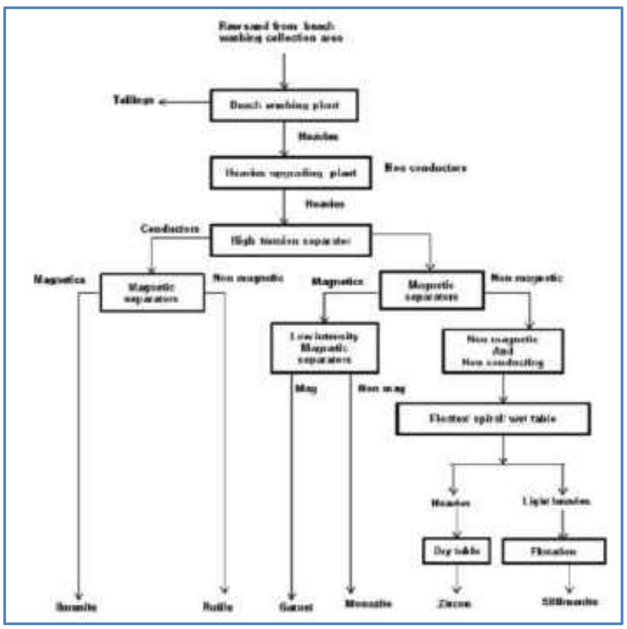

Figure 4 Flowsheet for IREL plants in India (IREL, 2011).

In India three beach sand beneficiation plants are being operated by Indian Rare Earths Limited, at Chavara (Kerala state), Manavalakurichi (Tamil Nadu state) and Chatrapur (Odisha state). The highest concentration of total heavy minerals in beach sand is found in the Chavara deposits, Kerala (50-80% THM). The Chavara placer deposits contain ilmenite, rutile, leucoxene, sillimanite, zircon, monazite, garnet and kyanite. Manavalakurichi deposits contain about 39% THM, Visakapatnam and Chatrapur deposits have 20-22% heavy minerals. The heavy mineral deposits of Ratnagiri, Maharastra vary from 1-91% with ~ 23.2% of magnetite (Nair, 2001).

The IREL practice for recovery of THM is to subject the feed sand to washing plant and then to upgrading plant. At the mine site by using spiral concentration, the heavy mineral content is enriched to ~90%. The upgradation of heavy minerals is done up to 97% in Mineral Separation Plant (MSP), which is called Total Heavy Minerals (THM). The total heavy minerals are subjected to high tension separation. Ilmenite and rutile minerals are recovered by subjecting the conducting fraction to magnetic separation. The non-conducting fraction is subjected to magnetic separation to recover garnet and monazite. The non-magnetic fraction of magnetic operation is subjected to gravity and flotation to recover zircon and sillimanite.

The manufacturing plant at KMML comprises the Mineral Separation (MS) unit and the Titanium dioxide Pigment (TP) unit. The MS Unit is where the separation of ilmenite, rutile, leucoxone, monazite, sillimanite etc from the beach sand takes place, through various stages in the wet concentration plant, dryer plant, dry mill, rutile and zircon recovery plants. The MS unit employs gravitational, magnetic, high tension electrostatic techniques for separation of minerals from the sand. The TP unit is where the raw ilmenite obtained from the MS unit is taken for further processing, through the various stages in the ilmenite beneficiation plant, acid regeneration plant, pigment production plant, oxygen plant and utility section. Titanium dioxide is manufactured using the chloride route (KMML, 2011).

The beach sand beneficiation practice at Trimex industries is first raw sand is subjected to gravity separation and different specific gravity products are collected. The lowest specific gravity product is subjected to flotation. Then all gravity and flotation cell products are dried and subjected to high tension separation. After this, magnetic separation at different intensities produces heavy minerals such as ilmenite, rutile, sillimanite, zircon and garnet. The mine site for Trans World Garnet, Andhra Pradesh deposit contains about 40%-45% heavy minerals out of which garnet 18%-20%, ilmenite 9%-12%, leucoxene 3%-6%, sillimanite 10%, rutile and zircon each of 0.4%-0.5%. Pre-concentration is done by using number of stages of spiral concentrator. The spiral concentrate is subjected to drum magnetic separator after drying. The recovered garnet is again subjected to electrostatic plate separator to increase the purity. M/s. Beach Minerals Company India Limited, Chennai is an established producer of garnet and ilmenite from its mine at Kuttam in southeast India. It is one of the largest garnet producers in the World. The recent drilling programme of the extensive surface dune system has demonstrated an in-situ heavy mineral grade of around 20%. These dunes have very low slime content (0.5% to 2%) and are of free-running sands (BMC, 2011). VV minerals (VV minerals, 2011), Tamil Nadu, a privately owned company operates a number of mining, concentrating and dry plants near the southern tip of India. It exists with mining, refining and processing of over 500,000 Mt per annum of beach sand mineral products such as garnet, ilmenite, rutile, zircon for variety of industrial application worldwide.

From the above discussion, it is found that the west coast of India particularly the states Kerala and Tamil Nadu own beach mineral producing plants: namely, IREL Chavara, Kerala Minerals and Metals Ltd (KMML), IREL Manavalakuruchi, VV Minerals and Beach Sand Minerals. In contrast to this the South Eastern Coast of India has only three beach sand plants: namely IREL Chatrapur, Trimex India Pvt. Limited and Trans World Garnet. Trans World Garnet plant produces only garnet minerals. Although the southeastern coast of India possess large tonnage resources of industrial minerals with a long coastline of 1460 km (Odisha and Andhra Pradesh), the scope to exploit the resources is limited. In view of this, an attempt has been made to highlight the advantages and thereby study and recommend beneficiation plants on deposits of South Eastern Coast of India.

MATERIALS & METHODS

Raw materials were collected from different locations of coastal stretch covering ~300 kilometres from Konark (Odisha) to Srikurmam (Andhra Pradesh). Mineral sand samples were collected from three different locations, two from Odisha state and one from Andhra Pradesh. Interestingly, it was seen during sample collection that the two extreme deposits, one in Odisha (Konark- Ramachandi) is rich in ilmenite and the other one in Andhra Pradesh (Srikurmam) is relatively rich in garnet with variable grain size. The details of sample collected from various locations for beach and dune sands are given below.

Beach sands were collected from

1. Konark to Ramachandi coastal stretch, Odisha,
2. Ganjam to Rushikulya coastal stretch, Odisha and
3. Kalingapatnam to Srikurmam coastal stretch, Andhra Pradesh.

Out of six plants, Indian Rare Earth Limited (IREL), Government of India owns three plants. The IREL flowsheet is primarily designed for Chavara deposits in Kerala and adopted in all IREL plants in India. The common practice in IREL plants is after pre-concentration, THM is subjected to High Tension Separator (HTS) to recover conducting minerals. The non-conducting fraction of HTS is subjected to magnetic separation to recover magnetic and non-magnetic minerals. The flowsheet is designed based on the mineralogical modal analysis of the Chavara coast. The Chavara coast contains total heavy minerals ranging from 50% to 80% (Nair, 2001), in which the conducting minerals ilmenite (conducting and magnetic) and rutile (conducting and non-magnetic) accounting to 68.0% and 7.0% by weight respectively. The garnet mineral (magnetic) contributes to only 0.35% by weight. Thus, in the conventional flowsheet, whole THM is to be dried before subjecting it to HTS to recover conducting minerals is justified. This process needs additional electrical fuel energy for drying the whole THM. In the present flowsheet [modal analysis given in Fig.5] THM is subjected to wet magnetic separation process. The magnetic minerals obtained from Wet High Intensity magnetic Separator (WHIMS) are further subjected to HTS operation to separate ilmenite and garnet minerals.

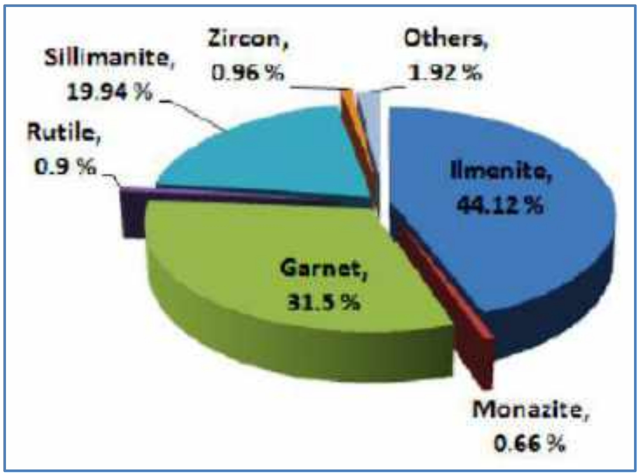

Figure 5 Modal analysis of heavy minerals.

Sillimanite minerals recovered from nonmagnetic fraction of HTS through flotation process. Again dry process is followed to recover zircon and rutile minerals. Sillimanite is ~20% of the total heavy minerals; hence this process claims to save around 20% electrical energy in comparison to the conventional process.

RESULTS & DISCUSSION

The composite sand sample with 16.7% THM is subjected to number of stages of spiral concentrator to recover total heavy minerals. The rougher spiral concentrate is again subjected to cleaner and recleaner spiral concentrator to achieve a THM of more than 98% grade. The THM contains 44% ilmenite, 0.9% rutile and 31% garnet. The modal analysis is shown in **Figure 5**. The flowsheet with mass balance to recover THM is presented in **Figure 6**

The THM is subjected to magnetic separation using WHIMS to recover ilmenite in magnetic fraction. As garnet and ilmenite both are magnetic in nature and reported in magnetic fraction of WHIMS. The magnetic fraction (mainly ilmenite and garnet) is subjected to rougher High Tension roll Separator (HTS) to separate the conducting (ilmenite) and non-conducting (garnet) minerals.

The non-magnetic fraction of WHIMS contains sillimanite, zircon, rutile and silica. The major portion of low density minerals like silica is eliminated by gravity table exploiting the density difference between them and heavy minerals like zircon, rutile and sillimanite etc. Gravity table concentrate is subjected to rougher froth flotation cell to recover sillimanite from other non-magnetic heavies by exploiting the difference in their surface properties. The flotation cell tailings contain zircon and rutile minerals. The flotation tailing is subjected to dry separation process using HTS operation which recovers zircon and rutile separately. The flowsheets to recover individual industrial minerals are given in **Figures 7-11**.

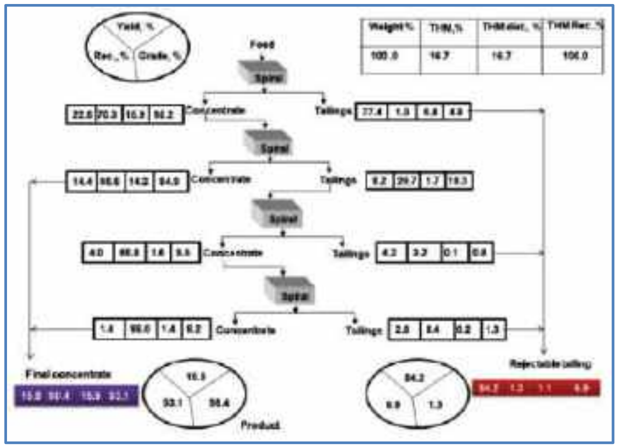

Figure 6 Flowsheet with material balance on recovery of THM from composite sample

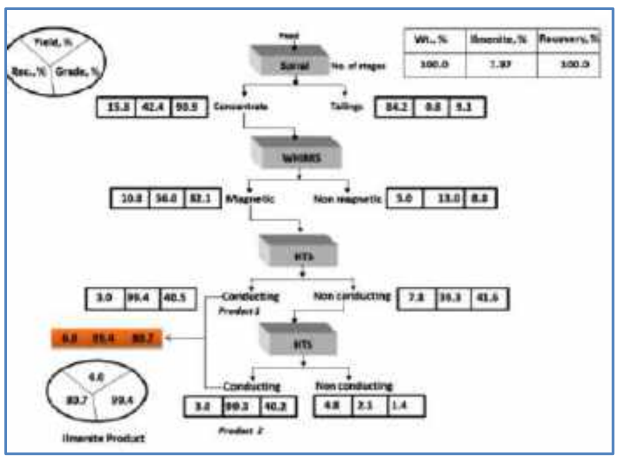

Figure 7 Flowsheet with material balance on recovery of ilmenite from THM.

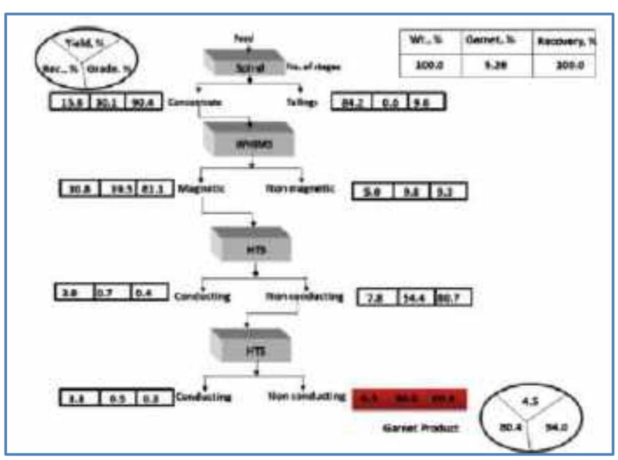

Figure 8 Flowsheet with material balance on recovery of garnet from THM

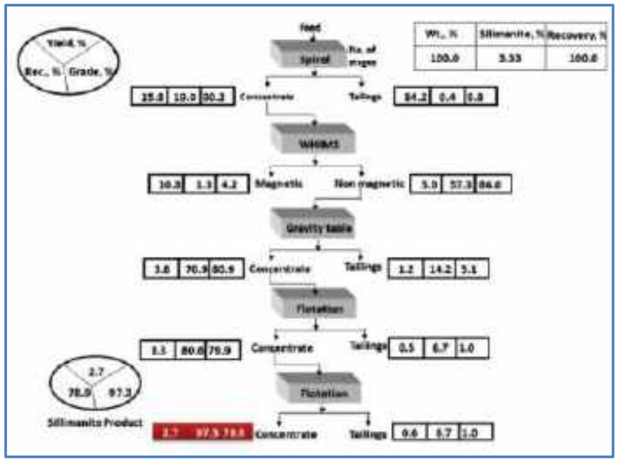

Figure 9 Flowsheet with material balance on recovery of sillimanite from THM

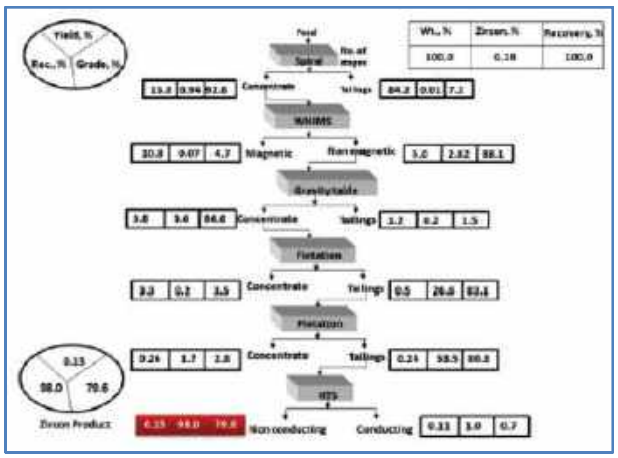

Figure 10 Flowsheet with material balance on recovery of zircon from THM

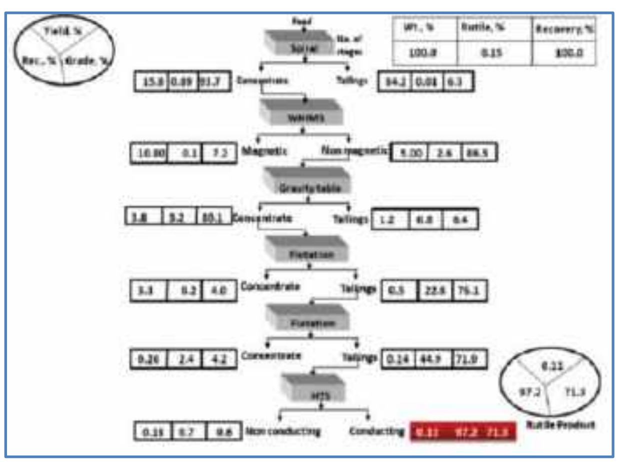

Figure 11 Flowsheet with material balance on recovery of rutile from THM

It is observed from the given flowsheets 7-11 that the recovery of individual heavy minerals in the present investigation proposed in most economical way to select the equipment alignment in the mineral processing industries as per the mineralogical modal analysis and its physical characteristics. Mineral concentration of rutile and ilmenite varies from west coast to east coast.

CONCLUSIONS

It has been observed from the study on Mineral processing technology in India that both the Present and future growth depends mostly on the various source available and mineralogical modal analyses. The various sources for heavy mineral deposits for future will be available from Beach sand heavy minerals, red sediments, deep sea lean deposits etc. It is also noticed that process flowsheet design for heavy mineral sand at Chavara deposit (India) is different from the South East Coast deposit (India) due to the variation of rutile mineral concentration. To summarize, the present investigation on beach sand comes up with a significant and novel finding to develop technology to pre-concentrate and recovery of individual heavy minerals. The technology suggested here is economical and can be implemented in the existing and upcoming industries.

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Influence of Fiber Orientation on Tensile Behaviour of Kevlar Epoxy Composite Material

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***Abstract**: Now a days light weight structure are very popular in construction industry. The design of fiber-reinforced composite structure is more difficult than metal structure. Composite materials are prepared with fiber and matrix. Its main strength depends upon the properties of the fiber. The matrix binds the fiber together, and helps to get the required shapewhen fabricated. The properties of polymer composite produce high quality, durable and cost effective product. Here, in this paper, as per construction industries requirements, Kevlar woven fabric is used for the analysis, due to its high tensile properties.Software analysis and laboratory experiments of tensile test performed with different fiber orientation. For the experiments, the shapes and sizes of the specimens are taken as per ASTM 3039. From the analysis, it is observed that, fiber orientation has a significant role on its strength, the stress and strain varies with the fiber orientations and tensile modulus are higher than any other normal metal. So it can be applied in future, on different important project of construction industries.*

***Keywords**: Kevlar fiber, Epoxy, Tensile test, Woven fabric, Fiber orientation*

INTRODUCTION

Contemporary challenges in civil engineering necessitate the construction of fortified structures capable of withstanding natural disasters such as earthquakes and hurricanes. The utilization of composites in civil engineering and structures offers numerous advantages and benefits. These include their inherent suitability and high strength, ability to resist crack propagation and chemical reactions, simultaneous lightweight and high strength characteristics, exceptional resistance against impact and corrosion, promotion of design sustainability, flexibility, and durability, as well as an extended lifespan. It is anticipated that the field of composite engineering will continue to advance significantly within the realm of civil engineering, assuming a pivotal role in driving the future of the building and construction process to unprecedented levels.

Now composites are very popular in several engineering fields for its high strength and high specific modulus. It is a combination of two or more material to form a new material. Their valuable properties enable them to produce better quality products [1]. Composites are light in weight due to lower density of the fibers and the matrices. Fibers are strong in tension but, cannot be used alone. The design of composite material can be suggest according to the requirements, with the material choice. The mechanical properties of composites are lower than fiber due to matrix. So, several researchers are interested to modify its mechanical properties [2]. The physical behaviour of composite materials are totally different from all the common materials. The physical properties of composites will vary with the location and orientation of the principal axis [3]. The design of a fibre-reinforced structure is considerably more difficult due to its anisotropic nature. The design flexibility can be utilized to selectively reinforce a structure in the direction of major stresses, increase stiffness in the preferred direction, and fabricate curve panels without any secondary forming operation. In between different fibers, Aramids are among the toughest fibers, they have very high specific strengths. Aramids can undergo some plastic deformation before fracture, and so they have higher toughness than brittle fibers. A common Aramids is marketed under the trade name Kevlar. Kevlar 29 and Kevlar 49 are the most popular types of Aramids in design industry. The difference between them are on the modulus of elasticity, Kevlar 49 is almost 30% higher than Kevlar 29 [4].

Suthan et al., demonstrates that Kevlar epoxy composites gives preferred mechanical characteristics over that of the aluminium [5]. The error obtained from FE analysis and corellated test values is 30% on tensile strength. Vladimir et al., showed the effective modulus of elasticity of the layered composite is significantly influenced by the ratio of the adhesive layer thickness to the gluing area [6].

The moduli of elasticity E_x, E_y and E_z will be different on each direction of load. Normally the fibers are parallel to the x-axis, the lamina will offer a much stronger resistance to a loading directed along the x-axis than to a loading directed along the y or z axis and E_x will be much larger than either E_y or E_z . Fabric reinforcedcomposites shows high stiffness and strength in two perpendicular directions. In a fabric, tows laid down in one direction , that is fill and the perpendicular tows are known as warp. The most common style of fabric is plain weave where fill and wrap are inter-placed to produce a check board effect with about 50% of fill and 50% of wrap exposed in each face of the fabric, so, it is strong and hard wearing [7].

The strain rate dependency of mechanical properties for bidirectional composites is still a controversial scientific topic[8]. The strength and stiffness of the fibers increases with strain and before ultimate tensile strength of fiber, material fails due to increase of fiber-matrix interface strength[9]. In this paper, investigation was performed to study the influence of the plain weave fabric orientation on tensile properties of composite materials, under axial tensile force. The tensile properties with the different orientation of fiber and different thickness was analyzed by Ansys software, following laboratory test and scanning electron microscope was performed for analysis.

BASIC STUDIES ON TENSILE PROPERTIES OF MATERIAL:

Tensile Properties

Tensile member is the most important member in the steel structure. Where the member changes its physical shape and internal structure due to tensile load. Tensile test is to measure the force required to fail a member and the extent to which the member stretches or elongates to that breaking point. Composite materials are used in the form of plates and shells, The tensile modulus is the ratio of stress to elastic strain in tension and a high tensile modulus means that the material is rigid and more stress is required to produced a given amount of strain.

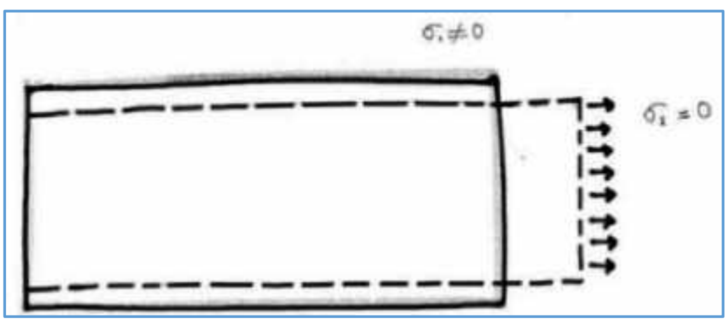

Figure 1 Tensile stress at direction x (1)

Properties of the Materials

In between different natural and synthetic fibers, Kevlar is better in tensile properties than other fiber. Several grades of Kevlar are available in the market, but due to high modulus, Kevlar 49 is used in cable and rope products. So, here Kevlar 49 is preferred to withstand a considerable amount of force, torque, tensile strength and impact. From literature, tensile strength of kevlar-49 is 3000 MPa and the tensile strength of epoxy is only 90 MPa.

The elastic modulus along the fiber direction can be controlled by selecting the volume fraction of fibers. Ibrahim et al shows that, 50 % ratio of Kevlar fibre gives the highest fracture strain.

RESULTS AND DISCUSSION:

Software Analysis

Before laboratory test, software analysis performed for tensile properties of the Kevlar-epoxy composite material. The orientation of reinforcements in a laminate is widely known to dramatically affect the mechanical properties of composites [2].

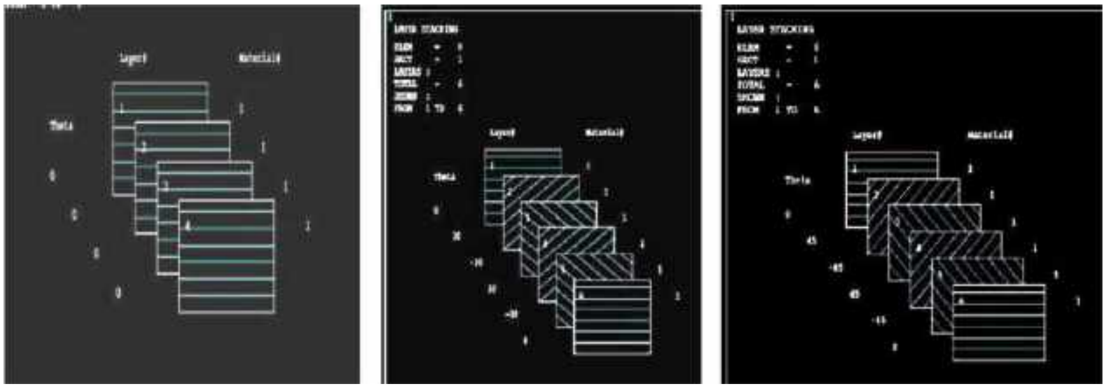

Figure 2 Arrangement of the fiber for fabrication

The orientation of fiber in a laminate is affect the mechanical properties of composites [10]. In the plain woven fabric wrap and weft yarn are arranged systematically on vertical and horizontal direction. By using Ansys R20 software, at first, 4-layers,6-layers,8-layers,10-layers, and 12-layers composites are consider for software analysis with 45-degree woven fibre orientation. The orientations of the layers are considered 0 degrees on the top and bottom layers and +45 degrees and -45 degrees in sequence on the inner layers form a 0-degree and 45-degree sandwich structure.

Table 1 Strain and deflection at 45^0 fiber orientation of composite materials

Number of layers	Orientation of plain-woven fibre	Max strain(%)
4	45	8.36
6	45	3.46
8	45	3.25
10	45	2.65
12	45	2.20

The maximum force applied for analysis is 250 MPa on each Kevlar epoxy composite specimen on x direction. **Table 2** shows, the first specimen of four layers of Kevlar epoxy composite materials observed a maximum strain of 8.36%, and the strain decreased in 6,8,10 and 12 number of layers gradually. The deflection is also shows same pattern, maximum on 4 number of layers. So, the tensile properties are changed with the thickness. As the thickness increases deflection will decrease. The deflections are higher on 4 number of layers and with the number of layers, it decrease gradually.

Figure 2 showing the stress zone of the materials.. So after the above analysis considering 6 layers, further analysis will be done with different orientations.

Laboratory Test

For better mechanical properties following Ibrahim et al, the ratios of the matrix and the reinforcing material are taken 50 % . The materials are, Bidirectional plain-woven Kevlar-49, Epoxy resin LY 556 and hardener HT972. The woven fiber of the test specimen are 45°, 60° . The aim of these orientation is the wrap and weft can transfer the applied energy on a specific manner through the layer and help to increase the overall mechanical properties of the material. Here, The configuration of the layer was symmetrical and contained 6 plies equal to C- (0/45/-45/45/-45/0), B- (0/60/-60/60/-60/0).

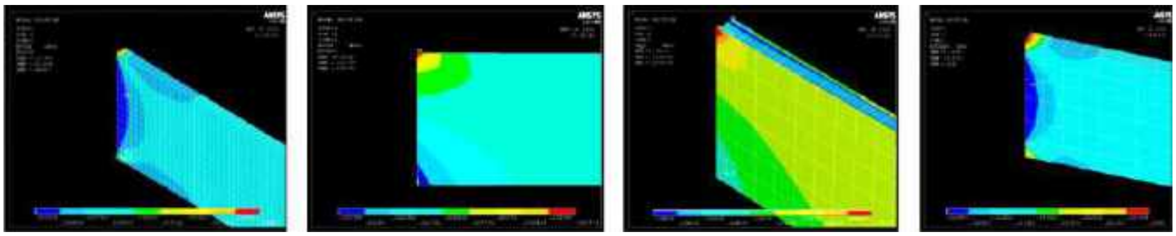

Figure 3 stress strain on fibers of the composite at tensile

Here, epoxy resin mixed with hardener at a ratio of 100:20 for fabrication, six layers fabric were prepared for (300× 300) mm^2 dimensions according to angle orientation by hand moulding method. Finally, five tensile specimens were prepared from each composite material sheet by a hand cutter. The sizes are considered as per ASTM 3039.

Figure 4 Preparation of tensile test specimens

Observations

As per ASTM D3039, the tensile test was performed with a rate of 2mm/min as per ASTM 3039 at 23^0 C temperature and humidity 54%. Tensile properties shows the reaction of the material under a tensile force.

Table 2 Tensile properties at yield

Specimen	Mean Tensile stress	Tensile strain
B	176.470 MPa	3.89%
C	270.558 MPa	4.47%

The mean tensile stress at yield of specimen B (60° fiber orientation) is 176.470 MPa and the specimen C (45° fiber orientation) is 270.558 MPa. So, the young's modulus is higher on specimen C than other two specimens, that means stiffness is more on Specimen C.

For further analysis, only 5 specimens of B and C are considered in the stress-strain curve, where number 1,2 and 3 are from specimen B and the 4,5 are from the specimen C.

Tensile modulus is the slope of the stress-strain curve of a specific material sample under direct tensile loading. Here, Modulus of specimen C shows higher values between two specimen. Higher modulus shows that specimen C is stiffer than other two.

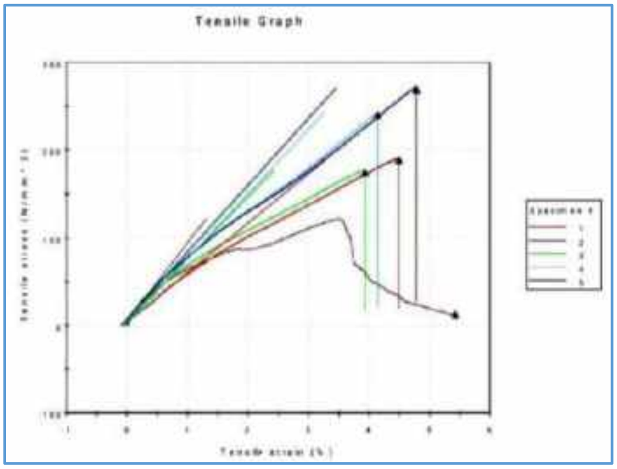

Figure 5 Tensile stress strain curve of specimen A,C

Table 3 Tensile modulus at different orientations

Specimen	Modulus
B	7032.18 MPa
C	7454.61 MPa

Figure 6 Specimens after tensile test

From the specimen status after the tensile test, layers are effected due to tensile force and upper layer of the fibers are failed in some cases. Matrix failed earlier than fiber so, the delamination is the first causes of failure under the tensile force.

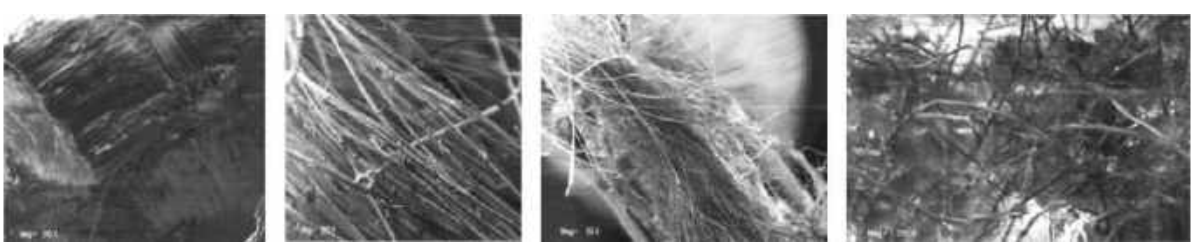

Figure 7 Scanning Electron Microscopic images after tensile test

Scanning Electron Microscopic images of different specimen, magnification ranging from 50X to 250X. The common failure observed during the test were deformation and matrix cracking.

RESULT ANALYSIS

The present research elucidates the varying tensile properties of composites based on the number of layers employed. It is evident from this study that an increase in the number of layers leads to a reduction in member deformation.

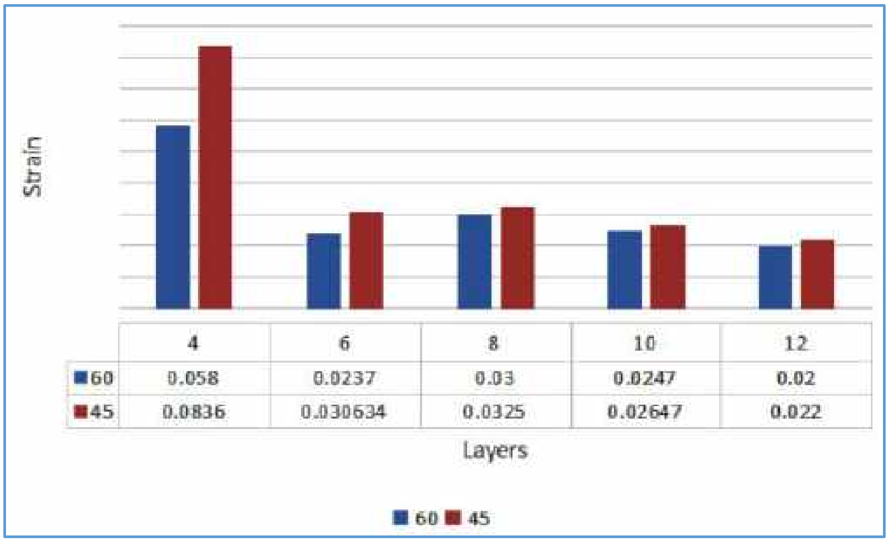

Figure 8 Tensile strain with number of layers

From the tensile test of all the section of different layers with various fiber orientation, [**Figure 3**] the value of strain are higher on 45^0 orientation. This phenomenon observed on all the specimen.

literature shows that a change in dimensions to the original dimension is the strain. Here original dimension is fixed, So it is clear that the amount of deformation of the specimen in the direction of applied tensile force is also higher on lesser thickness. Then it can say stiffness will increase with the thickness. Additionally, the orientation of fibers plays a significant role in determining the mechanical properties of composites. Notably, the tensile modulus is higher for composites with a fiber orientation of 45^0 compared to the orientations of 60^0, as well as bidirectional orientations of 60^0. So here it is clear that, 45^0 fiber orientated specimen required more force to deform due to the highly oriented fiber structure. In this paper, weight of the specimen are constant, so, the tensile modulus is not influenced by the weight .

The failures due to tensile force on the composites occurs due to matrix cracking. After the test, delamination observed on the specimens. Hence, by improving the properties of matrix, tensile strength of the composite materials can also be improved.

CONCLUSION

It has been observed from the literature that, 50% Kevlar epoxy shows better mechanical properties than other volume fractions, hence the 50 % fiber has been used in this paper for the analysis. For fiber orientation analysis, Bi-directional plain woven fiber is taken for better longitudinal and transverse strength. At the time of fabrication of specimen, different fiber orientations on each layer of the composite are considered 45^0 and 60^0 . Theoretically, the mechanical properties of 30^0 and 60^0 fiber oriented specimens are same due to symmetrical fiber distribution. Number of layers and the orientation of the woven fiber have a significant role on stress, strain of the composite materials. In the realm of the construction industry, the design of tensile members necessitates the utilization of diverse shapes and sizes to meet specific design requirements. A crucial consideration in this process is to ensure that the members exhibit adequate stiffness while minimizing excessive sagging caused by the combined effects of self-weight and eccentricity of applied loads during service.

ACKNOWLEDGMENT

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Synthesis and Characterization of Nano-Biocomposite Reinforced with Cellulose Nano Fibers obtained from Agricultural Waste for Food Packaging Applications

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Abstract: *The advancement of innovative biomaterials is one of the firmest growing fields in today's arena. As a substitute to petro-materials, "Nano-Biocomposites" reinforced with "Enzymatic Hydrolyzed Cellulose Nano Fiber (CNF)" derived from agricultural crops can provide a new range of characteristics. As a result nanocomposite obtained from renewable and natural resources have acknowledged remarkable attention. A homogeneously dispersed 16 nanocomposite thin films from PVA/Chitosan blend reinforced with CNF obtained from treated and untreated sugarcane bagasse at 20, 30, and 40 wt.% were fabricated by employing ultrasonication process in solution casting method.The performance of bio-composites were systematically examined in relationswith mechanical and antibacterial characteristics. Maximum and minimum strength of 80.47 MPa and 39.38 MPa were documented when 40 wt.% treated CNF was reinforced in PVA via sonication process and 20 wt.% untreated CNF was reinforced in PVA without sonication technique. Additionally, the homogeneous distribution was also analyzed by SEM. Maximum inhibitory zone against S. aureuswas recorded 15.21 mm. The developed film shows an extraordinary application in the field of food packaging.*

Keywords: *Enzymatic Hydrolysis, Ultra-sonication, Cellulose Nano Fibers, Antibacterial Nano-Biocomposite Film.*

INTRODUCTION

Humanity's awakening to the importance of ecosystem sustainability, as well as the advancement of sustainable methodologies, has turn out to beprogressively valuable to civilization [1]. Nearly every packaged food item incorporates petroleum-derived polymers that have a short shelf life but can persist in the surroundings for generations, posing a significant hazard to the health of the planet.Several initiatives have been undertaken to replace traditional synthetic materials with bioplastics that are recyclable, compostable, environmentally friendly, and economical to produce [2]. Although biodegradable plastic has demonstrated their potential in a variety of usage, that is imperative to expand a few of its characteristics to a degree that is akin to regular polymers[3].After modification, CNF have outstandingmechanical, and antibacterial characteristics, as well as enhanced crystal structure, resiliency, and application with a dynamic interface [4-5]. Agricultural leftovers are a fascinating source of the nano-cellulose, which is a plentiful, sustainable, and cost-effective substitute for other restricted natural and manufactured fibers [6-8]. Sugarcane (Saccharum) has an annual production of approximately 1.8 billion tonnes annually and incorporates 40 - 50 wt.% fiber in bagasse, that is considerably greater than wheat straw's cellulose content (31wt.%), corn (32wt.%), stalk of corn (33wt.%), and rice (34wt.%) [9, 10]. The bagasse from sugar cane (SCB) is a cost-effective, abundant, and recyclable waste product, making it an appealing nano-reinforcing material for innovative sustainable composites [11].

The primary purpose of this study is to create nano-biocomposite films utilizing bagasse from sugar cane and vinyl alcohol by changing the process of solution casting to make them suitable for packaging applications. A somewhat modified process for fabricating nano-biocomposite films is explained and improved characteristics are proven by findings.

MATERIALS AND METHODS

Materials

HPLC, India delivered Cold Polyvinyl Alcohol (M.W. 850000-124000 with viscosity of 24-39cP) as well as PEG 6000 (Having Molecular Weight 5000-7000 with melting point between 55-61^{0}C). Chitosan (Having Molecular Weight 3900-20000), $CH_3COOH$and NaOH were acquired from HIMEDIA. Maple Biotech Pvt. Ltd. India elated cellulose nano fiber (CNF) from sugarcane bagasse. The components utilized are non-hazardous environmentally friendly, and recyclable.

Methods

Modification of CNF

Before being used, the CNF derived from the bagasse of sugar cane had been rinsed in deionized water in order to eliminate unwanted particulates. For 6 hours, it was agitated in a heated stirrer at 250rpm with dilute CH_3COOH (5wt.%) concentration at 80^{0}C. The mixture was rinsed with purified water to obtained 7 pH, after that filtered and dried in oven at 50°C for 4 hours. Furthermore, 5wt.% NaOH suspension of aqueous solution was prepared in 500mL of deionized water, and CNF was refluxed at 80^{0}C for 24 hoursin a hot plate. The customized cellulose nanofiber was subsequently filtrated and parched in the oven in a vacuum at 50°C for another 24 hours before being employed as reinforcement in a nano-biocomposite film.

Synthesis of Antibacterial Nano Bio-Composite Film

5 weight % solution of polyvinyl alcohol was initially made by dispersing PVA granules in distilled water at 40^{0}C and agitating for 2 hours at 80^{0}C and 250rpm. Now, modified CNF at 20, 30, and 40% wt.% was used for an additional hour at identical conditions to create distinct bio composites. The resulting mixture was subsequently sonicated at 80°C for 30 minutes at 37% energy without delay in an Ultrasonic Homogenizer Probe Sonicator. PEG and chitosan were incorporated to the solution and vigorously agitated for 60 minutes at the identical temperature. To achieve a homogenous solution and eliminate any trapped air pockets, the final preparations were sonicated for 30 minutes at the same conditions. Lastly, the films were developed on a glass Petri dish and parched for 24 hours in a vacuum chamber at 80^0 degrees Celsius.

Nano-Biocomposite Film Characterization

Mechanical Characteristic

The mechanical characteristics viz. maximum tensile strength and percentage elongation were measured with AMT-SC-01521 universal testing equipment at a measuring speed of 1mm/min. Tensile investigations were carried out in compliance with the ASTM D882-12 standard, using a gauge length of 40mm and a specimen size of 60×10 mm^2 (**Figure 1**).

Surface Morphology Test

SEM was utilized to investigate the surface morphology of the films under optimal conditions, utilizing a JSM-6610LV with a 5 kV accelerating voltage (**Figure 2**).

Antibacterial Properties

The antibacterial properties of solely Polyvinyl Alcohol, Cellulose Nano Fiber, and developed films were evaluated against harmful microbes using the disc diffusion technique [12], and the inhibition zone diameter (mm) was discovered. Staphylococcus aureus (Gram-positive) germs were chosen for this research.

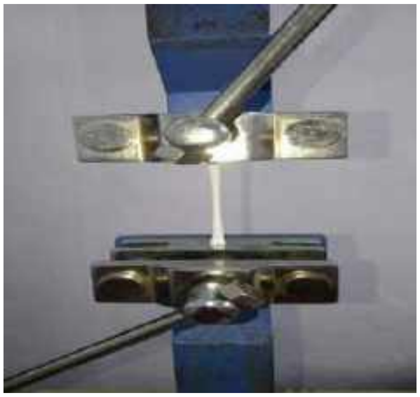

Figure 1 Sample Testing on UTM

Figure 2 Coated Samples for SEM Analysis

RESULTS AND DISCUSSIONS

Mechanical Properties

The UTS and %-E of antimicrobial films augmented at 20, 30, and 40wt.% mixed with PEG, CHT was tested using an ASTM D882-12 universal testing machine. When cast using the sonication process at 40% weight, the treated CNF sample had the maximum tensile strength of 80.47MPa, followed by the untreated CNF specimen with a tensile value of 70.13MPa. In the PVA/CNF at 40wt. % and PVA/CNF at 20 wt.% specimens, the maximum percentage elongation was determined to be 15.08%, subsequently followed by 11.97%.Thus, regardless of fiber modification, an improvement in mechanical properties was seen by using an altered solution casting process [13]. This could be attributable to better fiber distribution within the matrix, which increases interfacial adhesion among them in relation to the solution casting process. Furthermore, no bubbling or fiber aggregation occurred, resulting in the formation of homogenous films. The cured fiber, on the other hand, outperforms the natural fiber because it is more chemically reactive with PVA. The mechanical features of produced films are depicted using a bar graph in **Figure 3**.

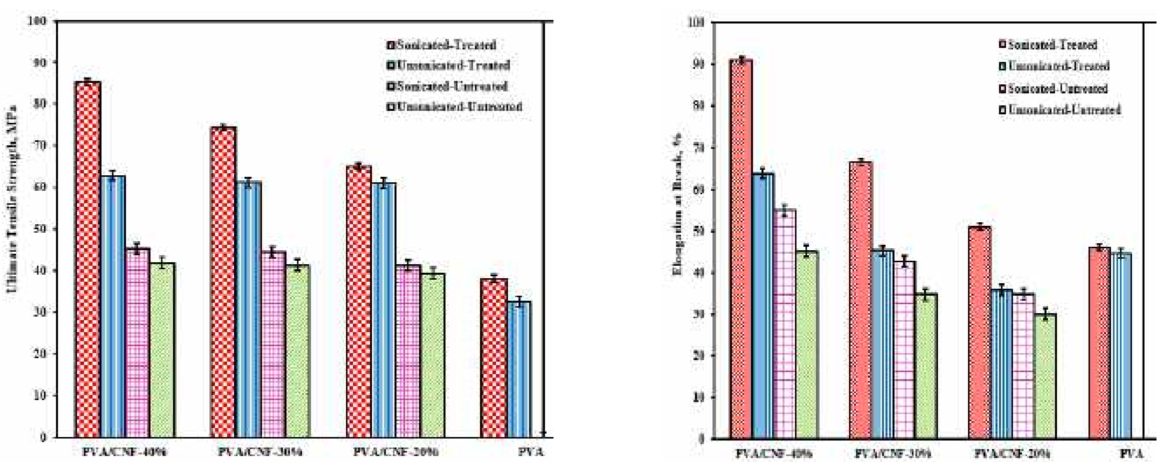

Figure 3 Consequence of Ultrasonication and Treatment on UTS and % Elongation of Nano-Composite Films

Surface Morphology of Nano-Biocomposites

The existence of permeability, regularity of the developed film, the existence of aggregate, and buildup of nano-materials within the dispersed phase are all shown by SEM. Figure 4(a-d) displays surface micrographs of nano-biocomposites, and it was discovered that the microscopic structure of the film had changed by the inclusion of

Cellulose Nano Fiber and by the use of the ultra-sonication technique. Results shown in **Figure 4a** and **4b** show that as the percentage of the weight of fiber went from 20% to 40%, reinforcement became additionally related to matrix, owing to the fact that nano-fibers are deeply embedded in the constant state and slightly have a wide phase separation or gap formation at the junction [14]. On evaluating the images obtained from the SEM at an identical resolution of x50, a clear difference was detected among a sonicated and unsonicated PVA/CNF film at 40% customized fiber (Fig. 4c and 4d). The photos show that following the sonication process, a uniform distribution of CNF in the PVA matrix was detected, resulting in enhanced connection, transparency, and attachment among them.

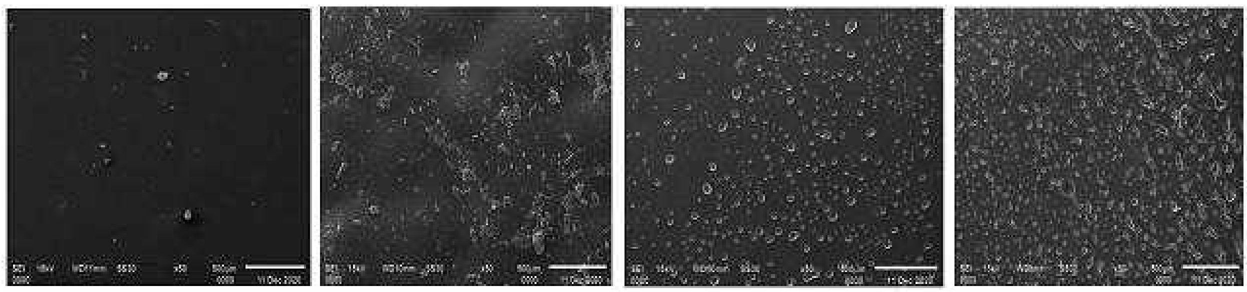

Figure 4 SEM images of (a) DevelopedFilm at 20 and (b) 40 weight percentage of ModifiedFiber; Biofilm at 40 wt. % with modified fiber (c) without ultra-sonication, and (d) with ultra-sonication method.

Antimicrobial Properties

The microbial vulnerability of the films was determined using a disc diffusion experiment against S. aureus microbes, as shown in Figure 5. As a baseline, an antibiotic called ofloxacin (5µg/disc) was used as a positive control. The antimicrobial impact was calculated using the area of inhibition diameter (mm), which came out to be 10.07 and 11.04 mm for neat PVA and CNF, correspondingly.Fortunately, the minimum inhibition zone diameters of the PVA/CNF at 40 wt. % reinforcement and ofloxacin for S. aureus were 15.21 and 17.23 mm correspondingly. As a result, the inclusion of nano-cellulose in the matrix demonstrated substantial antibacterial action against bacteria. This is because the chitosan strengthened in the biofilm strongly adheres to the inner wall of the cell of microbes via electrostatic magnetism, thus redesigning the microbe's cellular membrane and reducing the proliferation of bacteria surrounding the film [15].

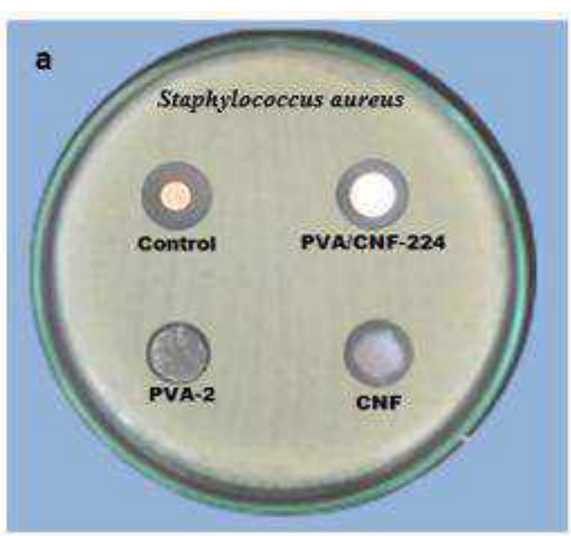

Figure 5 Photos of the Inhibitory Zone of Control Disc (ofloxacin), PVA/CNF-224 (Optimized Film),Pure PVA Film, and CNF Film againstStaphylococcus aureus Bacteria

CONCLUSIONS

The current study discovered that sonication reduces cellulose nanofiber re-agglomeration in vinyl alcohol, which occurs in the solvent casting process. Furthermore, a uniformly disseminated mixture was created with no pockets of air. All of the mechanical parameters were determined to be at their peak at 40% nano-cellulose inclusion. Being fabricated with a utra-sonication technique at maximum weight percentage, the treated CNF samples had a UTS of 85.38 MPa, followed by untreated CNF specimens with 74.31 MPa. In the film samples at 40 and 30 wt. %, the maximum elongation percentage was 91.08%, then followed by 66.625%. An inhibition minimum zone diameter of the PVA/CNF film at 40 wt. % was measured for S. aureusto be 15.21 mm. Because of its antimicrobial characteristics, the recently developed material could be employed in smart and proactive food packaging in order to boost product lifespan.

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MINING ENGINEERING DIVISION

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Application of Analytic Hierarchy Process for Prioritisation of Hazards Mitigation Exercise Based on Safety Management Plan of an Opencast Coal Mine

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***Abstract**: The mining industry, historically considered one of the most hazardous professions globally, faces risks associated with both underground coal mining and opencast mining. While underground mining traditionally posed greater hazards, mechanization and advanced equipment in opencast mining have increased its risks, including ground movement, limited space for numerous equipment, and slope failures in backfilled dumps. Recognizing these dangers, both the industry and government have taken proactive measures through self-regulation, legislation, and various strategies to maintain high safety standards. Following the repeal of the Coal Mines Regulations 1957 and the implementation of the Coal Mines Regulations 2017 in November 2017, a significant statutory requirement emerged—the preparation of a "Safety Management Plan" (SMP) by all coal mines in India. Similarly, the draft Metalliferous Mines Regulations 2019 proposes a similar obligation for metalliferous mines. However, challenges exist in the preparation of SMPs, as circulars from regulatory authorities highlight that these plans are often created without involving all stakeholders and are not audited for suitability and adaptability. Furthermore, the Hazard Identification and Risk Assessment (HIRA) process, commonly used in SMP preparation, lacks a hierarchical table, making it difficult to prioritize actions when multiple hazards have the same risk rating.*

This paper introduces the Analytic Hierarchy Process (AHP) as a tool for Multi-Criteria Decision Making (MCDM) to address these challenges. The AHP is proposed for prioritizing the implementation of controls based on risk ratings obtained from the SMP. The study utilizes data from an opencast coal mine to establish a hierarchical table of hazards, aiming to facilitate the implementation of controls through Control Plans. The goal is to enhance the prioritization of actions in managing risks, considering the specific limitations of each mine in terms of finance, manpower, and work processes.

***Keywords**: Safety Management Plan; Hazard Identification and Risk Assessment; Analytic Hierarchy Process; Multi Criteria Decision Making process; Mines Safety, Directorate General of Mines Safety.*

INTRODUCTION

Since the enactment of the Mines Act 1901, the mining industry in India has undergone significant legislative developments aimed at regulating and inspecting mines to prevent accidents and ensure the safety, convenience, and discipline of workers. Over the years, the industry has progressed from the early provisions, including the framing of special rules for self-regulation, to the enforcement of the Coal Mines Regulations 2017.

The trend in fatal and serious accidents in coal mines is illustrated in **Figure 1**. According to the Annual Report 2021- 22 of the Ministry of Labour and Employment, there is a consistent decline in serious injuries over the years, and a decreasing trend is observed in the death rate. This suggests a positive trajectory in the industry's efforts to enhance safety and reduce accidents.

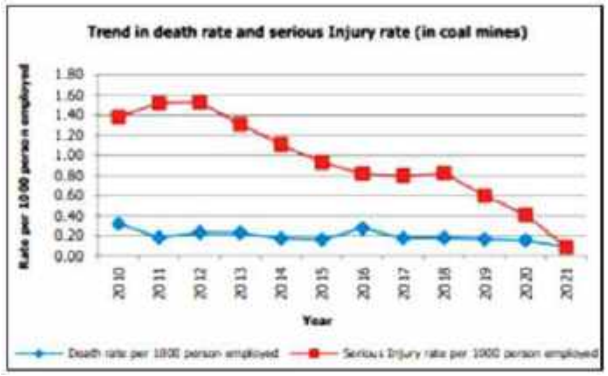


Figure 1 Trend in death rate and serious injury rate in Coal mines

The trend in fatal and serious accidents in metalliferous mines is depicted in **Figure 2**. Although both rates exhibit fluctuating trends, an overall observation from the data presented in the Annual Report 2021-22 of the Ministry of Labour and Employment (MOLE) indicates that the serious injury rate in metalliferous mines is on a declining trend over the given period.

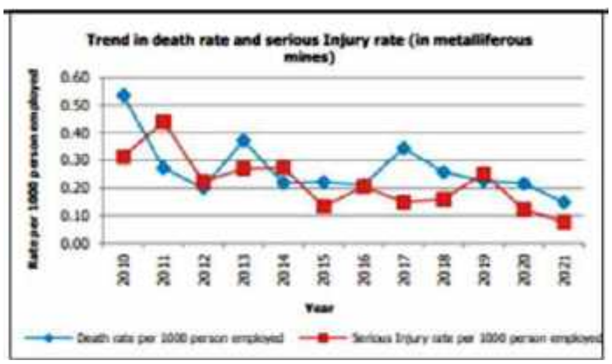


Figure 2 Trend in death rate and serious injury rate in Metalliferous mines

In the Annual Report 2021-22 from the Ministry of Labour and Employment, Government of India, presents accident trends in terms of fatal accidents and fatality rates per thousand persons employed in 10-year averages spanning from 1971-80 to 2011- 20, covering the last five decades. The data review reveals a consistent decline in fatal accidents and fatality rates in coal mines over the years. However, the trend is less favourable for non-coal mines, where a steady decline is not observed.

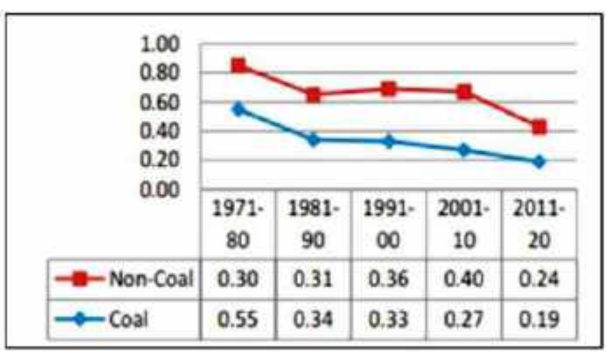


Figure 3 The long-term trend of fatality rate and decadal trend.

In the year 2000, a review of accident statistics spanning the past two decades indicated a generally constant fatality rate per thousand persons employed in coal mines (between 0.34 to 0.33) and non-coal mines (0.31 to 0.36). This led to a shift in the regulatory approach, moving from a prescriptive system to self-regulation. The Ninth Conference on Safety in Mines in February 2000 recommended the adoption of Risk Management as a tool for developing health and safety management systems in Indian mines. This recommendation, emphasizing a structured risk assessment process, was circulated to all mine owners in 2002.

Subsequently, DGMS issued "Safety Management System- Provision for auditing and review" in 2011 (Circular No. 02) and reiterated it in 2016 (Circular No. 5), including an integrated implementation strategy as guidance. With the introduction of the Coal Mines Regulations 2017, the Safety Management Plan became a statutory requirement under Regulation 104, making its formulation, preparation, and implementation the statutory responsibility of the Owner, Agent, and Manager in coal mines. However, in metalliferous mines, the Safety Management Plan remains an advisory provision under the Metalliferous Mines Regulations 1961.

Although most coal mines have prepared their Safety Management Plans in compliance with the statute, a study of Hazard Identification and Risk Assessment (HIRA) exercises revealed challenges. Many hazards had the same risk rating, complicating the scientific and logical implementation of controls. To address this, the study introduced the Analytic Hierarchy Process as a tool to create a hierarchy of hazards, enabling sequential mitigation and prioritizing controls based on the severity of the risks.

SAFETY MANAGEMENT PLAN (SMP)

The Safety Management Plan serves as a crucial tool in mining operations, aiding in hazard identification, categorization of activities from most to least hazardous, definition of controls, execution, and subsequent scrutiny through audits. However, the current practice often involves arbitrary decisions on the order of implementing control measures within a specific category.

The DGMS Circular No. 13 of 2002, dated December 31, 2002, circulated guidelines for Safety Management Plan preparation, establishing a common yardstick for risk assessment in mines across the country.

The Safety Management Plan is a statutory requirement for coal mines, while it remains advisory for metal mines. While there is no proposed deviation from the DGMS Circular of 2002 in risk assessment and ranking methodology, the paper suggests employing the Analytic Hierarchy Process (AHP) in the Hazard Control Plan for principal hazards. AHP is proposed to establish a chronological order for implementing controls, aiming to enhance the systematic and logical imposition of controls in mining operations.

THE ANALYTICAL HIERARCHY PROCESS (AHP)

AHP is a widely used multicriteria decision-making tool that addresses the measurement of both physical and psychological events. It distinguishes between the tangible (related to objective reality) and the intangible (involving subjective ideas and beliefs) aspects of measurement. AHP serves as a method for establishing measures in both the physical and social domains, making it a versatile tool for decision-makers and researchers. AHP is a prominent tool in Multiple Criteria Decision-Making (MCDM) processes, allowing for the comparison of multiple alternatives based on various criteria to identify the best option. It provides a methodology to calibrate numeric scales for measuring both quantitative and qualitative performances. This process organizes and analyses complex decision alternatives using a combination of mathematics and psychology. The AHP scale ranges from 1/9 for 'least valued than' to 1 for 'equal' and further to 9 for 'absolutely more important than,' providing a comprehensive spectrum for comparing alternatives in decision-making processes.

Decision applications of the AHP are carried out in two phases: hierarchic design and evaluation. The design of hierarchies requires experience and knowledge of the problem area. Two decision makers would normally structure two different hierarchies of the same problem. Thus a hierarchy is not unique. On the other hand, even when two people design the same hierarchy, their preferences may yield different courses of action. However, a group of people can work together to reach consensus on both the hierarchy (design) and on the judgments and their synthesis (evaluation). The evaluation phase is based on the concept of paired comparisons. The elements in a level of the hierarchy are compared in relative terms as to their importance or contribution to a given criterion that occupies the level immediately above the elements being compared. This process of comparison yields a relative scale of measurement of the priorities or weights of the elements. That is, the scale measures the relative standing of the elements with respect to a criterion independently of any other criterion or element that may be considered for comparison. These relative weights sum to unity. The comparisons are performed for the elements in a level with respect to all the elements in the level above. The final or global weights of the elements at the bottom level of the hierarchy are obtained by adding all the contributions of the elements in a level with respect to all the elements in the level above. This is known as the principle of hierarchic composition.

The popularity of AHP stems from its simplicity, flexibility, intuitive appeal, and ability to mix quantitative and qualitative criteria in the same decision framework. An important aspect of the AHP is the idea of consistency. If one has a scale for a property possessed by some objects and measures that property in them, then their relative weights with respect to that property are fixed. In this case there is no judgmental inconsistency.

But when comparing with respect to a property for which there is no established scale or measure, we are trying to derive a scale through comparing the objects two at a time. Since the objects may be involved in more than one comparison and we have no standard scale, but are assigning relative values as a matter of judgment, inconsistencies may well occur.

The given information pertains to the Consistency Ratio (CR) used in the Analytic Hierarchy Process (AHP) for decision- making. The CR is calculated using the Consistency Index (CI) and Random Index (RI), as expressed in equations (1) and (2). The CI is determined by the maximal eigenvalue of the judgment matrix. The Random Index values, based on Safety work, are provided in Table 3 for different matrix sizes (n). A CR value below 0.1 indicates sufficient consistency in the judgment matrix, while a value above 0.1 suggests inconsistency, necessitating a re-evaluation of pairwise comparisons or exclusion of the matrix from further steps.

$$CR = CI / RI \quad (1)$$

CR- Consistency ratio CI- Consistency Index RI- Random Index

$$CI = (\lambda max - n)/ (n - 1) \quad (2)$$

In Equation (2), λmax represents the maximal eigenvalue of the matrix. Based on the work of Safety [5], the values of RI are presented in **Table 1**.

Table 1

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The report proposes the use of Analytic Hierarchy Process (AHP) to determine the order of implementing controls when simultaneous implementation is not feasible. It emphasizes that a judgment matrix is considered sufficiently consistent if the Consistency Ratio (CR) is below 0.1. If the CR exceeds 0.1, the matrix is deemed unacceptable, prompting a need for re-evaluation through pairwise comparisons or exclusion from subsequent methodological steps. This criterion ensures the reliability of the decision-making process in the context of activity succession planning.

CASE STUDY- SMP OF GARE PALMA-IV COAL MINE

A Safety Management Plan was conducted at Gare Palma IV Coal mine of M/s JPL from 06.11.22 to 08.11.22, with the undersigned serving as a facilitator and involving all stakeholders. The risk rating of potential hazards was assessed, and a hazard plan was formulated based on the risk rating. A control plan was also developed for risk mitigation. In the process of creating the control plan, the decision and timing of control implementation were left to the discretion of the management for effective risk reduction.

However, when addressing multiple hazards with the same risk rating to expedite control implementation and lower the risk rating to 'As Low as Reasonably Possible (ALARP),' no mathematical model or algorithm was utilized. Instead, a specific date for implementing adequate controls was determined based on the experience of the responsible person tasked with control implementation.

Internally, the management has the option to employ the Analytic Hierarchy Process (AHP) to establish a ranking (weightage) of criteria and sub-criteria or hazards. This ranking aids in prioritizing hazards within a group, considering limited resources that must be optimally utilized for efficient control implementation as promptly as possible.

The Safety Management Plan (SMP) assessment for the mine showed no high-risk hazards rated at 200 and above. However, in the medium-risk hazard category, there were seven primary criteria, and at the secondary level, there were 37 sub-criteria. The primary criteria for hazards (**Table 2**) in the medium-risk category are as follows.

Table 2

Sl no.	Hazard	Maximum risk rating
1	Explosives	75
2	Haulage and Transport	175
3	Miscellaneous activities	75
4	Machinery	175
5	Electricity	35
6	Fly Ash	175
7	Slope Stability	150

The different sub-criteria (with rating of more than 20 with a maximum rating of 500 possible) in the secondary criteria under the primary criteria were as follows (**Table 3**)

ANALYTIC HIERARCHY PROCESS OF HAZARDS FOR MITIGATION PURPOSE

Table 3 highlights challenges in aligning numerous hazards under different primary criteria with the same or varying risk ratings. This complexity makes it difficult to establish a hierarchy for prioritizing mitigation efforts, especially given limited resources, a common constraint in mines. To address this, Saaty's Analytic Hierarchy Process (AHP) was integrated for determining the urgency of mitigation. Intensive discussions were conducted with experienced mining professionals, each having a minimum of thirty years of hands- on experience in coal mines. These discussions were instrumental in assigning the intensity of importance during the calculation of criteria weightage, ensuring not only the accuracy of the weights but also their consistency. This approach aimed to provide a more informed and nuanced decision-making process in dealing with diverse hazards.

The weightage of the different primary criteria was obtained in **Table 4**.

The calculation table for weightage determination of primary criteria "explosive" is indicated under **Table 5**.

Table 3

Primary Criteria	Secondary Criteria	Risk rating
Explosives	Simultaneous Transportation of explosives and detonator in explosive van	25
	Use of Mobile during blasting operation	75
	Fly rock due to blasting	35
	Charging in hot strata	25
	Improper charging of SME	25
	Simultaneous Drilling and charging	25
Haulage and Transport	Exclusive haul road is not provided in the mine (Plying of other vehicles in Haul road)	175
	Steep gradient of haul road	35
	Traffic rule not followed	75
	Inadequate berm along haul road	35
	Inadequate width of haul road	75
	Sharp bend in haul road	75
Miscellaneous activities	Alcohol in blood during working hours	75
	Lack of concentration of HEMM operators / LMV drivers due to use of mobile	75
Machinery	Running of dumper without safety features (rear view camera, automatic dipper, proximity warning, tail gate protection, fatigue sensing device).	175
	Poor parking brake in dumpers.	35
	Wearing loose garments near moving parts of machinery	21
	Non-provision of coupling guard of dewatering pump.	35
	Shortage of mechanical foreman.	70
Electricity	Shortage of Electrical supervisors	30
	Non-provisioning of cradling at points	25
	Lack of awareness regarding electrical systems at sub-station.	35
	Non-engagement of skilled persons.	21
	Improper identification/description of switches and cable	30
	Improper maintenance of electrical systems.	35
	Use of unsafe electric welding machine.	35
	Inadequate ground clearance of overhead lines.	35
Fly Ash	Fly ash getting stuck to dumper body	50
	Crowding of fly ash dumpers	175
	Improper illumination at dump yard.	50
Slope Stability	Inadequate size of height and width of bench.	150
	Ground water not properly coursed / drains out.	150
	Inadequate supervision / monitoring.	150
	Stacking of material on inclined / sloped surface.	45
	Dump lift height & width are not maintained properly.	150
	Rain water accumulation on dump surfaces.	45
	Improper monitoring of dump movement	150

Table 4

Primary Criteria	Relative Criteria weightage
Explosives	0.0420
Haulage and Transport	0.2547
Miscellaneous activities	0.0386
Machinery	0.2547
Electricity	0.0210
Fly Ash	0.2547
Slope Stability	0.1343

Table 5

	Explosive	Haul road	Misc.	Mach-inery	Elect-ricity	Fly ash	Slope failure	Criteria weights after normal-isation	λmax	CI	RI	CR	Remarks
Explosive	1.00	0.14	1.00	0.14	4.00	0.14	0.17	0.04	7.35	0.06	1.36	0.04	<0.10. Hence consistent
Haul road	7.00	1.00	7.00	1.00	9.00	1.00	3.00	0.25					
Misc.	1.00	0.14	1.00	0.14	3.00	0.14	0.17	0.04					
Machinery	7.00	1.00	7.00	1.00	9.00	1.00	3.00	0.25					
Electricity	0.25	0.11	0.33	0.11	1.00	0.11	0.14	0.02					
Fly ash	7.00	1.00	7.00	1.00	9.00	1.00	3.00	0.25					
Slope failure	6.00	0.33	6.00	0.33	7.00	0.33	1.00	0.13					
Sum	29.25	3.73	29.33	3.73	42.00	3.73	10.48	1.00					

Under each primary criterion, the weightages of the sub-primary criteria were determined in the similar process and the final values obtained as shown in **Table 6**.

Table 6

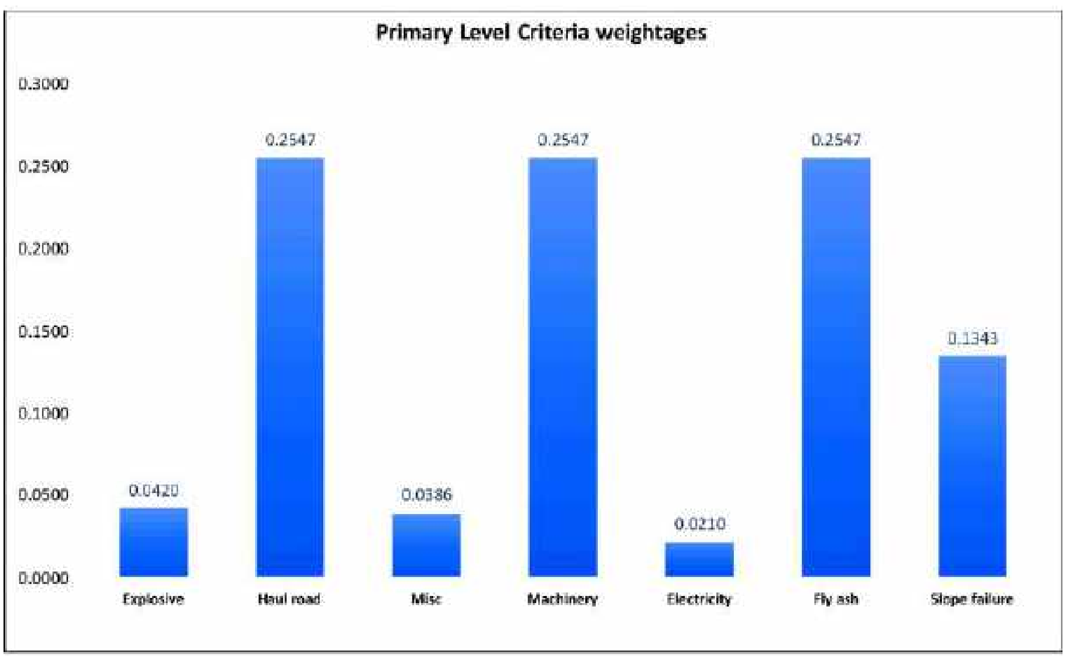
Primary Criteria	Weightage	Secondary criteria	Weightage	Final weightage	% weightage
Explosives	0.0420	Simultaneous Transportation of explosives and detonator in explosive van	0.0695	0.0029	0.2919
	0.0420	Use of Mobile during blasting operation	0.5301	0.0223	2.2264
	0.0420	Fly rock due to blasting	0.1920	0.0081	0.8064
	0.0420	Charging in hot strata	0.0695	0.0029	0.2919
	0.0420	Improper charging of SME	0.0695	0.0029	0.2919
	0.0420	Simultaneous Drilling and charging	0.0695	0.0029	0.2919
Haulage and Transport	0.2547	Exclusive haul road is not provided in the mine (Plying of other vehicles in Haul road)	0.4936	0.1257	12.5720
	0.2547	Steep gradient of haul road	0.0432	0.0110	1.1003
	0.2547	Traffic rule not followed	0.1400	0.0357	3.5658
	0.2547	Inadequate berm along haul road	0.0432	0.0110	1.1003
	0.2547	Inadequate width of haul road	0.1400	0.0357	3.5658
	0.2547	Sharp bend in haul road	0.1400	0.0357	3.5658
Miscellaneous activities	0.0386	Alcohol in blood during working hours	0.5000	0.0193	1.9300
	0.0386	Lack of concentration of HEMM operators / LMV drivers due to use of mobile	0.5000	0.0193	1.9300
Machinery	0.2547	Running of dumper without safety features (rear view camera, automatic dipper, proximity warning, tail gate protection, fatigue sensing device).	0.4855	0.1237	12.3657
	0.2547	Poor parking brake in dumpers.	0.0856	0.0218	2.1802
	0.2547	Wearing loose garments near moving parts of machinery	0.0395	0.0101	1.0061
	0.2547	Non-provision of coupling guard of dewatering pump.	0.0892	0.0227	2.2719
	0.2547	Shortage of mechanical foreman.	0.3003	0.0765	7.6486
Electricity	0.0210	Shortage of Electrical supervisors	0.0757	0.0016	0.1590
	0.0210	Non-provisioning of cradling at points	0.0359	0.0008	0.0754

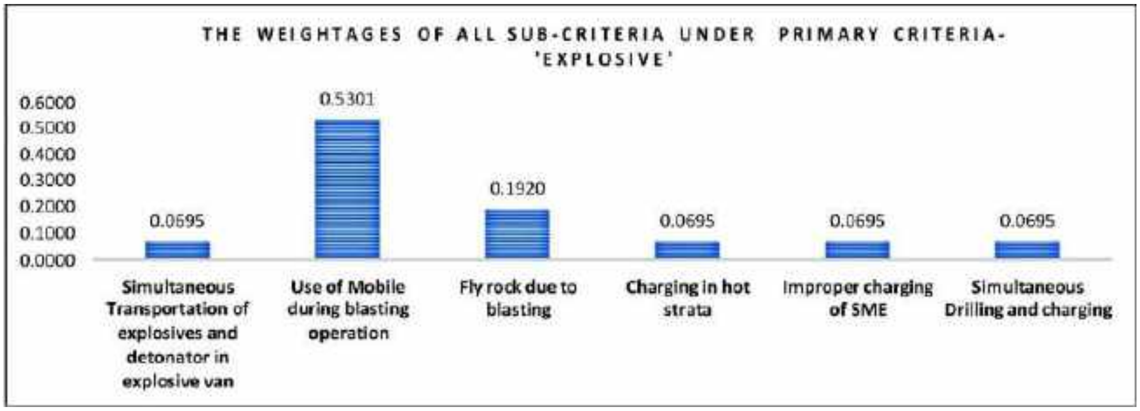
Accordingly, the final weightage of each of the sub-criteria was calculated to obtain the final hierarchy of all the hazards of medium risk rating in the mine with a risk rating of more than 20 is indicated under **Table 7**.

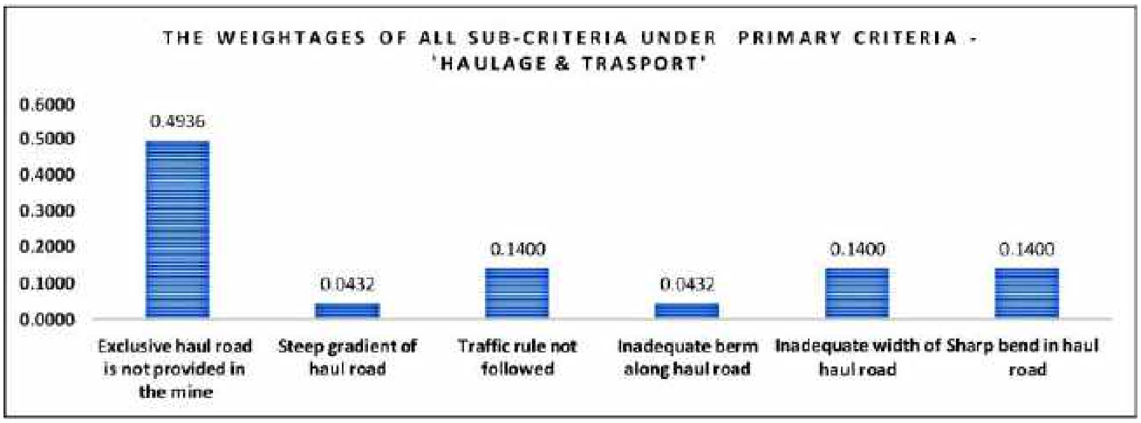
Table 7

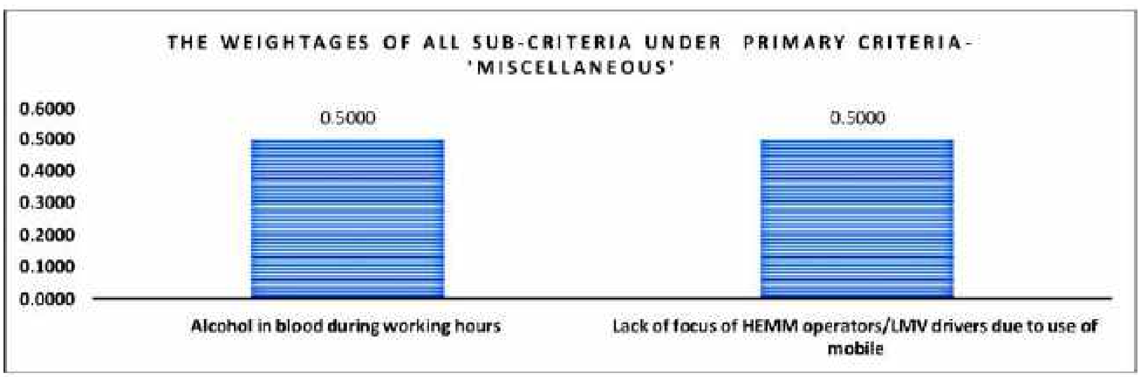
	0.0210	Lack of awareness regarding electrical systems at sub-station.	0.1966	0.0041	0.4129
	0.0210	Non-engagement of skilled persons.	0.0209	0.0004	0.0439
	0.0210	Improper identification/description of switches and cable.	0.0811	0.0017	0.1703
	0.0210	Improper maintenance of electrical systems.	0.1966	0.0041	0.4129
	0.0210	Use of unsafe electric welding machine.	0.1966	0.0041	0.4129
	0.0210	Inadequate ground clearance of overhead lines.	0.1966	0.0041	0.4129
Fly Ash	0.2547	Fly ash getting stuck to dumper body.	0.1667	0.0425	4.2458
	0.2547	Crowding (Bunching) of fly ash dumpers.	0.6667	0.1698	16.9808
	0.2547	Improper illumination at dump yard.	0.1667	0.0425	4.2458
Slope stability	0.1343	Inadequate size of height and width of bench.	0.1818	0.0244	2.4416
	0.1343	Ground water not properly coursed / drains out.	0.1818	0.0244	2.4416
	0.1343	Inadequate supervision / monitoring.	0.1818	0.0244	2.4416
	0.1343	Stacking of material on inclined / sloped surface.	0.0455	0.0061	0.6111
	0.1343	Dump lift height & width are not maintained properly.	0.1818	0.0244	2.4416
	0.1343	Rain water accumulation on dump surfaces.	0.0455	0.0061	0.6111
	0.1343	Improper monitoring of dump movement	0.1818	0.0244	2.4416

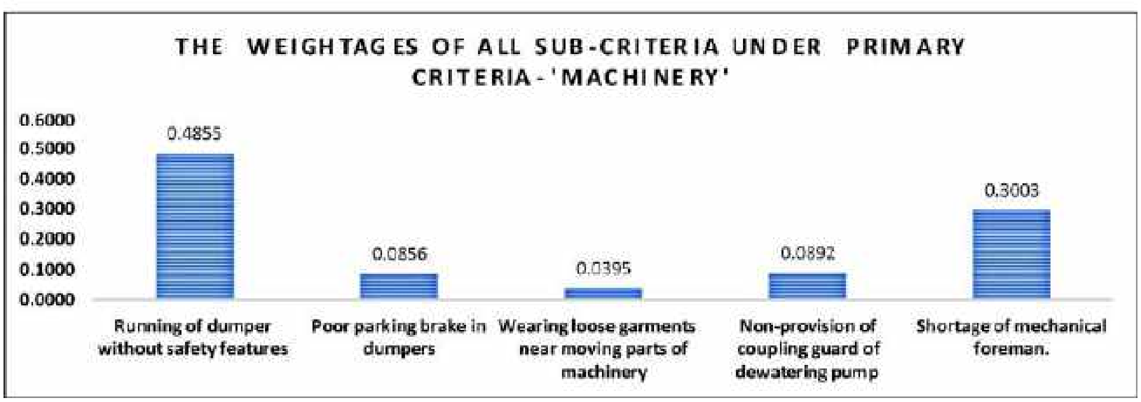
From the above table, it may be concluded that in a group of hazards that have been rated on the basis of DGMS Circulars, it is possible to conduct a hierarchical table to assist the management to mitigate those hazards that should be controlled on priority basis, in the instance of inadequate resources. In the above table, it is deduced that crowding of fly ash dumpers, exclusive haul roads for dumpers and ensuring that the dumpers are not driven without the safety features stand out among all the hazards and should be effectively controlled on priority basis. The other hazards can be similarly categorised for mitigation.

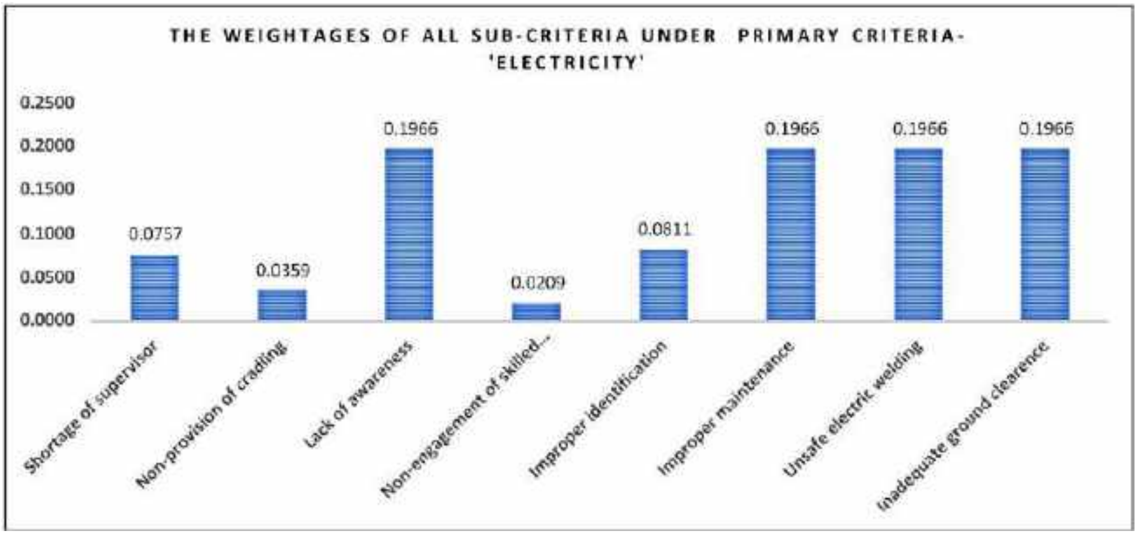


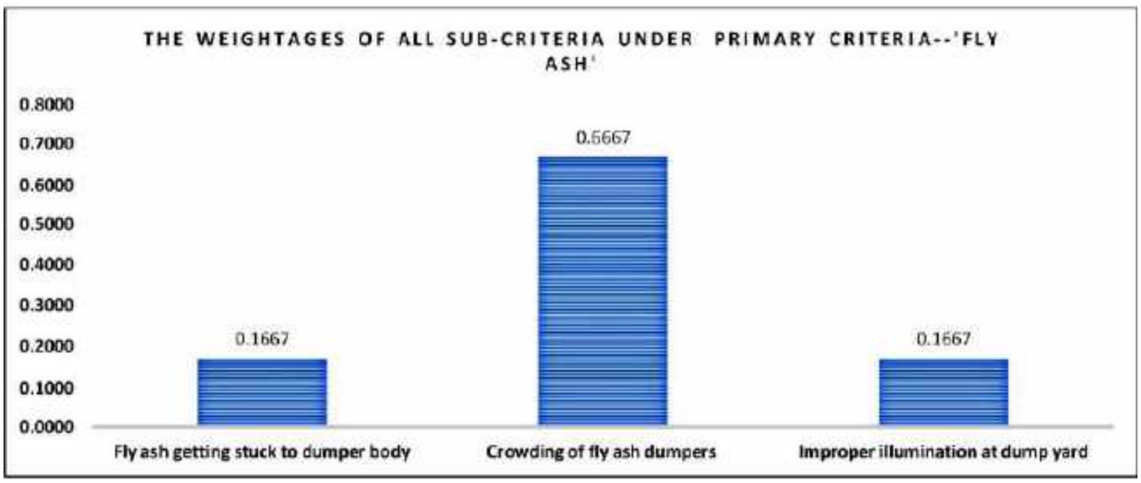

THE WEIGHTAGES OF ALL SUB-CRITERIA UNDER PRIMARY CRITERIA- 'EXPLOSIVE'
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
0.0695
0.5301
0.1920
0.0695
0.0695
0.0695
Simultaneous Transportation of explosives and detonator in explosive van
Use of Mobile during blasting operation
Fly rock due to blasting
Charging in hot strata
Improper charging of SME
Simultaneous Drilling and charging

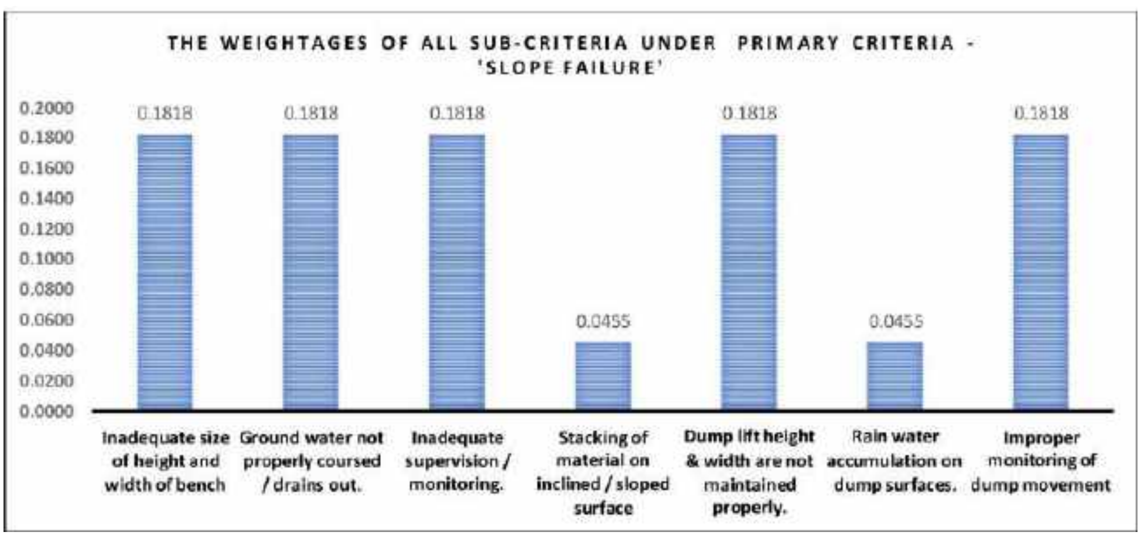

THE WEIGHTAGES OF ALL SUB-CRITERIA UNDER PRIMARY CRITERIA - 'HAULAGE & TRASPORT'
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
0.4936
0.0432
0.1400
0.0432
0.1400
0.1400
Exclusive haul road is not provided in the mine
Steep gradient of haul road
Traffic rule not followed
Inadequate berm along haul road
Inadequate width of haul road
Sharp bend in haul road

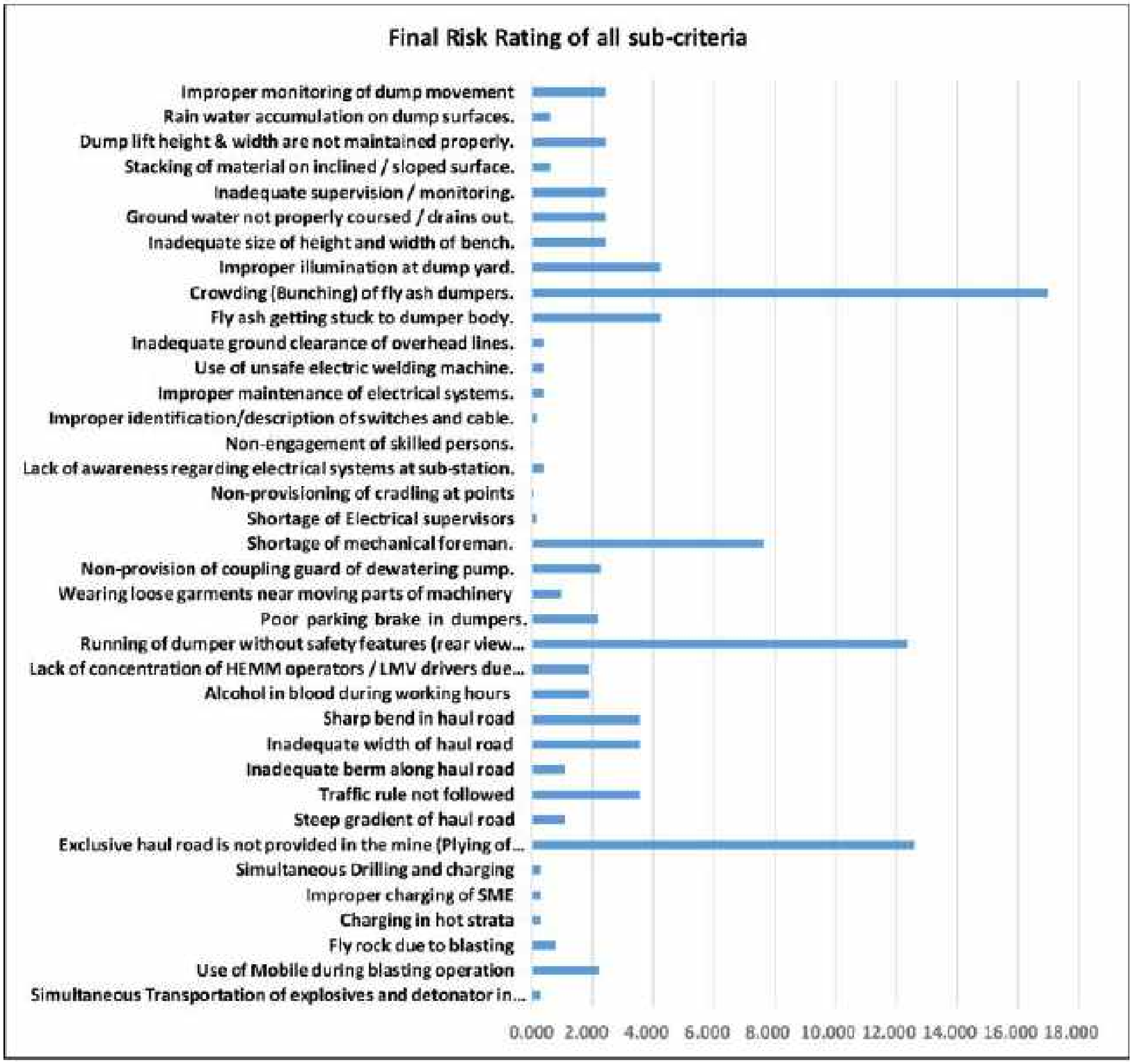

THE WEIGHTAGES OF ALL SUB-CRITERIA UNDER PRIMARY CRITERIA- 'MISCELLANEOUS'
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
0.5000
0.5000
Alcohol in blood during working hours
Lack of focus of HEMM operators/LMV drivers due to use of mobile


THE WEIGHTAGES OF ALL SUB-CRITERIA UNDER PRIMARY CRITERIA- 'MACHINERY'
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
0.4855
0.0856
0.0395
0.0892
0.3003
Running of dumper without safety features
Poor parking brake in dumpers
Wearing loose garments near moving parts of machinery
Non-provision of coupling guard of dewatering pump
Shortage of mechanical foreman.


THE WEIGHTAGES OF ALL SUB-CRITERIA UNDER PRIMARY CRITERIA-'ELECTRICITY'
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
0.0757
0.0359
0.1966
0.0209
0.0811
0.1966
0.1966
0.1966
Shortage of supervisor
Non-provision of crading
Lack of awareness
Non-engagement of skilled...
Improper identification
Improper maintenance
Unsafe electric welding
Inadequate ground clearence


THE WEIGHTAGES OF ALL SUB-CRITERIA UNDER PRIMARY CRITERIA--'FLY ASH'
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
0.1667
0.6667
0.1667
Fly ash getting stuck to dumper body
Crowding of fly ash dumpers
Improper illumination at dump yard


THE WEIGHTAGES OF ALL SUB-CRITERIA UNDER PRIMARY CRITERIA - 'SLOPE FAILURE'
0.2000
0.1800
0.1600
0.1400
0.1200
0.1000
0.0800
0.0600
0.0400
0.0200
0.0000
0.1818
0.1818
0.1818
0.0455
0.1818
0.0455
0.1818
Inadequate size of height and width of bench
Ground water not properly coursed / drains out.
Inadequate supervision / monitoring.
Stacking of material on inclined / sloped surface
Dump lift height & width are not maintained properly.
Rain water accumulation on dump surfaces.
Improper monitoring of dump movement



CONCLUSION

The evolution of legislation in India over more than 120 years has aimed at enhancing safety in mines. National conferences on mine safety have consistently emphasized the importance of continuous improvement in safety practices. The Safety Management Plan (SMP), now a statutory provision under the CMR 2017, serves as a crucial tool in this context. It involves hazard identification, risk assessment, and categorization into High Risk, Medium Risk, and Low Risk.

In the case of Gare Palma IV mine, the SMP identified 124 hazards, none falling into the major risk category, 87 in the low-risk category, and 37 in the medium-risk category. These medium-risk hazards were further classified under seven primary hazards (explosives, haulage & transport, miscellaneous, machinery, electricity, fly ash, and slope stability). Utilizing the Analytic Hierarchy Process (AHP), weightages for both primary and secondary hazards were determined. This comprehensive evaluation could assist the management in effectively prioritizing and controlling these hazards based on their severity in a chronological order.

This study establishes a foundational concept for prioritizing and evaluating critical mine hazards, offering valuable insights for government officials, policymakers, managers, safety experts, supervisors, technicians, engineers, and mine personnel. The focus is on formulating effective Safety Management Plans (SMP) to work towards achieving the goal of zero accidents in mines. The study emphasizes the importance of promptly detecting, evaluating, and ranking hazards for proper mitigation, including elimination, substitution, isolation, engineering controls, administration, training, and Personal Protective Equipment (PPE). The methodology introduced in this study centres on risk assessment within the SMP, incorporating the Analytic Hierarchy Process (AHP) to assess risks chronologically based on severity and consequences. This approach aids management and statutory authorities in identifying hazards requiring immediate control measures. While acknowledging that all hazards pose risks to people and resources and should ideally be controlled, the study suggests that, given resource constraints, the application of AHP in the SMP of mines has the potential to enhance safety statistics in the mining industry.

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Ecological Balancing during Progressive Mine Closure in Neyveli Lignite Mine 2

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***Abstract**: The major environmental concern of India today includes all physical (air, water, land etc.) and biological factors (plants & animals including man). But today man has emerged as the most powerful and intelligent component of environment, who keeps on modifying the natural ecosystem by the technocratic industrial development.NLC is harnessing the power of nature - like lignite mining and power generation. Being conscious that environmental regeneration is the foundation on which productivity has to be built, Neyveli Lignite Corporation started investing to 'Eco Care' long back in early eighties and is continuing to Re-Create the original beauty of Mother Nature. This paper highlights the various environmental problems faced during mining the lignite deposit in the Neyveli Mine2 and the tangible protection& remedial measures adopted to maintain the ecological balance where all species can live balancing each other i.e. Land reclamation & Soil dump stabilization; Air pollution control measures and Water pollution control measures , Ground water resources management Flora and Fauna development and sustaining them, converting mined out and refilled area into cultivable land and Orchids and rain harvesting ponds/lakes with aquaculture. In addition to this energy efficient zero emission drives are used with the latest concept of Green mining.*

***Keywords**: Neyveli Lignite, Ecology, Eco Care, Flora, Fauna, Air Pollution, Water Management, Land Restoration, Slope Stabilization, Artificial Recharge, Integrated Farming, Sustainability, Corporate Social Responsibility.*

INTRODUCTION

Neyveli Lignite Corporation Limited (NLC), a 'NavRatna' Government of India Enterprise functioning under the aegis of Ministry of Coal, became reality in the year 1956. Neyveli is situated in the Cuddalore District of Tamilnadu about 200 KM South of Chennai.NLC's expertise in lignite mining and power generation has opened up new avenues beyond its boundaries.NLC has ambitious expansion programmes in different parts of the country to meet the ever growing need for power. Simultaneously, as a responsible Corporate, NLC takes up many Corporate Social Responsibility initiatives to maintaining Ecological balance in and around Lignite mines areas for the betterment of the society at large.

Mining Lignite and Power Generation By NLC

The main constituent Units of the Company in Neyveli are three opencast lignite Mines linked to three Thermal Power Plants with a total mining capacity of 28.0 MTPA and Power Generation of 3390 MW.

Geology and Method of Mining

The Lignite field forms part of Cauvery Basin and spread over an area of 480 sq.km. The lignite is mainly single seam with overburden of argillaceous and ferruginous sandstone, clays and aquifer sand. The total identified geological reserve in the basin is 4150 MT. A huge reservoir of ground water occurs below the entire lignite bed, exerting an upward pressure of 5 to 8 Kg/cm^2. By continuous pumping out of water round the clock through bore wells, the ground water pressure is controlled.

Continuous opencast mining technology which is a environment-friendly technology which generates less dust compared to other mining system is adopted in Neyveli mines [BWE, Conveyor & Spreader] for excavating and transporting huge quantities of overburden and extracting and transporting and stacking of lignite.

ECOLOGICAL AND ENVIRONMENTAL CARE

Since the NLC complex is engaged in a wide spectrum of industrial activities, the environmental problems to be tackled become pronounced from the stage of lignite mining, its utilization and final disposal of the wastes. NLC's afforestation efforts are conceived as a measure for preserving ecological balance and for increased stability of the soil dumps. Many migratory birds are vising Neyveli mine afforested area and lakes developed in the reclaimed area.

LAND RECLAMATION

Necessity

During the Project formulation stage, NLC has planned for refilling and reclamation of mined out area. Excavation of overburden for mining lignite is a pre-requisite for mining operation. NLC is acquiring land for its mining activities in a phased manner from the adjacent villages by paying suitable compensation as per GOI R& R Policy. These lands are to be given back to state government for redistribution to land owners.

Concept of Land Reclamation

The soil excavated is backfilled in stage- dump and is stabilized by using Conventional Mining Equipment. These dumps are consolidated using bull dozers and back –hoes over a period of two years for compaction and stabilization.

Methodology of Reclamation

The back filled areas are reclaimed by adopting mainly by biological methods. The land is reclaimed for agriculture, horticulture crops and development of forestry, pasture land etc. as shown in **Photo 1**.

Facts about Reclamation and Afforestation

NLC has reclaimed so far 50% of the mined out area and about 82% of reclaimed area has been afforested in all the three mines apart from agriculture and horticulture land development.

INTEGRATED FARMING SYSTEMS (IFS)

Concept

- Integrated Farming System an innovative concept has been adopted in reclaiming the mine spoil banks.
- The sustainable integration of different agriculture related products with animal components
- Provides ways to recycle products and by-products of one component serves as input to another component and reduce the cost of production as shown in the Flow Diagram

Objectives

- Standardization of crop, husbandry fish culture poultry and allied enterprises
- Improving soil fertility for sustainable crop production
- Evaluation of seed hardening and seed pelleting technologies to various tree and crop species
- Monitoring soil physical and biochemical properties in rehabilitated mine spoil eco system

- Monitoring the restoration potential of biodiversity in the rehabilitated mine spoil
- Exploitation of microbial systems for improving the mine spoils to sustain crop production.

Photo 1 Initial Stages of Afforestation in the reclaimed Mine spoil at Neyveli Lignite Mines.

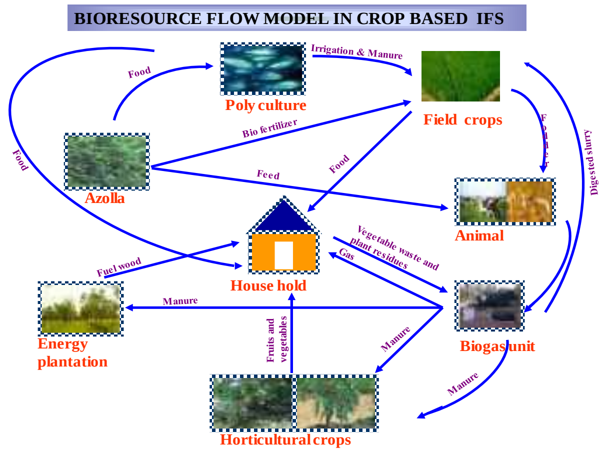

Figure 1 Bioresource Flow Model in Crop Based IFS

The following activities carried out in Integrated Farming System (IFS.):

Cropping System

Improved varieties of sorghum, maize, cow pea andsugarcane were cultivated. Similarly, vegetable crops, flower crop and medicinal park were cultivated / established. With regard to fodder crops Cumbu, Napier, Hybrid Grass variety was established.

Agro –forestry

To establish silvipasture system in the mine spoil, multi purpose tree species viz., Vagai, Simaruba, Sissoo, Vengai, Neem, Karuvel, Pencil tree, Glyricidia, Subabuland Neermaruthu were planted. In order to provide nutritious fodder for animals, a drought resistant cenchrus spp. along with stylo santhus hamates were planted in 3:1 ratio.

Establishment of Fruit Trees

Mango, Saputo, Jamun, Cashew, Tamarind, Amla, Pomegranate, Annona, .Lime, and fruitOrchards developed.

Establishment of Animal Components

Milk animal, Guinea fowl, Sheep and Poultry are maintained.

Aquaculture

Composite culture involving Catla fish, rogu, mirghal, common carp, silver carp and grass carp was taken up in an area.

Economic Benefits of the IFS Components

- Integration of the above inter-dependent enterprises with cropping systems would help to obtain an average net income around Rs.30,000 per hectare/annum and provides an employment generation.

- The quality of the products is enhanced due to usage of organics for soil, pest and crop management activities.
- Aerial environmental benefits obtained due to this bio – diversity farming practices.
- Higher values of species richness, species evenness and species diversity are also observed
- Erosion control is also achieved by increased fertility of soil cover.

Recently 50 mw solar plant being executed in the refiled area.

SLOPE STABILISATION

The external over dumps created during the initial Mines cuts are causing a lot of environmental problems. In order to fulfill social obligations, (viz) the huge quantities of mines spoil dumped over a large area may have to converted into vegetative one making it fit for habitation, a Project namely SLOPE STABILISATION of the mines over burden dumps has been undertaken with the collaboration of Tamil Nadu Agricultural University, Coimbatore. These dumps were terraced to different Benches with proper drainage facilities and irrigation facilities and suitable species are identified for plantations in the slopes in order to have soil compact ability and for green belt. In order to have proper moisture on the slopes, drip irrigation system has been developed and the slopes are being stabilized.

Objectives

- Evaluating soil conservation measures and erosion control measures towards slop stabilization.
- Screening best suitable trees, shrubs and grasses which are come up well in the mine spoil eco system; to stabilize the slope from erosion.

Activities carried out in mine slope

- The drainage channel – mines spoil filled gunny bags were lined (gabion structure) to reduce the erosion.
- Benches were made along with each slope.
- Irrigation – micro irrigation (drip sprinkler (rain gun)) installed in all the slopes.
- Each slope divided in to four blocks and four different pit sizes were used to evolve the best suitable pit size in mines spoil eco system.
- Pot culture experiments were conducted.
- Based on the screening , selected grass pieces ,shrub species and tree species being planted as shown in **Photo 2**

ARTIFICIAL LAKE

Artificial lakes have been developed fully in all the three mines for a total area of 46 hectares with aqua culture and original habitant formation is being brought back. Mine-II artificial lake is developed under Indo-U.S. project collaboration is shown in **Photo 3**. In Mine-I, the lake has been formed in the afforested area which serves as a bowl for collecting rain water. The whole area around this lake has been converted as a park by planting flowering trees, fruit trees and rest shelters.

A Mini Zoo has also been developed with spotted deer, rabbits, peacocks, lovebirds, parrot, doves, fowls, etc. besides boating facilities. Different kinds of fishes are also reared in the aquarium maintained in the park. Apart from this, a nursery has also been developed. Fauna Flora has been developed very well and more than 250 species of birds are migrating to this area.

GREEN BELT DEVELOPMENT — CREATING LUNG SPACES

- N.L.C. is maintaining thick and massive green belt in its Industrial Units and Township.
- Township is maintaining greenery by planting trees like Neem, Eucalyptus, etc. including fruit bearing trees like mango, jack fruit, etc.
- Every year, additional tree plantations are being taken up.

- A Golf Course ground has been developed in the Township with beautiful landscape with lawn and made it to International Standard.
- Horticulture: There are four Nurseries maintained in the Township by N.L.C. Horticulture Department for raising saplings of fruit bearing trees, flowering trees and shrubs.
- Around 20 million trees have been planted in and around Neyveli Township and Production Units, which helps in maintaining clean environment, dust suppression, noise control, lowering the atmospheric temperature and maintaining ecological balance.

Photo 2 Overall view of outside dump slope at Mine 2

Photo 3 Artificial Lake formed in the refilled area

DEVELOPMENT OF AN ORCHARD, HERBAL AND MEDICINAL PLANTS:

An orchard has been developed in an area of 100 ha. by planting different varieties of fruit bearing trees and also Herbal cultivation is undertaken in the reclaimed area to cater the needs of Ayurveda dispensary of NLC and also public. The yield from this land is as good as the product from natural and normal agricultural lands.

DUST CONTROL

Dust emission during the mining operation has a major role in determining the impact on Environment. Dust is mainly generated

- At the excavating faces of the Bucket Wheel Excavators as shown in **Photo 4**.
- At the transfer points of the conveyors where the over burden and the lignite are transferred from one conveyor to another conveyor.
- At the haul roads due to movement of earth moving equipment and transport vehicles.
- At the dumping side of the over burden soil.
- Blasting hole drilling area.

The concentration of dust samples are measured periodically and the results are not exceeded the threshold value.

Dust Suppression Measures

In order ensure that the dust concentration is within the threshold limits, the following remedial measures are undertaken.

- The excavating face & dumping side of the mine is wetted constantly
- The transfer points/hopper at the conveyor is provided with hoods/covers
- The belt cleaning devices and rubber wiper are checked up daily.
- Water Lorries, water dumpers, sprinklers are deployed for wetting.
- All employees are provided with respirators, goggles and dust masks.

- Dense tree belts are created at the surface of the mine.
- Trees are planted on both sides of the roads to arrest dust.
- Readings of the dust samples are collected and analysedat frequent intervals.
- All the roads along the conveyors have been provided with spray line to suppress the dust.

Ambient Air Quality Monitoring

As required by the Government of India and Tamil Nadu Pollution Control Board (TNPCB), continuous air monitoring is being carried out in 13 locations in and around Neyveli region and the air ambient quality monitoring for the assessment of PM10, SO2&NOX have also been carried out twice in a month in different locations in the mines.It is observed that ambient airquality are within the permissible limits prescribed by the statutory authorities.

GROUND WATER AND STORM WATER

Water pumping operations in the mines relates to pumping of ground water from the aquifer which is under artesian condition occurring immediately below the lignite bed. The other one, namely storm water operation being the pumping of extraneous water Viz. rain water and seepage water collected in the benches of the mine. The storm water is let out for irrigation to the downstream/adjoining villages. The water samples are regularly sent to Tamilnadu pollution control board lab for analysis and the analysis results are within the standard limits. Layout of SWC operation is shown in the **Photo 5**.

Photo 4 Dust emanation at Bucket Wheel Excavator in overburden cut face and controlled by continuous water spray arrangement

Photo 5 Storm Water Control Operation in Lignite Mines at Neyveli

GROUNDWATER MANAGEMENT

NLC as part of water groundwater management plan is continuously monitoring the ground water basin's conditions with particular reference to extraction of ground water for mine safety control purpose.

WATER CONSERVATION MEASURES

The ground water pumped from mines are completely diverted and consumed by industrial units. However, with an eye on regional ground water budgeting the Optimizations of mines pumping is attempted in right earnest by adopting certain field measures viz.Creating check dams, Percolation ponds nearby village Nallahs, ,Artificial recharging of ground water .and

- By pumping at nearest location to the excavation phase leading optimisation.
- Controlling the pumping rate according to the level of excavation.

- Diversion of treated storm water from mines used for domestic / Industrial purposes, leading preservation equal quantity of Ground water.

EFFLUENT TREATMENT PLANT

Canteen ETP

All the Lignite mines got canteen facilities to serve to employees in all the three shifts. The effluent water generated from the activities like food preparation, grain washing, vessels and floor washings is being treated with Physical and Biological treatment process and let the treated water to open canal.

Mini Auto Garage ETP

All the Lignite mines have Auto Garage for servicing all vehicles working for mining activities. The effluent water from vehicle cleaning,washings,spillage of oil and grease is being treated oil separator,clarifier and chemical system of alum/ polyelectrolyte method and let the treated water to open canal.

Both the samples after treatment are tested and found within the limit prescribed by Tamil Nadu Pollution control Board.

Resettlement and Rehabilitation Policy of NLC

In acceptance of its social responsibility, NLC has been offering jobs to the Project Affected Persons (PAPs) to the extent possible, apart from resettling them in the well-developed Resettlement Centres (RCs).Further, a Corporate Resettlement and Rehabilitation Policy (RAP) has also been framed and being implemented for the benefit of the various sections of the PAPs who have given lands from 1.7.1989 onwards. The displaced persons are being resettled smoothly as per the provisions of the RAP in NLC Resettlement Centres (RC).

Resettlement

Resettlement and rehabilitation of Project Affected Families (PAFs) is carried out by giving a plot of land in well developed Resettlement Centres (RC) or a lump sum package to settle at a place of their choice. The RC is provided with proper infrastructure amenities and services

Economic Rehabilitation/Livelihood Assistance

Over and above the legal/RAP entitlements for compensation and resettlement, the RAP also envisages livelihood assistance as detailed below.

- The PAPs are given permanent job opportunity in NLC by earmarking 60% of the vacancies arising in unskilled category.
- Every year PAPs are being exclusively selected for ITI apprenticeship training by notification through press/local advertisements instead of through Employment exchange as in general case.
- 40% of the temporary jobs arising under various contracts are earmarked for the PAPs who are not eligible for permanent job or who await permanent job in NLC.
- Training for self-employment is being arranged at NLC training complex in co-ordination with Gandhi gramRural institute.
- Several contracts are awarded to PAP societies on concessional terms in order to provide self-employment to the members of PAFs.

After notification of NRRP 2007 on 31.10.2007, NLC has agreed to implement the same in NLC with effect from 31.10.2007.

PERIPHERAL DEVELOPMENT SCHEME (PDS)

NLC has been allocating funds in the annual budget for PDS and infrastructure development works such as provision of drinking water, schools, roads etc. Sinking of new bore wells, repairing and reconditioning of pumps are done by NLC for providing drinking water in the peripheral villages. New schools are constructed and existing schools are also renovated for the education of children in the peripheral villages. NLC is running 3 higher secondary schools, 2 high schools, 6 middle schools and 5 elementary schools in which 13,000 students are studying, of which 82% are from nearby villages. Health care camps covering maternity, childcare, immunization, cardiology, orthopaedics, eye care etc. are conducted periodically. Patients from the peripheral villages are treated in the NLC General Hospital, Roads, footbridges, causeways are constructed to enhance the access and connectivity in the peripheral villages.

The enhanced compensation cases are being settled through Lok-Adalat as per applicable rates decided in the meetings and approved by the Management.

CONCLUSION

“Ecological balance is to preserve nature and untiring efforts are being put in all the three Mines to maintain and sustain the ecological balance in spite of the continuous mining activity necessary for development of economy and employment generation. The Neyveli Lignite Mine’s Environmental Management System and maintaining Ecological Balance are becoming a symbolic role model for any of the open cast mines in the Southeast Asia. The efforts have been appreciated and awarded by the governmental and non- governmental agencies.Renewable energy sources like solar plant installation are being done in the mined out area as well.

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Shaping the Future of Minor Mineral Sector through Responsible Mining and Ethical Practices: In Indian Context

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***Abstract** : Mines & Mineral Development and Regulations Act1957 under Act -3(e) , says Minor Mineral means building Stone, gravel, ordinary sand other than sand used for prescribed purpose and other mineral which GOI may by notifications declare to be minor mineral. Mines extracting minerals are by majority, barring a few, are operated by small mine operators who are in unorganized sector. Unethical practices in minor mineral mines and it's consequences are well evident. Major environmental issues like poor mineral recovery, huge waste generation, no concerns to social development, air and water pollution are major issues in present minor mineral sector. However major environmental and social impact can be avoided/ minimised if the lessee operate the mines according to best practice standards of mining committed to sustainable social development. Social Ethics bind the mine operators to adopt fair labour practice and create healthy working conditions. The objective is to ensure that the social, economic well- being and health of workers is maintained. Bible allows responsible mining. Social welfare is the ultimate aim and goal of any mining activity.*

***Keywords**: Minor Mineral, Social Sustainability, Ethics, Ethical Behavior, Environment.*

INTRODUCTION

Minor mineral sector contributes largely towards country GDP besides large employment to local people. There are 55 minor minerals in India. Total Contribution by minor mineral as estimated in 2013-14 was Rs 52 ,490 Cr. Contribution of various States varied from 23.62% in AP, Gujarat by 23%, Rajasthan 12.9%, Maharashtra 14.6% , Karnataka 3.9,% MP 3.7% Goa 1.6 %and in smaller proportion in other states.

Ethics in minor minerals have many dimensions. On pretext of small scale of mining, low profit, low production, they show unwillingness to comply with any Law of land related to Labour.

The operators unwilling pay the minimum wage. They feel that they are paying high wages than they get in return. It's only Governments enforcement, regulation, fine that pay the wages. In canoyance of Union's and Enforcing authorities, they try to find some ways to pay less and skip or avoid to pay fringe benefits like PF. Bonus, Leave and benefits as provided in Labour Laws.

ETHICAL BEHAVIOR OF MINE OPERATORS

Stake holders for environmental binding on mining minerals includes, Mine operators, State Government, Ministry of Environment and Forest Conservation GOI through its Pollution Control Board and the respective Regional Office. Ethically it is expected of mine operators to pay the Govt Revenue in time and right amount to discharge it's social responsibility towards the nation. IRMA specify that there has to transparency of revenue payment.

IRMA Standards says that the capacity of governments to effectively manage and disclose material payments and revenues received from mining industries derived from the extraction of a country's mineral wealth has an impact on reducing poverty or generating broader economic growth or benefit than may have otherwise been possible.

Increased transparency of material payments to and revenues received by the host country government can be one step toward addressing this matter.

Governments, companies and civil society working together to improve openness and accountable management of revenues from natural resources allowing citizens to see for themselves how much their government is receiving from their country's natural resource.

The purpose of this is to increase the transparency of material payments made by mining companies and/or received by governments, providing communities and the general public with the information they need to understand and assess the fairness of financial arrangements related to mining operations. It is ethical for minor mineral industry as well to pay all applicable tax and revenue to Govt. Payments Transparency Requirements Means of Verification of the mine operators of production entitlement, royalties, profit tax, dividend licence fees, rental fees, entry fees and other considerations for licences and/or concessions and any other significant payments and material benefit to government.

SOCIAL ETHICS

Social Ethics bind the operators to adopt fair labour practice and creat healthy working conditions. There are existing standards that aim to protect labour rights and ensure fair working conditions. Workers having first-hand knowledge of environmental, human rights and labour practices must have the right to participate in the verification process without fear of employer retribution, as needed by the independent auditor. This can be best guaranteed by workers having the right to freely establish or join trade unions of their choosing without employer interference and through protections provided in collective bargaining agreements.

The objective is to ensure that the social and economic well-being and health of workers is maintained or enhanced. This will be accomplished by ensuring that companies protect the basic rights of the workers they employ directly and those that are employed by its contractors and suppliers. Government has laid down Indian Labour laws governing working conditions, payment of wages and other benefits such as PF, bonus, earned leave, medical care, gratuity and other social benefits.

The mine operators including those mining minor minerals are expected to comply to discharge their social duties. The intent of this issue is to ensure that a company provides a safe and healthy environment that protects and promotes workers' health and their working capacity. This will be accomplished through consultation and cooperation with workers and/or their representatives to identify workplace hazards and risks, implement measures to eliminate or minimize workplace hazards and risks, and develop and provide information and training programs to promote workplace safety and health.

Malaria has been a dreaded disease but GOI campaign for Malaria eradication has been of great success. Besides State Govt efforts, lessees take adequate measures against malaria mosquitoes by avoiding standing water, sprays and creating health awareness among workers. Setting up dispensary at mine level for immediate aid to such worker and his family member. Another serious problem found among mine workers is TB. Dust is created at drilling site and vehicular movement within mine area. Inhaling dust certainly effects lungs if exposed over a period of time. Besides this consumption of alcohol, in-sanitation and food deficiency leads to TB.

Social ethics binds mine operators to avoid falling of any heritage prepare adequate R/R plan for shifting habitation close to mining area diverting pumping water to nearby agriculture fields, sharing BCS excavated from mine area for improving land status, making good arrangement of drinking water even in residential colonies, setting up primary schools at mine level, setting up college for higher studies, no indiscrimination among cast, religion among workers, accidental compensation as per law and immediate.

ISSUES RELATED TO SUSTAINABILITY IN THE MINING OF MINOR MINERAL IN INDIA

Minor Mineral

Mines and Minerals Development and Regulation Act 1957,under Act-3(e), says Minor Minerals means building stone, gravel, ordinary clay, ordinary sand other than sand used for prescribed purpose and any other material which GOI may by notification in Official Gazette declare to be a minor mineral. Scale of operation and level of mechanisation in minor mineral mines is very low.

The minor mineral are by majority, barring a few, are operated by small mine operators who are in unorganised sector, with limited investment and limited production and mostly manual. Their most concern is their profits. They don't believe in compliance of any law. They feel environmental compliance as additional financial burden rather than as integral part of his mining activity.

SUSTAINABLE DEVELOPMENT

Mining is a complex and intensive process that can have major environmental and social impact. Even in the best managed mine some degree of disturbance is inevitable. In some cases the potential of harm may mean that a decision not to mine may best decision. However in most cases the most negative social and environmental impact can be avoided/ minimised if the lessee operate the mine according to best practice standards of mining and committed to Sustainable Social Development. There is always conflict between mine operators and environment regulators.

ETHICS AND MINOR MINERALS OPERATORS

Unethical practice in minor mineral mines and it's consequences are well evident. On pretext of small scale of mining, low profit, low production, they show unwillingness to comply with any Law of land related to Labour. The operators unwilling pay the minimum wage. They feel that they are paying high wages than they get in return. It's only Governments enforcement, regulation, fine that pay the wages. In unlawful understanding with Union's and Enforcing authorities, they try to find some ways to pay less and skip or avoid to pay fringe benefits like PF. Bonus, Leave and benefits as provided in Labour Laws.

Major environmental issues like poor mineral recovery, huge waste generation, no concern to social development, air and water pollution are major issues in present minor mineral sector.Breach of ethics and it's principles in mining is not acceptable to society. Every mine operator has to take social license before mining.

RESPONSIBLE MINING

Responsible mining leads to sustainability and ethical system and Vice-versa. However IRMA Standards -16, has prescribed certain standards of Ethical system for mine operators to abide.These have been summarised as below:

Revenue and Payments Transparency: IRMA Standards

The capacity of governments to effectively manage and disclose material payments and revenues received from mining industries in resource rich countries is sometimes underdeveloped. Revenues derived from the extraction of a country’s mineral wealth sometimes have a lower impact on reducing poverty or generating broader economic growth or benefit than may have otherwise been possible. Increased transparency of material payments to and revenues received by the host country government can be one step toward addressing this matter.

Governments, companies and civil society are working together to improve openness and accountable management of revenues from natural resources allowing citizens to see for themselves how much their government is receiving from their country’s natural resource.

There is need to increase the transparency of material payments made by mining companies and/or received by governments, providing communities and the general public with the information they need to understand and assess the fairness of financial arrangements related to mining operations. It is ethical for minor mineral industry as well to pay all applicable tax and revenue to Govt.

Payments Transparency Requirements Means of Verification of :

a. The host government's production entitlement.

b. National state-owned enterprise production entitlement.

c. Profits taxes.

d. Royalties.

e. Dividends.

f. Bonuses, such as signature, discovery and production bonuses.

g. License fees, rental fees, entry fees and other considerations for licenses and/or concessions.

h. Any other significant payments and material benefit to government.

FAIR LABOUR AND WORKING CONDITION, IRMA STANDARD

There are existing standards that aim to protect labour rights and ensure fair working conditions. Workers having first-hand knowledge of environmental, human rights and labour practices must have the right to participate in the verification process without fear of employer retribution, as needed by the independent auditor. This can be best guaranteed by workers having the right to freely establish or join trade unions of their choosing without employer interference and through protections provided in collective bargaining agreements.

IRMA Objectives

The objective is to ensure that the social and economic well-being and health of workers is maintained or enhanced. This will be accomplished by ensuring that companies protect the basic rights of the workers they employ directly and those that are employed by its contractors and suppliers

ACTUAL STATUS IN KOTAH STONE MINES (MINOR MINERAL)

In compliance to Indian Labour laws no worker is allowed to work for more than 8hrs/day or 48hrs/ week. Each worker is allowed one day off/ after 48hrs working. In case work is of continuous nature (24x7), each worker is given one day off by rotation.

Employment of females is prohibited after sunset.

Payment of PF, Gratuity, Paid leave, Bonus, Medical care. Payment direct transfer to Bank a/c, Children creche for female workers drinking water at work place, high level of safety standards at work level, infect there was sharp reduction in mining accidents.

Paid leave is given to each worker @rate prescribed I'd Act.

Equal remuneration to male-female workers for same nature of job.

Each worker, at the time of appointment, is given 7 days initial training in Vocational training centre. Periodic training is organised to develop skill.

Local workers given preference, +80% workers from close-by villages. Skill development and promoting entrepreneurship among local workers on various mining activities, awarding contracts.

Workers are free to form and join a Union for addressing their problem before management.

All workers are enrolled in a Register of Employment with his personal details. A unique code of identification is given to each worker. There is participation of worker in Safety Committee, Labour Welfare Committee, PF Committee and other where interest of worker is involved.

The intent of this issue is to ensure that a company provides a safe and healthy environment that protects and promotes workers' health and their working capacity. This will be accomplished through consultation and cooperation with workers and/or their representatives to identify workplace hazards and risks, implement measures to eliminate or minimize workplace hazards and risks, and develop and provide information and training programs to promote workplace safety and health. The number and nature of occupational illnesses, injuries or fatalities.

ACTUAL STATUS in ONE OF THE STONE MINE EXTRACTING KOTAH STONE ADOPTING RESPONSIBLE PRACTICE

Each worker is given safety gadgets as required and prescribed under Indian Mines Act. The innovated clean technology has not only reduced mine accidents to 1/6th but has also helped in improving work efficiency by 2.5 times. The use of water at pressure for cooling diamond tool has helped in creating a cool and comfortable working environment at working level.

In the innovated technology many manual, hazardous and ordeous operations have been mechanised reducing physical fatigue and mental stress and reducing personal injuries. Continuous training on job and in class has helped in reducing injuries improving work performance.

With clean working floor probabilities of injury from slipping and falling has almost eliminated. With clean floor head loading of Kotah Stone slabs/tiles and carrying distance away has reduced as transport vehicle can be parked close to stacks. Many accidents have been eliminated.

Malaria has been a dreaded disease but GOI campaign for Malaria eradication has been of great success. Besides State Govt efforts, lessees takes adequate measures against malaria mosquitoes by avoiding standing water, sprays and creating health awareness among workers. Setting up dispensary at mine level for immediate aid to such worker and his family member.

Another serious problem found among mine workers is TB. Yet dust is created at drilling site and vehicular movement within mine area. Kotah Stone does not contain free silica but it is intrinsically held and does not cause Silicosis ailment. However inhaling dust certainly effects lungs if exposed over a period of time. Besides this consumption of alcohol, in-sanitation and food deficiency leads to TB.

No heritage falling area, adequate R/R plan for shifting habitation close to mining area. Diverting pumping water to nearby agriculture fields, sharing BCS excavated from mine area for improving land status.

Making good arrangement of drinking water even in residential colonies, setting up primary schools at mine level, setting up college for higher studies, Human Rights: No Indiscrimiation among cast, religion among workers, accidental compensation as per law.

ISSUES RELATED TO SUSTAINABILITY IN THE MINING OF MINOR MINERAL

Sustainable Development

Mining is a complex and intensive process that can have major environmental and social impact. Even in the best managed mine some degree of disturbance is inevitable. In some cases the potential of harm may mean that a decision not to mine may best decision. However in most cases the most negative social and environmental impact can be avoided/ minimised if the lessee operate the mine according to best practice standards of mining and committed to Sustainable Social Development

RESPONSIBLE MINING

Bible allows Responsible Mining. Social welfare is the ultimate aim of and goal of any mining activity. Any activity which is harmful to society or damages environment which can't be repaired or minimised / rehabilitated cannot be sustainable. Best Practice and Responsible Mining for Kotah Stone

To address economic, safety & health and environmental issues arising from manual mining, an innovative mining technology was evolved by the author. The concept is to first cut the layers in- situ before separating the layers of Kotah Stone . Blocks are cut in desired width and length. Width is generally 2'. All sides cut blocks are then separated from natural bondage with crowbar giving gentle leverage. These are then splitted along cleavage plane to yield all sides cut single solid slab/ tile.

Figure 1

Figure 2a

Figure 2b

Figure 3

For cutting the layers of Kotah Stone in- situ portable electrically operated machine fitted with 36" dia steel blades were designed and perfected. The steel blades are tipped with diamond impregnated segments 64 in numbers. These machines locally known as Jhiri m/c are operated on 2' wide portable track

Water at pressure is forced into slit cool the cutting tool and also flush out the cutting slurry. The machine is operated at given peripheral speed of 33-36 m/ sec which cuts layers to a depth of 12" at a linear speed of 30"/ mint.

In this system there is hardly any breakage except when there is a natural crack. Physical human efforts has substantially reduced leading to increase in productivity to 2.5 times. Density of employment reduced from 1 to 0.4 per square ft floor area providing more walking space. Earlier with manual mining layers only -3" thick we're mined and rest thrown as waste. But with mechanised mining all solid layers irrespective of thickness are being mined successfully. This improved mineral conservation.

CONCLUSION

If you have to choose between ethics and job, choose ethics because you can get many jobs. Ethics in minor minerals have many dimensions. On pretext of small scale of mining, low profit, low production, they show unwillingness to comply with any Law of land related to Labour. The players unwillingly pay minimum wages. They feel that they are paying higher wages than they get in return. It's only Governments enforcement, regulation, fine that they pay the right wages.

But now after adopting Responsible Mining technology, economics has highly improved. Now mine operators can happily pay to their workers mote than their legitimate rights. It's rightly said a Happy worker is highly productive and safe.

Social welfare is the ultimate aim and goal of any mining activity. Any activity which is harmful to society or damages environment which cannot be repaired/minimised/ rehabilitated cannot be sustainable. Bible allows Responsible Mining. Mining for people needs ethical behavior of mine operators and ethical practices.

Mine operators should observe self-restrain from any action which is not ethical and harmful to society. Mine operators should treat workers as their business partners and share with them their dues. Social license is now essential before starting operations.

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Sustainable Mining Practises in Open Cast Mines

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***Abstract**: Sustainable mining aims to maximise resource utilisation, to minimise adverse impact of Mining in a sustainable way, to ensure the Carbon Neutralityto avoid Climate change andto ease the lives of people and communities residing in and around mining areas. Sustainable mining also focusses on Air quality management, Water quality management, reutilisation of pumped water from mines in effective way, Refilling the mined-out area by maintaining same soil strata as originally present before mining. Sustainable mining also emphasis on effective recycling and reutilisation of mining products by producing different possible products like Over Burden to Sand, Ball Clay production etc during Lignite or Coal mining.This minimises the need of multiple mines. Sustainable mining also needs utilisation of state of art technology like Artificial Intelligence in Mining Equipments, Mine planning, Digital twin of mine model, Automation of Mines, Remote monitoring of mines to enhance safety, GPS based remote monitoring of CME equipments for effective utilisation of equipments. Adopting VVVF drives for power and material saving, Pipe conveyor for effective material transfer, Drone survey and many more to improve effective mining and to improve safety and productivity. Refiling and Reutilisation of mined out area in effective way also enhances the mines sustainability. Developing Afforestation, artificial lake, Goshala and manure development for soil enriching the refilled area soil,Eco tourism, Solar power generation, developing pumped storage plants, in mined out area makes closure of mines in sustainable way. Reusing the mine out area for Green Hydrogen generation [1] is a major trust area for India. Because huge quantum of area will be available after refilling the mined out area at cheaper price, along with mine water and Electricity facility. This can be used for Green hydrogen production at competitive price. In addition it will improve the employment of the local people in long term. Exploring new ways of mining through Research and Development, like underground gasification of Coal or lignite. Exploring new ways of utilising the mined out products, like converting lignite to humic acid, Lignite to methanol, lignite to Graphane etc also improves sustainability of Mines. Sustainability of mines also depend on perception of inhabitants around the mining project. In general, any mining project, change the traditional lifestyle of the original inhabitants and indigenous communities and also change the socio-economic profile of the area. CSR activities also focus on women Empowerment, Skill development, Education facilities, Drinking water facilities, sanitation facilities etc. When these projects improvesemployment, financial and health condition of the inhabitants and the Corporate Social Responsibility activities carried out by the Mining companies, together creates a positive perception about the projects, as it will create a positive change in the inhabitants life style.*

***Keywords:** Sustainable Mining, Green Mining, Sustainable Green Mining, Green Mining Practices, Sustainable Mining Practice*

AIR QUALITY MANAGEMENT [2]:

Open cast Mining operations normally leads toheavy dust. The normal best practices followed by industries are

a. Green Belt: Inhabitants around the mines or Bunker may be affected by the dust from mines or Bunker. Dust suppression by Green belt development in Bunker Areas & around the mining area effectively improves the air quality around the area. Native trees were planted with a density of 2500 trees per ha [3]
b. Electrically Operated equipments normally improves air quality by reducing emissions from IC engines. Adoption of Electrically Operated specialised mining equipments like Bucket Wheel Excavators, Belt Conveyor System, Mobile Transfer Conveyor, Spreader systems drastically reduces movement of heavy equipments. All together improves air quality and reduces carbon foot print.

c. Installation of Water sprinkler/Fog systems, Haul road water sprinklers, Vehicular water spraying/Pressurized mobile water sprinkling system for roads inside the mines, Conveyor water spraying, Working face water spray pipelines, Fixed water sprinklers guns in Bunker area, Fog Cannon dust suppression system in Coal Stock Yard may improve air quality in Open cast mines.
d. Wet operated Drills, controlled blasting also improves air quality.

Now a days in addition to following all statutory norms and conducting frequent Air quality tests from authorised labs, some of the companies installed Continuous Ambient Air Quality Monitoring Stations (CAAQMS)[2]

WATER MANAGEMENT [3]

Water pumped from mines is limited by Ministry of Environment, Forest and Climate Change. The storm water received from mines are treated and used for township, power plants etc. Through a network of wells, the ground water level and its quality are monitored frequently.

Percolation wells and Percolation Ponds are very effective for Artificial Recharge, of water into ground. Artificial recharge through Deep Injection technique is useful to recharge deep seated confined aquifer. A detailed study is required to design a Artificial Recharge plans.

A optimal plan for ground water pressure control in mines is required and near by area inhabitants wells also needs to be monitored to avoid becoming dry. Some of the mines, reuses the water for their thermal plant water requirements, nearby village irrigation purposes, even for nearby metros drinking water purposes.

REFILLING OF SOIL

Over burden Dumping areas needs to be identified through scientificmanner. The total height of dumps should not exceed, 65m in two or in three stages. The overall dump slope should not exceed 28 degree. Backfilling and rehabilitation should start from fifth year of operation [3].

RECLAMATION OF DUMPED AREA

One of the key sustainable initiatives to enhance the green cover in and around mining areas through activities like ecological reclamation of mined out land and overburden dumps, plantation in and around mines, avenue plantation, and restoration of flora and fauna with an aim to leave a lighter mining footprint after the closure of mining.

While preparing dumping area Artificial lakes, Native plantations, Eco tourism parks, slope stabilisation, dust suppression, High tech agriculture, Polly house agriculture, Vertical farming, soil preparation all are considered.

Goshala in dumped area with native varietycows with integrated elephant grass plantation in dumped area for feeding cows, manure preparation in Goshala, Goats rearing for integrated farming, Free roaming Desi Chicken, Cock in the farm land is the natural way to reclamation of land [4].A study aimed at determining biogas production from codigestion of Elephant grass and cow dung using batch digester, showed better results than normal process[6].

Vriksharopan Abhiyan is organised by Ministry of coal and Coal and Lignite PSU planted plantations in large scale in suitable areas. Seeding distributed in nearby areas [5]

Ground mounted solar plants are executed in dumping area [7]. Execution of Pumped storage plants to meet peak load is under study. Abandoned mines, suitable areas in mines are under study to execute this project [8]

ALTERNATIVE USE OF OVER BURDEN (OB)

As per Ministry of Coal, Sustanability in Coal Mines chapter -7 emphasis on alternative uses of OB. Over burden to Sand, Bal clay from Over burden are under progress in different Coal /Lignite companies in India [4]. These sands are technically found fit for construction purpose. This type of activities may minimise the need of river based sand quarries and its adverse effects.

ALTERNATIVE USE OF LIGNITE/COAL

As per CMPDIL annual report [9] page 82 Low grade coal to High grade Graphene and Carbon nano particles for energy storage are under study. Lignite Mines companies successfully developed Humic Acid from Lignite [10]. This humic Acid is used to make Graphene quantum dots [11]. All together Lignite Mining companies has great potential to develop new business in near future.

Our Hon'ble Prime Minister's Vision of reducing the import dependency on oil and GAS [14], The Methanol Economy [12] emphasised lot to reduce import of Crude oil. Coal to methanol pilot projects are successfully experimented [13]. Commercial operation of lignite tomethanol[15] and Coal tomethanol [16] are under progress.

FIRST MILE CONNECTIVITY (FMC) PROJECTS

Ministry of Coal 's, National Coal Logistic Plan includes FMC projects.FMC projects is to reduce the use of fossil fuel powered vehicles for coal transportation. To achieve this Conveyor belts are used or roads to nearest railway siding [16]. Ministry of coal has prepared plan to improve the mechanized coal transportation and loading system under FMC projects.A total of 67 FMC Projects with 885 MT capacity are being taken up in three phases to achieve capacity of 1BT mechanized handling of coal.

This FMC projects will help to reduce carbon foot prints, mitigating the climate change, to reduce air pollution, to reduce noise pollution due to heavy vehicle transport etc.

CONCLUSION

Easy the life of people in and around the project area is most important result achieved from above activities. Improving employment and skill of inhabitantsisalso important for easy of executing the project. With all these efforts India's commitment to reduce Emissions Intensity of its GDP by 45 percent by 2030, from 2005 level; achieve about 50 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030 [17], and Net carbon Zero will be achieved by 2070 without affecting our GDP growth with the contribution of Mining In sustainable way.

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Critical Mineral Deposits in India: Resource Management from Primary Mineral Deposits and Secondary E-waste with Sustainable Resource Management Practices: A Typical Analysis

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Abstract: *Critical minerals (CMs) are metals and non-metals that play a significant role in developing a country's economy and security. Geologically, most countries worldwide have identified critical minerals as per their national priorities and future requirements and developments. The lack of critical metallic and non-metallic mineral deposits in the country leads to disrupted supply chain vulnerability and impacts the nation's development. The critical minerals occur in three major resources. They are primary mineral deposits. Secondary minerals extract waste materials such as electronic waste and tertiary. Factors influencing the designation of critical minerals by individual nations in the world.Each nation has its own designated mineral deposit potential to sustain its economic and defense requirements. The main factors that influence criticality depend upon five prime dimensions, such as: i) economic dimensions; ii) supply chain; iii) technology requirements; iv) geopolitical issues; and v) geological parameters that influence the criticality of minerals. Each nation listed the critical minerals based on their reserves, resources, and the extent of restrictions on exploitation and requirements. The United States of America (USA) listed 50 mineral commodities critical to their economy in 2022. The United Kingdom declared 18 critical minerals, the European Nations listed 34 raw critical minerals, Japan designed 311 minerals for its economy, and Australia declared 26 critical minerals based on the country's requirements. The Ministry of Mines and Government of India officially declared 30 critical minerals for the year 2022. These minerals include antimony, beryllium, bismuth, cobalt, copper, gallium, germanium, graphite, hafnium, indium, lithium, molybdenum, niobium, nickel, PGE, phosphate, potash, REE, rhenium, silicon, strontium, tantalum, tellurium, tin, titanium, tungsten, vanadium, zirconium, selenium, and cadmium. The primary source materials for CMs are different minerals and ore minerals that occur in diverse rock types and ore deposits on Earth. These primary sources—ore deposits, hosted by the magmatic, sedimentary, and metamorphic-metasomatic rocks—are all affected by diverse mineralisation processes that include hydrothermal activity, syn-/dia-/epi-genetic effects, remobilization-recrystallization, weathering, transportation (as in placers), etc. India can give top priority to astrogeology and astro-mining to explore and exploit critical minerals from the Moon and other planets. Critical mineral resource management necessitates, exploiting primary, secondary, and e-waste with the latest innovativetechnologies.*

Keywords: *Critical Minerals, Primary Minerals, Ore Mineral Deposits, E-Waste Geological Parameters, Astro-Mining, Resource Management.*

INTRODUCTION

Critical minerals refer to mineral resources, both primary and processed, which are essential inputs in the production process of an economy, and whose supplies are likely to be disrupted on account of non-availability or risks of unaffordable price spikes. These minerals lack substitutability and recycling processes. The global concentration of extraction and processing activities, the governance regimes, and environmental footprints in resource-abundant Countries adversely impact availability risks. While some of these minerals are inputs for traditional industries, many are crucial for the high-tech products required for clean energy, national defence, informational technology, aviation, and space and research, (Chadha 2020).Most of the countries in the world have identified critical minerals as per their national priorities and future requirements. In India also, some efforts have been made in the past to identify the minerals which are critical for the country. However, international commitments towards reducing carbon emissions require the country to urgently relook at its mineral requirements for energy transition and net-zero commitments. This Ministry has therefore identified the thirty critical minerals needed for meeting the growing demands of the country. We will be revisiting the list periodically. (Vivek Bhardwaj, 2022)

The committee constituted by the ministry has analysed the list of critical minerals of various countries, taken inputs from stakeholders and ministries to identify the requirement of minerals for their sectors, analysed the reserve position of these minerals in the country and import dependency of such minerals before finalizing the list(Vivek Bhardwaj, 2022)

What are "critical" minerals, and why do they matter?

The term "critical minerals" is the most common terminology, and it is often used interchangeably

Withthe terms "strategic minerals," "strategic and critical minerals," and "energy transition minerals. "The minerals and ore-minerals required to sustain low carbon emission that are required for the renewable energy transition to a more sustainable low carbon future are also referredto as critical minerals. There is no universally agreed-upon definition of what "criticality" means, and criticality changes over time, depending on the needs of society and the availability of supply.

FACTORSINFLUENCING THE CRITICALITY OF MINERALS

Critical minerals designation depends upon various factors. Several nations listed the critical minerals based on their resources, shortages, and requirements for industrial, defence, sectors. Most of the nations listed the minerals based onthe international action plan on climate change and sustainableeconomicdevelopment. The following factors are determined for the listing of critical mineralsdepending upon economic considerations, and the supply chain of designated critical minerals. Critical mineral designation depends upon five dimensions namely i) economic dimensions, ii) Supply chain dimensions,iii) Technology,iv) Geopolitical issues, and v) Geological-mineral resources. (Martiai.H, 2022).

Critical Minerals listed by the Ministry of Mines Government of India-2022-2013: The Ministry of Mines and Government of India officially declared 30 critical minerals for the year 2022. These minerals include antimony, beryllium, bismuth, cobalt, copper, gallium, germanium, graphite, hafnium, indium, lithium, molybdenum, niobium, nickel, PGE, phosphate, potash, REE, rhenium, silicon, strontium, tantalum, tellurium, tin, titanium, tungsten, vanadium, zirconium, selenium, and cadmium (Anon 2022).

Critical minerals importing: Major critical hundred percent minerals importing-Lithium, Cobalt, Nickel, Vanadium, Niobium, Germanium, Rhenium, Beryllium, tantalum, and strontium. Zirconium (80%), Graphite, natural (60%), Manganese, (50%) Chromium, (2.5%) Silicon<1 %.(Anon 2022)

The plan for extensive mineral exploration and exploitation depends upon the geological availability of primarily mineral deposits—a secondary source of CMs: processing, recycling, and extraction technology. (Dhana Raju 2020, Dhana Raju and Venkat Reddy, 2017, 2018)

CRITICAL MINERAL EXPLOITATION, MINING WITH –SUSTAINABLE RESOURCE MANAGEMENT –A-CRITICAL ANALYSIS

The primary source materials for CMs are different minerals and ores that occur in diverse rock types and ore deposits on the earth (suggested from the Indian perspective). These primary sources—ore deposits, hosted by the magmatic, sedimentary, and metamorphic-metasomatic rocks—are all affected by diverse mineralization processes, including hydrothermal activity, syn-/dia-/epi-genetic effects, remobilization-recrystallization, weathering, transportation (as in placers), etc., and are mined conventionally after: (i) comprehensive mineral exploration by the geological-geophysical-geochemical and related laboratory-based studies and (ii) establishment of a cost-effectively (Dhana Raju,(2020).

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Geological availability of Critical Mineral Deposits

The critical mineral deposits,which include metallic and non-metallic deposits, are formed under diverse geological formations with associated common mineral deposits and occurrences in the geographical locations of our country. The Ministry of Mines initiates exploration for designated critical minerals. The Geological Survey of India is actively involved in locating mineral deposits in diverse geological formations. The mining of proven reserves of critical minerals requires the use of sustainable practices. The mining of critical mineral deposits depends on geological controls, which have an impact on the recovery of mineral deposits. Presently, improved methods of mining operations are being utilized with sustainable practices.

FACTORS AND DIMENSIONS FOR DETERMINATION OF CRITICAL MINERALS

The critical mineral designation primarily depends upon factors that influence the criticality of individual minerals based on the five dimensions suggested by Murtiani Hendriwardani (2022) listed in **Table 1**.

The determination of critical mineral dimensions plays a significant role based on the factors affecting the listing. Most of the nations determined the listing of critical minerals based on their specific dimensions and corresponding factors. Geological dimensions play a vital role in assessing nations' mineral resources and their restricted geological factors for availability and non-availability.

CRITICAL MINERALS AND ORE MINERAL DEPOSITS (METALS) ARE AVAILABLE IN DIVERSE GEOLOGICAL HOST MINERALS IN INDIA CRITICAL REVIEW

The Ministry of Mines and Government of India, with the consultation of experts and discussions, announced 30 critical minerals for our country. The designated 30 critical mineral deposits are not sustainable and are not available in geological formations in our country. Few mineral deposits are available for non-economic recovery. Few minerals are imported from other countries. A few critical mineral deposits with common host minerals in Indian examples are listed in **Table 2**. (Dhana Raju, 2020; Dhana Raju and Venkat Reddy, 2015, 2017). India can work on incentivizing exploration and other policy changes to boost the mining of critical minerals domestically. The supply chain of critical minerals must be maintained to sustain the country's requirements.

Astro-mining Geology-Mining:Exploitable resources few critical minerals from the Chandrayaan-Moon Mineralogical Mapper-M3-utilised for exploration of strategic and critical minerals

The primary science goal of M3 was to characterize and map lunar surface mineralogy in the context of lunar geologic evolution. This translates into several sub-topics relating to understanding the highland crust, basaltic volcanism, impact craters, and potential volatiles. The primary exploration goal was to assess and map lunar mineral resources at high spatial resolution to support planning for future, targeted missions. The M3 scientific instrument was a high-throughput pushbroom imaging spectrometer, operating in the 0.7 to 3.0 µm range. It measures solar reflected energy using a two-dimensional HgCdTe detector array (Anon ISRO-2017).

Table 1 Factors for determination of critical minerals after Murtiani Hendriwardani 2022

Sl no	Dimensions	Factors
i	Economic Dimensions	Economic Security, Strategic or competitive advantage, Industrial development objectives, social development goals, and Infrastructure development needs.
ii	Supply chain dimension	Supply risks and vulnerability, Import dependency, The geographic concentration of production and processing (refinery, Viability of substitutes and availability of secondary sources, Value chain opportunities.
iii	Technology dimension	Essential input to clean technologies, Required for low-carbon transition, Required for low-carbon transition.
iv	Geopolitical dimension	National security considerations, Risks of resource nationalism and stockpiling, External shocks, and geopolitical realignments.
v	Geological dimensions	Natural resources endowment, Availability of reserves and production capacity, Availability of reserves and production capacity.

Table 2 Critical minerals (CMs), their common host minerals/ ore-minerals/ores, and their occurrence in diverse deposits and Indian (after-adopted/partly Dhana Raju, 2020, IBM 2022, Anon GSI-2022)

Critical Minerals (Metallic-non-metallic minerals)	Common host minerals metallic-nom metallic)	Occurrences in India
Antimony/Sb	Stibnite, native Sb, cervantite	Stibnite and lead ores (Rajasthan, AP)
Beryllium	Beryl, chrysoberyl, helvite	Rare metal pegmatite, Sn–W ores (Bastar)
Bismuth,	Native Bi, bismuthinite, Bi-ochre	Fissure veins, hydrothermal/tin deposits
Cobalt	Linnaeite, cobaltite, smaltite-chloanthite	In copper, silver, lead, and zinc ores (Malanjkhand, Zawar, etc.)
Copper	Chalcopyrite ,Cuprite, Malachite, Azurite etc	Khetri copper belt in Rajasthan, Singhbhum copper belt in Jharkhand, Malanjkhand copper belt in Madhya Pradesh
Gallium	Galliumis a soft, silvery-white metal	As a by-product of Cu and Zn ores, coal Trace elements in sphalerite and,bauxite)
Germanium,	Germanite, argyrodite	Zinc-refinery slimes (Rajasthan)
Graphite	Crystalline/amorphous graphite	Graphite deposits (Eastern Ghats – AP and Odisha)
Hafnium	solid solution with zirconium	In zircon of placer mineral sands (AP, TN)
Indium	Indium is a minor component in zinc sulphide ores	produced as a by-product of zinc refinement from Zinc residues (Rajasthan
Lithium	Spodumene,lepidolite, amblygonite	The Geological Survey of Indiahas for the first time established Lithium 'inferred' resources(G3)of 5.9 million tonnes inthe Salal-Haimana area of the UT of Jammu & Kashmir discovered - Rare metal granite pegmatites (Bastar belt), subsurface brines
Molybdenum	Its associated minerals include pyrite, chalcopyrite, quartz, anhydrite, fluorite, and scheelite .	Recovered as a by-product of copper or tungsten mining and extraction
Niobium	Pyrochlore, columbine, fergusonite, samarskite, betafite	Rare metal granite pegmatite (Bastar), carbonatites and A-type granites (TN
Nickel,	Pentlandite, pyrrhotite	Ultramafic–mafic igneous complexes

		(Odisha), laterite, meteorite, earth's core and mantle
PGE, (platinum group of elements)	They are transition precious metallic elements with similar physical and chemical properties. central ultramafic–mafic portions of large tholeiitic intrusions of late Archean to early Proterozoic ag	Niligiri, Boula-Nuasahi, and Sukinda areas in Odisha and the remaining 1.5 million tonnes of PGE ore in the Hanumalpura area in Shivamogga schist belt of Karnataka.
Phosphate (Apatite group of minerals-rock phosphate)	It is the most abundant crystalline phosphate mineral found as an accessory mineral in practically all kinds of igneous rocks. Sometimes, it is concentrated in pegmatites, metallic veins, and magmatic deposits.	Of the total reserves/resources, 34% are in Jharkhand, 31% in Rajasthan, 19% in Madhya Pradesh, 8% in Uttar Pradesh & Uttarakhand each, respectively. (IBM-2000)
Potash (group of minerals Potash is an impure combination of potassium carbonate and potassium (K) salts. sylvinite, a mixture of sylvite (KCl) and halite (NaCl).	sylvinite, a mixture of sylvite (KCl) and halite (NaCl).	A major part of these resources (91%) are located in the Nagaur district of Rajasthan, followed by Panna district, Madhya Pradesh (5%), and the balance in Sonbhadra & Chitrakut districts, Uttar Pradesh (4%). Occurrences of potash are also reported from the district of Arunachal Pradesh;
REE (Rare earth elements) The rare earth elements (REE) are a set of seventeen metallic elements. These include the fifteen lanthanides on the periodic table, plus scandium and yttrium.	Bastnaesite, monazite, xenotime	REE–Nb–Fe ore deposits, shoreline/fluvial placers (AP), alkaline group pegmatites, veins
Rheniumis an extremely rare metal	Rhenium is one of the rarest elements in Earth's crust with an average concentration of 1 ppb	Approximately 80% of rhenium is extracted from the porphyry molybdenum deposit.(molybdenite roaster flute dust) ores (TN), Cu-ores (Malanjkhand), and coal ash
Silicon	Quartz is comingasa minor mineral. Siliconhas varied industrial applications listed under critical minerals.Elemental silicon is produced commercially by the reduction of silica (SiO_2) with coke in an electric furnace	Silicon is primarily extracted from quartzminerals, quartzreefs(Rajasthan Andhra Pradesh Telangana Gujarat Maharashtra, Karnataka)
Strontium	Celestite, strontianite	
Tantalum	Tantalite,microlite, yttrotantalite,euxenite, polocrosse	Rare metal granite pegmatites, carbonatites, A-type granitoids (Chg, TN
Tellurium	Closely related to selenium	Cu-ores/refining sludges, native form.
Tin	Cassiterite, stannite, teallite	Cassiterite, stannite, teallite
Titanium	Ilmenite, rutile, anatase, titanite	Beach/stream placers and anorthosite (TN)
Tungsten	Scheelite, wolframite, ferberite, huebnerite	Fissure veins, replacement, contact-metasomatic and placer W-deposits (Chg)
Vanadium	Patronite,roscelite, vanadinite, carnotite	Carnotite deposits, oxidized Ag–Pub–Mo ores, sedimentary phosphate rock
Zirconium	Zircon	Zircon in mineral sands (Odisha, AP, TN)
Selenium	Related to tellurium	Copper ores, flute dust in soil
Cadmium	Cadmium occurs as a minor component in most zinc ores and is a by-product of zinc production	The primary ore of cadmium is sphalerite (Zinc mining from Rajasthan state

AP= Andhra Pradesh; Chg= Chhattisgarh; Kar = Karnataka; Ker=Kerala; TN=Tamil Nadu.Rajasthan Andhra Pradesh Telangana Gujarat Maharashtra, Karnataka.

The M3 has a wide range in spectral dimension, which is only surpassed by the Imaging Infrared Spectrometer (IIRS) from the Chandrayman-2 mission. M3 is a spectrometer that operates in the solar-dominated portion of the electromagnetic spectrum with wavelengths from 430 nm to 3000 nm (0.43 to 3.0 microns). The M3 was chosen for this analysis since it has a wide range of spectral wavelengths (Thoresen1 and A. Cowley, 2023) The difference in wavelength provided by composite rock-mineral compositions with different bands is presented in **Figure 1**. This information will both provide clues to the early development of the solar system and guide future astronauts to stores of precious, resources. (Anon ISRO-2017)

Occurrence and Recovery From Primary Sources

The primary source materials for CMs are different minerals/ores that occur in diverse rock types/ore deposits on earth (**Table 1**; suggested from the Indian perspective). These primary sources – ore deposits, hosted by the magmatic, sedimentary, and metamorphic–metasomatic rocks, all affected by diverse mineralization processes that include hydrothermal activity, syn-/dia-/epi-genetic affects, remobilization–recrystallization, weathering, transportation (as in placers), etc. are mined conventionally after (i) comprehensive mineral exploration by the geological–geophysical–geochemical and related laboratory-based studies, and (ii) establishment of a cost.(Dhan Raju 2020, Dhana Raju and Venkat Reddy, D (2017,2018).

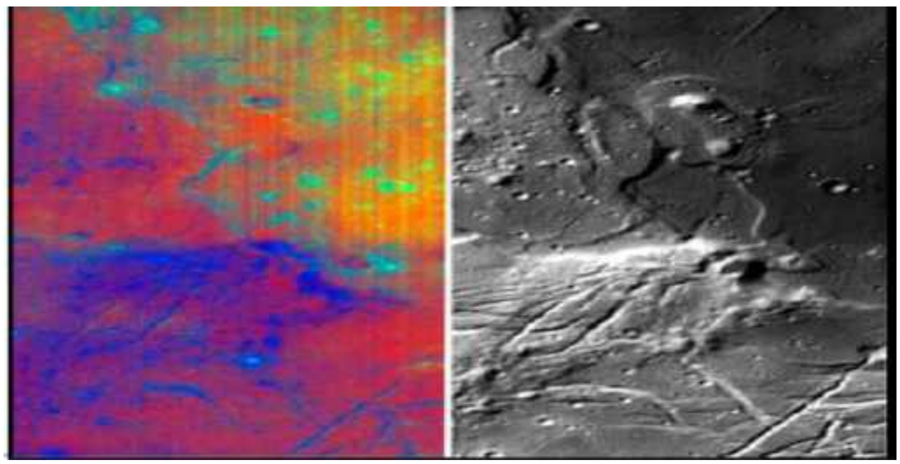

Figure 1 Difference wave Length provided with composite rock-mineral composition of the Moon with different bands (Credit NASA NASA/JPL Brown)

CMs are usually recovered from such ores as by-/co-products and occasionally as major products by mineral processing, which comprises pre-concentration, beneficiation, and extractive metallurgy like hydro-/pyro-metallurgy, followed by smelting and purification. The mineral industry usually focuses on the extraction of the main product (s) of ores, with little importance to their potential by-products like many CMs. For example, in the diverse types of U-deposits in India, the emphasis is more on the extraction of U and less on its possible high-value CMs like Au, Ag, Mo, Co, V, etc.10. To extract the main product (s) and co-/by-products, like some valuable CMs from different ore deposits as well as from their waste, generated during mining and ore-processing, it is better to synergize the mineral-, chemical- and nano-technology, after comprehensive characterization of different ores by state-of-the-art analytical techniques like electron micro-probe analysis, to identify both qualitatively and quantitatively different constituent metals in different ore minerals (. (Dhan Raju 2020, Dhana Raju and Venkat Reddy, D (2017, 2018).

Secondary Source of CMs as by bi-products Products, Processing, Recycling, and Extraction from E-Waste

According to the data collected from countrywide sales and the average life of electrical and electronic equipment (EEE) as mandated under the E-waste Management Rules, 2016, India generated approximately 13,46,496.31 tonnes and 16,01,155.36 tonnes of e-waste in the financial years 2020-21 and 2021-22, respectively (Anon (MoEFCC,2023)

Critical mineral deposits that are designated by our country are not available to sustain requirements. Secondary sources to recover a few critical minerals extracted from E-waste. The detailed chemical analyses of E-Waste confirmed about 60 chemical elements including critical-strategic and other minerals are present. The present extraction technology know-how facilitates to recovery 10 minerals. The E-waste extraction process is complicated and efforts are ongoing to develop efficient new technologies to extract elements from e-waste. Supplies of some CRMs are likely to be disrupted due to their non-availability or the risk of unaffordable price spikes. The factors impact the critical mineral supply, including the global concentration of extraction and processing activities, import dependence, governance policies, lack of substitutes, low rate of product extraction and recycling,etc. (Dhan Raju 2020, Dhana Raju and Venkat Reddy, D(2017,2018,Venkat Reddy 2023).

CONCLUSIONS

i) Critical minerals (CMs) are metals and non-metals considered vital for the economic well-being of the world's major and emerging e-economies. Each nation has a short supply due to its limited or non-availability of geological resources, mineral trade policies, and other factors. Most countries in the world have identified critical minerals as per their national priorities and future requirements.

ii) The Government of India has released a list of 30 critical minerals for India in 2023. These minerals are antimony, beryllium, bismuth, cobalt, copper, gallium, germanium, graphite, hafnium, indium, lithium, molybdenum, niobium, nickel, PGE, phosphate, potash, REE, rhenium, silicon, strontium, tantalum, tellurium, tin, titanium, tungsten, vanadium, zirconium, selenium, and cadmium. The listing of further minerals can be reviewed periodically based on their supply chain, geological scarcity, etc.

iii) The CMs occur in three major sources: primary—in different minerals and ore minerals that are extracted from the earth; secondary—in waste materials such as e-waste; and tertiary—in imports

iv) E-waste contains about 60 chemical elements and the present extractive technology facilitation recovery of 10 minerals.Advaced research on going to develop new extractive technology to extract of elements for the sustiable utlisation.

v) The latest mineral exploration techniques have to implenented with exploration divisions to probe micro-level mineralsurveys for The combined mineral exploration techniques have to implement with coordinated efforts by explorations departments .

vi) Critical mineral deposits exploration required in microlevel geological,geophyical,geochemical ,Remote sensing ,mineral mapping techniques and exploitation required with combined required to in depth surveys.

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MARINE ENGINEERING DIVISION

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A Detailed Review on the Usage of Heat Pipe Technology for Cooling Shipboard Electronic Systems

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***Abstract**: The electrical power generation and its use in shipping industries has increased the significance of strong shipboard electronic cooling systems. Though there are many cooling technologies like use of heat sinks, natural air cooling, forced fan cooling etc. the heat pipe technology is said to be the best option available in the market. The present research paper is mainly focused on understanding the use of heat pipe technology in marine industry for maintaining the thermal balance of the electronic structures. This review research paper presents the data of heat pipe working, heat pipe materials, working fluids used and different applications on board. The key challenges faced in using the heat pipe technology in different electronic systems used on board are discussed in detail. The data related to the use of heat pipe technology along with other cooling options and its suitability for a particular application are described in detail. The research paper summary is provided at last.*

***Keywords**: Marine industry; Electronics Cooling; Heat Pipe Technology; Applications*

INTRODUCTION

The demand in downsizing of the electronic devices are increasing because of the recently developed techniques. The faster running of the small sized electronic devices are possible with increased power density. Hence, the more heat is generated in such circuits which elevates the operating temperature of device [1]. Under such situation, where the small size of the device is involved and power density is increasing, calls for strong cooling technology which is flexible in terms of shape, size and high heat carrying the capacity. The heat pipe cooling technology (which follows the Moore's law) is preferred to be the best cooling technique from currently available sources. The heat pipe cooling technology serves following advantages: (a) Capacity to carry the higher heat flux [2], (b) Ability to work in the different orientation with external power, (c) Flexibility in the material used for specific the application (eg. Copper, aluminum), (d) Flexibility in choosing the working coolants used in the system, (e) Fabrication flexibility in terms of the size and shape, (f) Flexibility in using different wick structures, (g) Flexibility to use in different environments (low temperature and high temperature), (h) Versatility in using it for different applications (solar, electronics, waste heat recovery, geothermal energy, nuclear energy etc.), (i) Ability to maintain the uniform temperature at required space [2], (j) passive method and hence no noise and vibrations in the system [3].

WORKING OF THE HEAT PIPE

The basic model of the heart pipe carries following important arrangements which are shown in the **Figure 1**. The heat collection section called as the evaporator section. In this section the heat is collected from the electronic structure (which generates the heat) and the working fluid is converted from the liquid to vapour state by absorption of latent heat. The heat rejection section called as the condenser section. The heat carried in the vapor is rejected in the cooling media (air, water or any other medium). The middle section most of the times insulated and connects the evaporator section and condenser section. This portion of the wick transfers the liquid from the condenser section to the evaporator section.

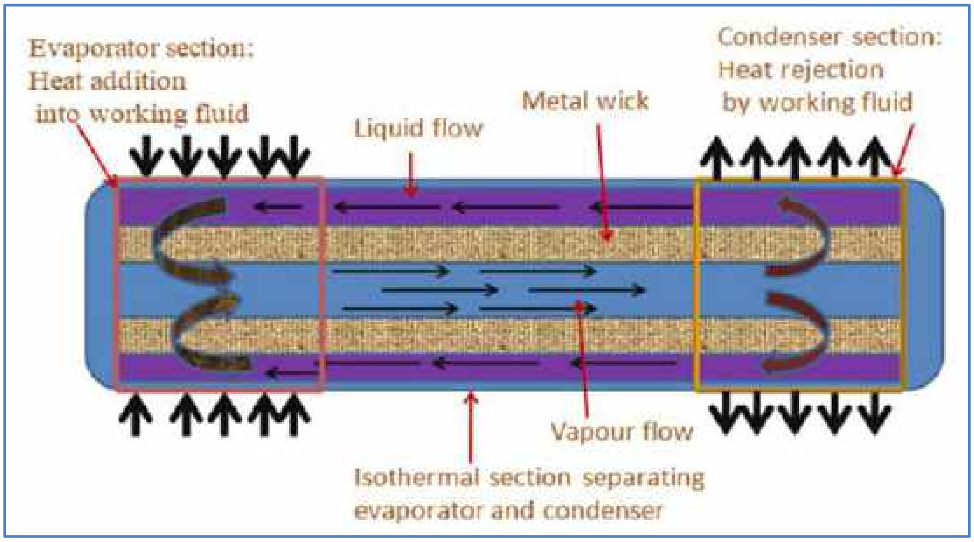

Figure 1 Working principle of the heat pipe

HEAT PIPE MATERIALS

The selection of the material of the heat pipe plays significant role in maintaining the life of the heat pipe system and thermal balance of the electronics structure. The different heat pipe materials, their properties, limitations are described in the **Table 1**. This helps in selecting the heat pipe material for a particular electronics structure cooling on ship board applications. The heat pipe material should have following important properties when it is used in the electronics cooling structures. (a) Thermal conductivity - It should be as high as possible to handle the heat in system, (b) Mechanical strength - The mechanical strength of the heat pipe casing should be sufficient to sustain under the liquid pressure and the vapour pressure which is formed during the condensation and evaporation processes respectively, (c) Flexibility - The material of the heat pipe should have flexibility to fabricate it easily (by different fabrication techniques commercially available), use it in different size (in microelectronics size should be small), fabricate it in different shapes (cylindrical, circular, flat etc.) as per the requirement of the application, make it compatible with the working fluid operate it in different environmental conditions (compact and open), (d) Weight - The heat pipe material should have less weight (this is requirement in the micro-electronics cooling systems), (e) Cost- should be less, (f) Availability – Should be easily available.

WORKING FLUIDS USED IN THE HEAT PIPE

Table 2 presents the essential properties of the working fluids (coolants) and their requirements in the heat pipes technology. This information is very important in view point of selecting the specific working fluids for particular application. The data related to the working temperature ranges of the different working fluids used in heat pipes are presented in the **Figure 2**. The main target while selecting the working fluid should be handling of the amount heat as per the requirement of the application. The collection of the heat in the evaporator section (by converting the liquid into vapour) and to transfer the working fluid from one location to other plays very important role in the successful running of the heat pipe technology.

The working fluids often called as coolants used in the heat pipes should possess properties as mentioned here, (a) Heat flux carrying capability - Should be as maximum as possible, based on the heat balance requirement in the system [1], (b) Thermal stability - The working fluid should be thermally stable in order to handle the heat in the system [2], (c) Wettability - The fluids used should have good wet-ability with the wall material and the wick structure. The wettability helps in avoiding losses in the flow of liquid and vapour in the system and during the conversion phases and travel of the fluid from evaporator to condenser section or vice-versa, (d) Vapour pressure - The vapour pressure should be sufficient to carry the vapors from the evaporator section to the condenser section to complete the working cycle in the prescribed time. In case if the vapour pressure is not sufficient the vapors after forming will be gathered near to the wick structure in the evaporator and it will jam the passage [4], (e) Latent heat - The amount of heat required to change the phase of the substance at a given temperature is called as latent heat and hence it should be as high as possible in heat pipe fluids [4], (f) Compatibility - The working fluid should be compatible with the heat pipe and wick structure material in order to avoid damage to the system (e.g., Corrosion, chemical reactions with the gases, decomposition of the fluid), (g) Clogging tendency - The working fluid should not clog the internal passages during the heat rejection at the condenser section. It even reduce/stop the liquid flow towards the evaporator, (h) Surface tension - The surface tension value should be sufficient for pumping of the liquid through the wick structure so that it will provide the sufficient liquid to the evaporator section to collect the heat from the application whose temperature is to be maintained [3,21], (i) Capillary force - This property is important to maintain sufficient liquid level in the evaporator section so that the maximum latent heat transfer takes place. The pressure loss in the wick structure and the maximum heat transfer at the evaporator section plays important role in successful running of the heat pipe. The experimental studies which involved the pressure loss studies and the maximum heat transfer conditions were mentioned in the studies [22-25], (j) Viscosity - The viscosity of the vapor and liquid should be low for the easy movements of fluid through channels [3], (k) Reliable - The working fluids used in the heat pipes should maintain the performance within the prescribed period of the working, (l) Cost – should be less, (m) availability – should be commercially available at the required location easily.

Table 1 Materials used for the heat pipes and their importance

Sr. No.	**Heat pipe type Material**	**Used in the heat pipe system because of following important feature**	**Limitations**
1	Aluminium	Less weight Flexible in manufacturing Strength can be increased by adding alloys Good thermal conductivity Easy availability Compatible with the electronic systems	Cannot be used for highertemperature applications Cannot be used when great strength is required
2	Copper	Very high thermal conductivity Good mechanical strength Compatible with the electronic systems	Cannot be used when great strength is required
3	Stainless steel	Good mechanical strength Compatible with the electronic systems	Should not be used with water as a working fluid it forms the cold plugs in the channel during condensation [6]
4	Ferritic steel	Good mechanical strength Compatible with the electronic systems Corrosion resistant [5] Can be operated at elevated temperatures (up to 1000 ^{0C}) [5]	Lack of design guidance [5]
5	Silicon	The more flexibility in fabrication [7] More compatible with electronic [11] systems [4]	Incompatible with some of the working fluids
6	Polymers	Flexibility in manufacturing Costs are less Different types are available (PTFE, PCTFE, PA, PP, PVDF etc.) [8-10]	Flexible polymers may damage the internal wick structure, which leads to decreased heat transfer performance of the heat pipe
7.	Titanium alloys	Protection against formation of the condensable gases [12]	Incompatible with some of the working fluids
8	Magnesium alloys	Protection against formation of the condensable gases [12]	Incompatible with some of the working fluids

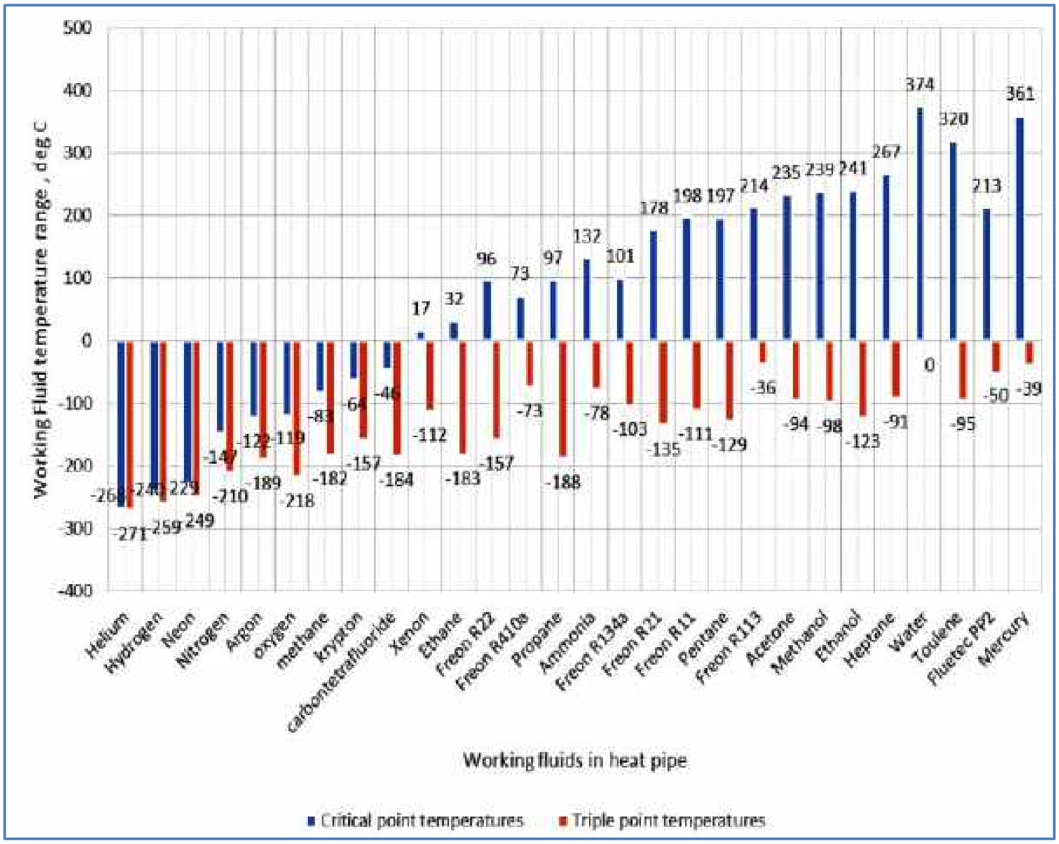

Figure 2 The working fluids and their sustainable temperature range [3, 13, 14-20]

HEAT PIPE USE FOR SHIP BOARD APPLICATIONS

The following data table describes the data of the heat pipe material, compatible working fluids, working temperature ranges and suitable shipboard electronics cooling systems.

Following mentioned electronics systems on ship can use the heat pipe cooling technology to maintain the thermal balance of the system. (a) The electronic equipment used in the naval combat systems (which includes sensor systems, weapon system, naval combat management, ship information systems) have higher thermal density because of their higher specifications, (b) Self steering system: coordinate data from many devices on the ship and interface with control and propulsion system which keeps the vessel on a correct path and location, (c) Chart plotter: it is a device used for marine navigation purpose to combine the GPS data with an electronic navigational chart to display the position, heading and speed of the vessel, (d) Compass: It uses series of fiber optic gyroscopic sensors and computers to locate north. This is including the sensors, controls and display equipment, (e) Sonar or fish finder: acoustic devices using electronically emitted and detected pulses of sound to locate underwater objects. Mainly includes receivers, transmitters and equipment to analyze the acoustic information, (f) GPS: global positioning devices are space-based radio-navigational systems that broadcast highly accurate navigation pulses to users on or near earth, (g) Fuel monitoring and management systems: This system uses advanced controls the fuel uses in ship using the technologies to monitor, measure and prepare the reports of fuel usage, (h) Maine VHF radio: used mainly by all big ships for communication purpose to communicate with harbors, locks, bridges and marinas etc. It combines the transmitter and receiver and generally operated on international frequencies used for marine purpose, (i) Radar: It is an object detection system which emits electromagnetic waves and analyzes their interaction with different objects. These systems are generally used to identify the range, altitude, velocity of the objects (e.g., Ships, aircrafts etc.)

Table 2 Heat pipe material, working fluid compatibility and suitable application/s [2,3, 26,27, 14]

Heat pipe Material	Compatible Fluid	Working range of temperatures, deg. C	Suitable application/s
Copper	Acetone	0 to 120	Micro-electronics cooling
	Dowtherm	150 to 650	Micro-electronics cooling
	Methanol	< 25	Micro-electronics cooling
	Water	25 to 150	Micro-electronics cooling
	R 134 a	-103 to 101	HVAC/Energy recovery
Aluminium	Acetone	0 to 120	Micro-electronics cooling
	Ammonia	For < - 60	Spacecraft thermal control
	Freon-11	-40 to 120	Low temperaurature handling applications
	Freon-21	-40 to 87	Low temperaurature handling applications
	Freon-113	-10 to 100	Low temperaurature handling applications
	Heptane	0 to 150	Micro-electronics cooling
	Ethane	-123 to -33	Crogenic applications
Stainless steel	Acetone	0 - 120	Micro-electronics cooling
	Ammonia	For < - 60	Spacecraft thermal control
	Dowtherm	150 to 650	
	Methanol	10 to 130	Micro-electronics cooling
	Cesium	500 to 900	
	Water	30 to 277	Micro-electronics cooling
	Mercury	250 to 650	
	Sodium	600 to 1200	High temperature applications /isothermal furnace liners
	R 134 a	-103 to 101	HVAC/Energy recoveryss
	Nitrogen	-203 to -170	Cryogenic applications
	oxygen	-200 to -154	Cryogenic applications
	Hydrogen	-259 to -242	Cryogenic applications
	Helium	-271 to -269	Cryogenic applications
	Neon	-246 to -236	Cryogenic applications
Titanium	Water	Up to 300ºC (for short time),Up to 280ºC (for long time)	Micro-electronics cooling
Monel	Water	Up to 300ºC (for short time),Up to 280ºC (for long time)	Micro-electronics cooling
Speralloys	Cesium	450 to1100	High temperature applications /isothermal furnace liners
	Potasium	450 to1100	High temperature applications /isothermal furnace liners
	Sodium	450 to 1100	High temperature applications /isothermal furnace liners
Tungston	lithium	1000 to 1800	High temperature applications /isothermal furnace liners
Molybdenum	Lithium	1000 to 1800	High temperature applications /isothermal furnace liners

KEY CHALLENGES IN USING THE HEAT PIPE TECHNOLOGY

Following main problems arise, while using the heat pipe technology in marine electronics system cooling:

(a) The mercury which is used as the working fluid in the heat pipe technology is toxic. It has high density and creates problem in wetting the heat pipe wick

(b) The sulphur and sulphur iodine have higher viscosities, lower thermal conductivities and are chemically aggressive

(c) The organic fluids used in heat pipe technology will decompose at higher temperatures

(d) Working fluids like super alloys e.g., TiCl4 have low fluid transport factor compared to the water

(e) The liquid metals like Potassium and Cesium face the difficulties in handling and compatibilities with structure of the heat pipes

(f) Some working fluids faces problem of the vapour locking in the chambers

(g) The transport of the working fluids in the chambers should be completed in the given period of time to reject heat at the required rate, which is not achieved in all the types of working fluids and all types of heat pipe materials

(h) Fabrication of the required wick structure of the heat pipe is difficult

(i) Maintaining longer life of the heat pipes for higher temperature applications is difficult

CONCLUSION

The research paper has discussed the heat pipe technology sutability in the marine engineering field. The working of the heat pipe, heat pipe material and its significant properties and limitations are discussed in detail. The working fluids used in the heat pipes and their compatibility with the heat pipe material is discussed. The heat pipe (combination of the heat pipe material and working fluid) suitability in electronics cooling applications on ship board are discussed in this paper. The key challenges faced is using heat pipe technology on ship board electronics cooling are mentioned in separate section.

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PRODUCTION ENGINEERING DIVISION

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Fostering Circular Economy and Sustainable practices in Coal mining sector

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***Abstract**:-The coal mining industries conventionally follow the sequential modus operandi for their operations. The effective resource management and waste utilization involved in the coal mines have a significant potential to greatly contribute to the establishment of a circular economy. Using novel technologies is being promoted for optimized resource utilization and mitigating environmental concerns. This paper focuses on tackling the aspect of generating a circular economy by diversification and secondary product generation in the pit head power plants. The authors deliberate the latest technologies for maximizing the recovery of by-products and waste materials for creating value-added products. The best practices in the integrated coal mining and energy sector promote the concept of circularity and certainly improve the nation's economy. This paper emphasizes the need for governance measures to improve the waste management strategies and sustainability of the coal mining ecosystem. The challenges faced during mining operations for implementing circular economy frameworks were presented. The transformation of the coal mining sector towards a circular economy is an opportunity for attaining efficiency, considerable profitability, and the generation of wealth within the domains of mining and energy.*

***Keywords**: Circular economy; Resource management; IoT; Ecosystem; Waste to wealth; Sustainable mining.*

INTRODUCTION

The resource exploration, production, and utilization activities of the Coal industry traditionally adopt a sequential approach for the operation. The processes and operations are carried out in a linear model where one operation sequentially follows another without looping resulting in open loops. The process of a closed-loop system was not envisaged due to abundant resources and a lack of environmental concerns in past decades. **Figure 1,** shows the illustration of the linear economy model.

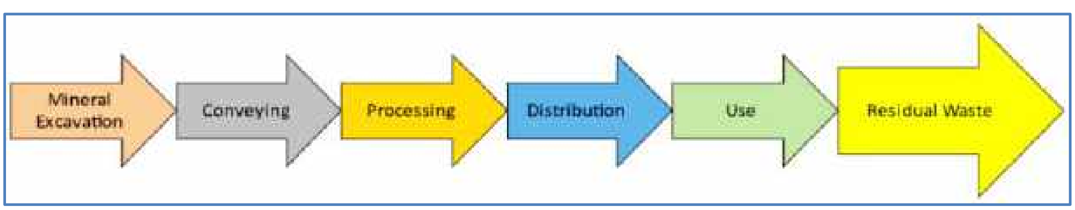

Figure 1 Linear Economy Model.

The principles of circular economy (CE) are applied to create more efficient processes and better management of resources in any industry. It involves recycling and reusing by-products and damaged products as raw materials for new production cycles. A circular economy creates an ecosystem that sustains socially, financially, and economically. The circular economy aims to maximize resource utilization, minimize waste and emissions. The circular economy helps mining companies adapt to global environmental benchmarks. The circularity flow cycle comprises 'Recover, Recycle, Repurpose, Remanufacture, Refurbish, Repair, Reuse, Reduce, Rethink and Refuse'.

The scope of the present study is to assess factors in the operating model of the coal and power industry that contribute towards the creation of a circular economy. The recent developments in the transition of the coal industry towards sustainability are explored in terms of material, equipment, and land use while applying the circularity principles. The practices and technologies that encourage the integration of coal and energy sectors for developing cross-domains to overcome the linear operating models have been discussed in this paper.

LITERATURE

Several studies have explored the potential of circular economy principles in the mining sector. Closed loops are created based on circularity principles at macro, meso, and micro levels for mining enterprises [1, 2, 3]. Based on a detailed study regarding the adoption of circular economy in diverse industries, [4] have reported that 96% of study respondents view the circular economy as vital for their company's future success, and 84% expect to step up investment in circular economy initiatives. Circular economy concepts are applied in the context of mine waste reprocessing activities and reducing the liability from mining waste [5, 6].The practical application of the circular economy concept for mining operations provides significant environmental benefits and generates value from mine waste. The methods of mineral extraction and processing can significantly impact the circular initiatives in the mining industry [7]. The progression of the mining sector towards circularity minimizes the environmental footprint in the form of greenhouse gas emissions, water, or other forms of waste. Circular models are efficiently used for developing a conceptual framework for new business models in coal mining, and power generation to reduce production costs, expand the product range, improve sustainable development indicators, and deliver growth in company value [8]. Various business models have evolvedfor exploring the business opportunities of embracing circular economy concepts in the mining industry [9, 10]. The business model of the sharing economy (SE), based on shared consumption of goods and services developed from the CE concept provides new opportunities for firms in emerging industry 4.0-related technologies. The adoption of the concepts of CE along with the best available technologies helps the mining industry to convert the challenges of circularity into new opportunities to keep up with innovative industry leaders [11].

MINING METHODOLOGY

Mining has contributed significantly to human existence from the prehistoric era to the present. Coal/Lignite is a flammable mineralwith25-50% carbonaceous material, calorific value of about 4500 kcal/kg for coal and 2500 kcal/kg for lignite.

Coal mining has evolved from the early days of men tunnelling, digging, and manually extracting coal on carts, to automated open-cut and long-wall mines. Various methods of mining a coal seam can be classified under two major headings: surface mining and underground mining. Underground mining involves digging a shaft over the earth's surface and extracting minerals sideways from the earth. The removed minerals are transported using haulages. Open-cast mining is the process of initially removing the overburden of minerals and then excavating and transporting the minerals.

Conventional surface mining technology employs the usage of shovels and dumper equipment for the activities. Continuous mining technology utilizes Bucket Wheel Excavators (BWE), belt conveyors, and spreaders for excavating and conveying the mined-out materials. This comprises a continuous bulk material transporting system for conveying the overburden/coal. The drive station operates the conveyor andtransports the material to the required destination.

CIRCULAR ECONOMY IN THE MINING SECTOR

The implementation of circular economy principles in mining & power leads to the development of products with market value, thus creating an ecosystem with symbiosis between the mining industry and end users in various industries.

The utilization of coal as a primary fuel has limitations in its ability to be used only in industry-specific applications. However, with the advent of innovative technologies, the efficiency of the material can be increased to create secondary products that find a way in other industries thus creating closed-loop systems. **Figure 2** shows the circularity model operating in the Integrated Coal Mining Power plant Industries (ICMPI).

Figure 2 Circularity model operating in the Integrated Coal Mining Power plant Industries (ICMPI).

The research on technologies of gasification and conversion of coal/lignite to liquid are more aligned with achieving global emission targets. The existing methods of utilization of coal/lignite as a main product and overburden as a waste can be readdressed in the purview of circularity principles and efficient material balances.

Resource Utilization

In the era of decarbonization and diversification, it is imperative to explore the utilization of coal across all industrial fronts. The circularity principles are applied for synthesizing secondary products, rare earth elements and alternative fuels from coal that promote the development of other industries**. Figure 3**, shows value-added products that exist in the ICMPI. Further innovation and developments warrant the tree to grow circularly.

Value-added products

Several studies are available on the use of coal-derived carbon nanomaterials for energy applications (Li-ion batteries (LIBs), electrocatalysts, supercapacitors),sensing applications, biomedical applications, environmental remediation (electrocatalysis, adsorption), and sustainable energy generation.

The production of carbon-based nanomaterials from coal can greatly contribute to the long-term viability of affordable environmentally friendly products for global benefit [12]. The carbon allotropes in Coal exhibiting variation in following the degree of coalification and the concentration of carbon makes it a valuable source for the synthesis of carbon-based nanomaterials such as carbon nanotubes, nanofibers, nanoparticles, spheres, graphene, graphene oxide, graphene quantum dots, and carbon dots. The utilization of lignite wastes as a rich carbonaceous source for the extraction of humic acid is also an organic fertilizer. The extraction process and energy efficiency are studied by using sophisticated methods for improved properties of humic acids also making them suitable for use as a biochar activator for the adsorption of heavy metal ions.

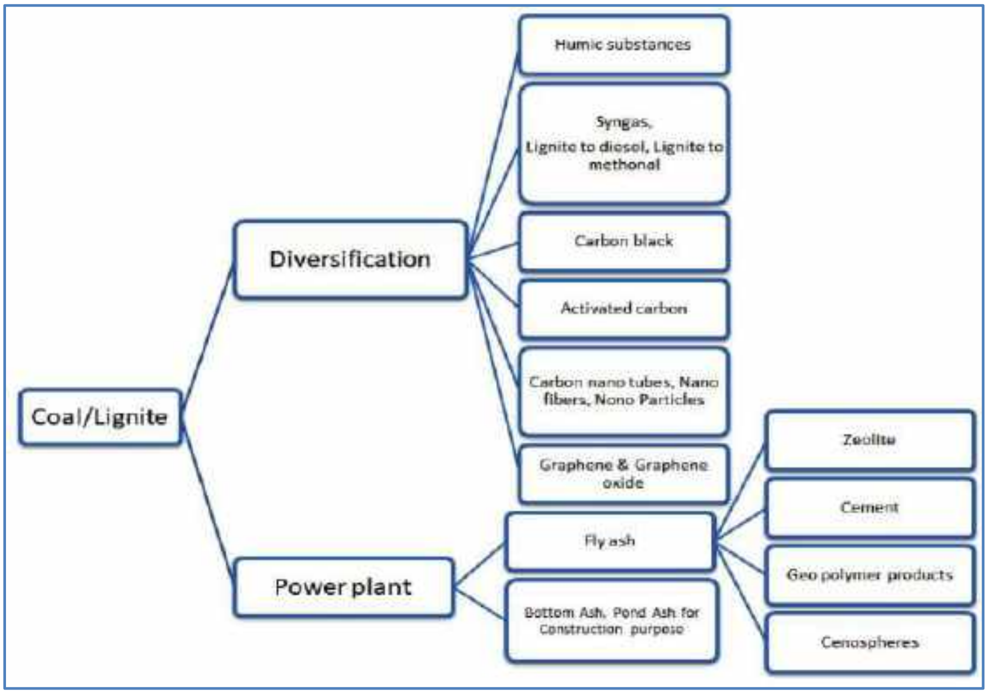

Figure 3 Value-added products in the ICMPI.

Clean Coal Technologies

Coal gasification is a recognized process involving the conversion of coal to synthetic gas. Recent research progress on various coal gasification techniques, including conventional and relatively new methods were reviewed in terms of gasifiers, process parameters, advantages, and challenges[13]. The synthetic gas from coal gasification can also be used in combined cycle technology to increase electricity production efficiency. The Coal-to-liquid (CTL) technology has the potential to replace petroleum-based fuels, promoting the clean and effective use of coal Inthis context, production of alternative fuels such as methanol, diesel, liquefied natural gas (LNG), Dimethyl ether (DME), Polyoxymethylene dimethyl ethers (PODE), hydrogen offer advantages in reducing emissions and clean coal utilization [14].

Overburden waste utilization

Huge volumes of excavated wastes are available in the form of overburden material and mine tailings in open-cast mines. The exploitation of such wastes for extraction of value-added products has emerged as a new business opportunity for sustainable economic development and ensures the mining activity remains eco-friendly. The alternative to river sand is one of the useful products processed from overburden soil. The overburden could directly be utilized in the construction activities, raw material for the manufacture of building materials, Rare earth elements extraction, etc. The clay recovered after processing mines overburden may find its application in the manufacture of clay-based aggregates, bricks, floor tiles, coatings and resins. The materials excavated during overburden removal along the coal seams such as silica sand and ball clay could be exploited in the foundry, refractory, glass-making, and ceramic industries.

Land use

The mine closure and post-mining activities in open-cast mines envisage the utilization of mined pits and the repurposing of land. Further, the utilization of mine dump areas, and abandoned mine tailings area encompasses significant circularity components leveraging the extensive energy transmission infrastructure present in the vicinity.

Reclamation/Green Belt development:

The topsoil in the mines is reclaimed and repurposed for the development of green cover. Paddy, edible legumes, aromatic herbs, and cereals are considered most suitable for reclaimed mine surfaces, while the cultivation of energy crops can be taken up after improving the soil characteristics. Novel methods such as aeroponics and hydroponics can be adopted in challenging conditions for reclamation.

Photo Voltaic park/Solar

The establishment of photovoltaic parks on post-mined land, within existing mine boundaries, and solar PV systems on rooftops in regions moving away from coal augment the renewable energy capacity wherever possible. The necessary surface development and the installation structures are retrofitted in the mined out area for the development of PV parks.

Pumped storage

The minecavities are utilized for water storage at two distinct elevations to operate pumped storage power stations, allowing surplus power from renewable sources to meet energy demands during peak periods [15].

Infrastructure development

At the stage of mine closure, land is reused for afforestation activities, water storage reservoirs, ecosystems that promote natural habitats, and tourism spots such as mine heritage parks, artificial lakes.Further, it tackles issues of restoration activities, such as the scarcity of nutrient-rich topsoil and water required for the irrigation of cultivated crops.

Equipment use

The condition of the equipment and machinery of plants are significant for profitable operation. The extension of service life by repair, refurbishment, and reuse greatly contributes to building circularity.

Repurposing using retrofitting, and refurbishment: The provision of rebuilding and refurbishment services can yield numerous benefits, including the reduction of downtime and the mitigation of costs associated with mining equipment. By opting to rebuild and refurbish outdated, inefficient, or malfunctioning equipment, significant savings can be achieved in terms of purchasing new machinery.

Internet of Things (IoT) and Automation : Internet of Things (IoT) in the mining industry has the potential for sustainable and efficient mining practices. The application of advanced technologies like sensing, artificial intelligence, and robotics can enable autonomous operations in hazardous and harsh mining environments, reducing the need for human manpower. IoT technology is used for real-time monitoring the environmental parameters, increasing safety, productivity and reducing downtime.

Artificial Intelligence and Machine Learning (AI-ML): The integration of AI and data analysis software with geological, topographical, and mineralogical mapping data during mineral exploration stages greatly improves operational safety with continuous monitoring and autonomous communication systems.

Groundwater Monitoring System

The groundwater control system (GWC) comprises of bore well water pumps, stormwater pumps, and an allied pipeline network. The efficient operation of the pumps can be ensured on a real-time basis based on the requirements. The Radio Frequency/GPRS-based type transmission is used for online transmission of different GWC system parameters from the process station to control station for centralized monitoring of water levels and remote pump house operation.

Mines water

In open cast mining system, the ground water is pumped into mine artificial ponds and conveyed to the pit head thermal station for power plant utilization. The mine water is also used for drinking and agriculture purposes for developing green belts in nearby habitats.

Power plant

The Pit-head thermal power plants have advantage of proximity to mines by gettingtheir feedstock such as coal/lignite and water. Power plants affect the environment by releasing carbon dioxide, Sox&NOx, ash, etc. To mitigate these issues various statutory provisions are created to install Flue Gas Desulphurization, Carbon Capture system. The waste extracted shall be converted into useful products with proper technology and innovations.

Carbon Capture and Storage

The process of recycling carbon dioxide into a fuel resource and other value-added products reduces the carbon footprint and minimizes emissions. The implementation of carbon capture, utilization, and storage (CCUS), Carbon to methanol, and mineral carbonation alongside renewable energy sources can further enhance the carbon circularity in the mining industry.

Fly ash, Bottom ash, pond ash

Fly ash is utilized in cement manufacturing, the production of zeolites, geopolymers, precast products, extraction of cenospheres, soil stabilization, and neutralizing the tailings acid mine drainage. Bottom ash is used substitute for aggregates in construction, while ash disposed in a slurry form in large ponds and is used for filling purposes.

Floating solar

A thermal power plant usually has water storage pools and ash ponds in its vicinity. These water bodies can be utilized for installing floating solar systems, which reduce water evaporation during the hot summers and contribute to renewable energy generation meeting the auxiliary service needs of the thermal plant.

SOCIETAL BENEFITS

- The principles of circular economy are applied to create more efficient processes and better resources management.
- CE creates an ecosystem that improves social, financial, economical conditions.
- CE reduces the concern for global warming,decarbonization.
- Job creation at different levels [16].
- CE promotes social unity, foster local communities.
- Augmenting new technology, innovations and waste to wealth conversion.
- Developments in the MSME sectors, such as recycling and remanufacturing.
- Development of business models for embracing the circularity principles.

CHALLENGES

- Investment, skilled manpower, additional manshifts, stakeholder engagement anddeveloping value chains.
- Additional Capex requirement for installing environment monitoring and control systems.
- Demand sustainability for the value added products in the market.
- Technological threat.
- Societal awareness and public perception.

GOVERNANCE MEASURES

Government policies and regulatory framework:

- Create regulations for waste reduction, and resource efficiency.
- Develop and enforce stringent waste management initiatives, regulations and standardization.
- Providing incentive schemes for businesses adopting sustainable waste practices.

Ownership Responsibility:

- Industrial responsibility for the entire lifecycle of their products from production to disposal reduction.
- Adherence to green and sustainable practices
- Boost waste collection, segregation, and building recycling facilities

Collaboration, training and Certification:

- Develop industrial standards and providing certification programs.
- Association between government bodies, private entities, and local communities to share resources, knowledge, and best practices.

Research & Development and Innovation:

- Government and industry should encourage and invest in research aspects that promote circularity
- Research outcomes are to be shared with the stakeholders for developing innovative waste management technologies and solutions.

CONCLUSION

In the past, mining and power plant activities caused significant environmental pollution due to waste generation. However, there is presently a global push for net zero and green initiatives to safeguard the planet. Apparently, the utilization of fossil fuels can't be avoided abruptly in the transition of the coal industry towards the net zero approach, hence carbon capture is a future challenge. As India has a target to achieve net zero by 2070, the thermal power sector is anticipated to continue for five more decades. The reduction of carbon emissions and utilization of captured carbon are significant challenges as well as opportunities for the development of the circular economy in the integrated mining and power industry. The energy efficiency of the power plant can be enhanced by the adoption of innovative technologies such as Integrated gasification combined cycle and using enriched fossil fuels. The material balance of Coal/lignite mines comprises fossil fuel, overburden and water, each of them with its intrinsic value. The produce has to be efficiently retrieved from mines and usage is to be optimized. Coal/lignite and wastes generated can be efficiently directed to the circular economy cycle. The mined-out land shall be reclaimed and put back to its original state. The research, innovation, and government policies are the major components to achieve the circular economy as a whole.

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AI Embedded Additive Manufacturing: Challenges and Opportunities

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Abstract*: Among emerging technologies, Additive Manufacturing (AM), which is also popularly known as 3D printing, along with reverse engineering, is making a steady penetration into industry. Though additive manufacturing has more design freedom and is environmentally friendly, it is yet to attract all sectors of industry. 3D printing techniques suffers with low productivity rate, inferior quality and uncertainty of final part mechanical properties. The process control of additive manufacturing and its optimization is an imperative to address such challenges of additive manufacturing. The inherent limitations of traditional optimization methodologies have forced engineers and scientists to device stochastic heuristics that mimic the functioning of a human brain and the behavior of natural species to solve such complex decision making problems of real the world. Such techniques are popularly known as artificial intelligence (AI) tools, namely Evolutionary Algorithms (EA), Artificial Neural Networks (ANN), Adaptive Neuro Fuzzy Systems (ANFIS) etc. In solving complex decision making problems, artificial intelligence tools are making significant contribution in various stages such as designing, fabrication and quality assessment towards producing cost effective, customized quality products. Therefore, embedding artificial intelligence techniques in design and manufacturing may give improved results and making the manufacturing process more agile and quality oriented. This paper aims to focus on to map available additive manufacturing methodologies based on their process mechanisms, and review the modeling and optimization methods with respect to AI tools and techniques.*

Keywords*: Artificial Intelligence; Additive manufacturing; Reverse Engineering; Optimization*

INTRODUCTION

Additive Manufacturing (AM) is the process of joining materials to fabricate objects using three dimensional model data in contrast to the subtractive manufacturing methodologies, such as traditional machining. Since AM offers advantages such as near zero material waste, tool less fabrication and excellent design freedom that facilitates quick fabrication of work pieces with complex geometry at low cost [1-3]. Despite these advantages AM is a relatively new and yet to mature technology. Currently, in this domain of AM, researchers are striving to figure out best practices and optimal processes conditions to bring out quality end product to the satisfaction of dynamically changing market needs [4]. By employing suitable modeling and simulation tools and techniques many attempts are being made to optimize AM processes with respect to key performance indicators. It is also reported that AM has the low productivity rate due to the build time (It is the time required for part fabrication excluding design time and extraction time of STL file from computer aided design file.) and quality issues such as uncertain mechanical properties[5]. To address the uncertainty issues in the end product's mechanical properties the use of meta-materials i.e., functionally graded heterogeneous substances are also being used for developing intelligent devices that integrate sensing, actuating and control [6, 7]. But, decision making in AM is very challenging due large dimensional space, inherent processes uncertainties (more particularly the fluctuation of thermal boundary conditions) and skewed information. As the AM process is highly interdependent and nonlinear it is extremely difficult for operators to select optimal parameters for precise and good quality product [8]. Human expertise alone is barely sufficient to solve demanding issues of decision-making in AM. Therefore, the need to introduce machine intelligence as an effective tool for decision making in AM, has become an imperative to meet high quality and low production cost. [14,15]. Since its inception, AM has been popularly recognized as a digital manufacturing process, in contrast to other manufacturing technologies, this technology depends heavily on one or more digital platforms.

And thus this technology has become a very good candidate for realizing intelligent manufacturing [9, 10]. In this paper we discuss the challenges and opportunities in practically realizing the full potential of 3D printing i.e., Additive Manufacturing (AM). The paper is further organized as follows: in the succeeding section two current trends in AM are discussed. In section three and four the challenges and opportunities in the domain of Artificial Intelligence (AI) Embedded Additive Manufacturing (AM) are discussed. And, finally conclusions are drawn accordingly which are followed by references.

Current AI Trends in AM

AI encapsulates ML and intern ML encapsulates DL. ML may be further sub-classified into Supervised Learning, Un-supervised Learning and Reinforcement Learning. Accordingly DL may be sub-classified as Multilayer, Convolutional, Artificial, Recursive, Recurrent, and Shallow NNs. It is reported that integration of AI algorithms and platforms would be very useful as this can bring more convenience and innovation in AM technologies for rapid model generation, error correction and object customization [13]. Reports suggest researchers are innovating different techniques to exploit AI integration into AM [11]. For example Machine Learning (ML), Deep Learning (DL) and Neural Networks (NN) heuristics are being designed to automate information processing and machine assisted controls to arrive at rational decisions for self-correction in product development [12]. Although it is in general believed that AI embedded with 3d Printing technology has huge potential in achieving high-throughput, high-quality since it highly applicable for object monitoring, controlling and situ correction [14]. The potential applications of AI embedded AM cannot be not restricted to the manufacturing and construction sectors, but they are being extended to other sectors, such as health, design, architecture, and aerospace.

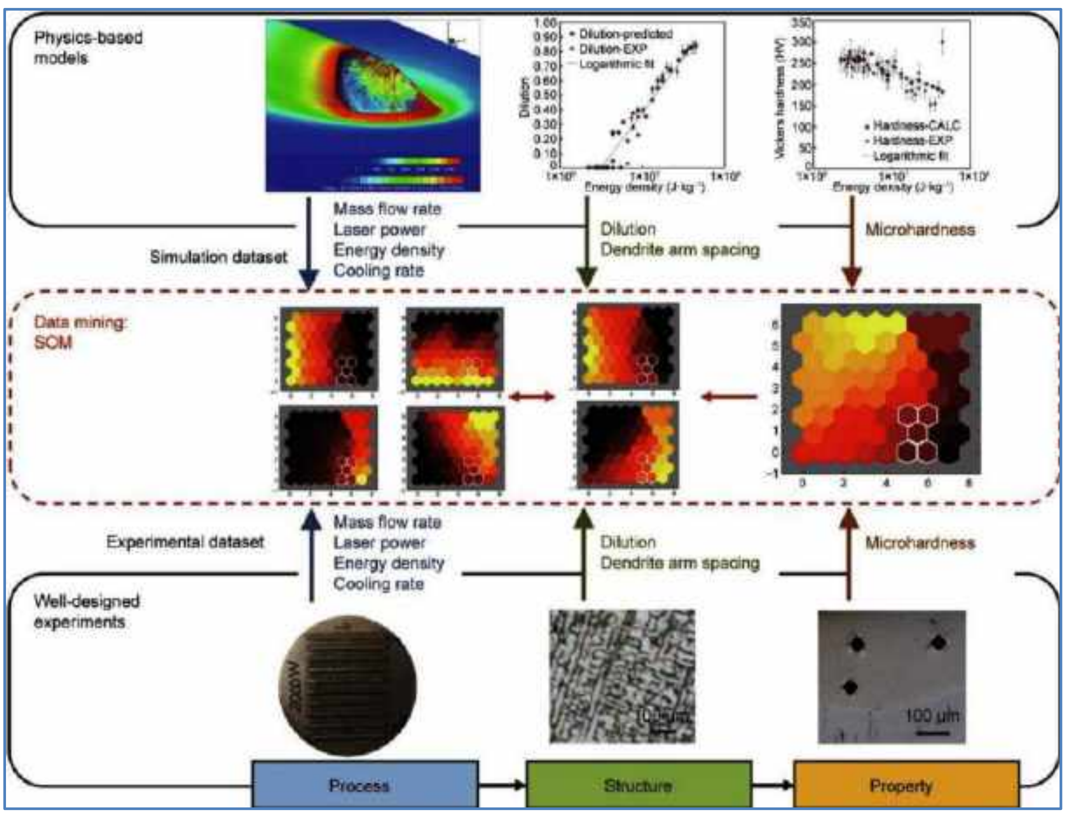
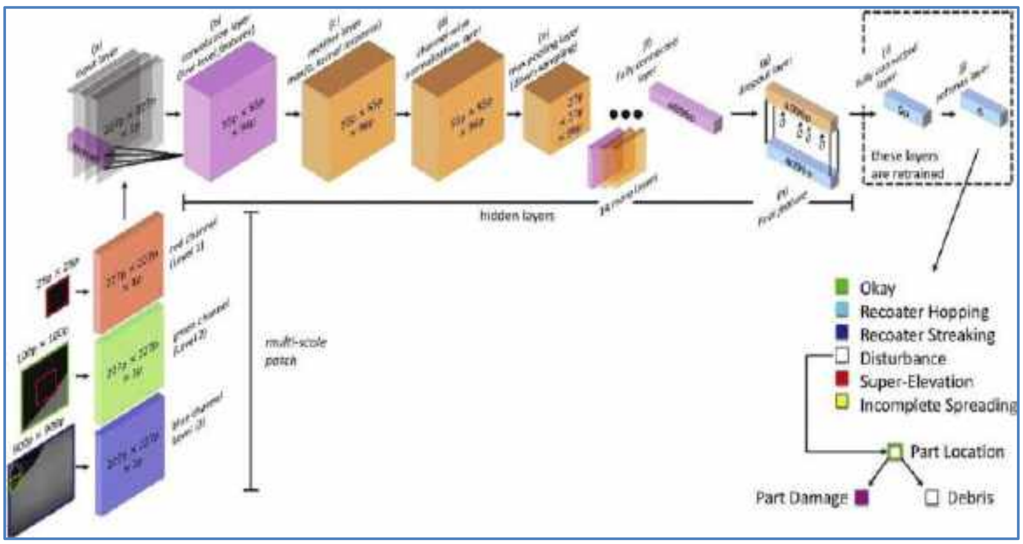


Illustration of workflow of current numerical studies (fist row) and of experimental investigations (second row), ML technique integration to identify process-structure-property relationships (third row) [21]

Currently, AI is employed in various aspects AM such as product design, process optimization, end product quality, in-situ monitoring, slicing acceleration, nozzle path optimization and service evaluation. The effective applicability of AI embedded AM is also observed increasingly in the fields of Remote Fault Detection (RFD), Orthodontics, AI-

Based Printability Checker for 3D Printing and finding Novel AI-Based 3D Printing of Materials [15]. The AI integration in AM enables designers to take quick decisions at the design stage by using hybrid algorithms for hierarchical clustering [16]. Although numerical simulations can evaluate CAD models digitally in order to reduce the cost of experimentations, numerical simulations are computationally costly and time-consuming and not feasible for online monitoring of the printing processes. And thus researchers used DL based frame work to predict stress distribution on the cured layer of the SLA in almost real-time. A database of AM model of complex geometries was generated to conduct FEA simulations and further the derived data sets were trained DL network using convolution neural network (CNN) [17]. It has been demonstrated that ML algorithms are suitable to be embedded in AM for composite design and in tuning material properties in particular. Some ML algorithms can generate optimal designs that outperform existing conventional designs [18]. By employing Self Organizing Map (SOM) algorithm, multiple objectives were optimized by estimating optimal process parameters with help of large and high-dimensional dataset that are generated from numerical simulations, and the results are validated experimentally [19]. The AM process is very complex and highly non linear in nature that involve discrete and continuous variable data of large search space. And therefore for such process optimization support vector regression (SVR), ANN and Genetic Algorithms (GAs) were used to improve the process conditions [20, 21].



CNN based computer vision for in-situ monitoring of 3D Printing [22]

It is reported that, a CNN based Computer Vision (CV) techniques are used in-situ monitoring systems. They used high resolution cameras to acquire information about the printing conditions, defect detection [22]. Besides this, some used Scale Invariant Feature Transform (SIFT) method to extract features of melt pool, and Histogram of Oriented Gradients (HOG) clustering method and SVM to learn the defects such as under-melting. Reports suggest that CV and ML techniques are employed to detect anomalies such as re-coater hopping, re-coater streaking, debris, super-elevation, part failure, and incomplete spreading [23].

It is an appreciated fact that, Artificial Intelligence (AI), Additive Manufacturing (AM) Could Manufacturing (CM), Digital Manufacturing (DM) and Intelligent Manufacturing (IM) are emerging technologies of the Industry 5.0 that demand high order of data security. To mitigate and figure out malicious attacks in a Fused Filament Fabrication (FFF), a supervised learning algorithm called k Nearest Neighbours (kNN) is applied and an unsupervised algorithm and Random Forest Algorithm (RFA) was used to detect anomalies and found that unsupervised algorithm achieved 96.1% accuracy, kNN that achieved 87.5% accuracy and RFA achieved 95.5% accuracy [24]. It is also felt that, it is desired avert any threat to 3D printable data that me be confidential or pose dangerous national or societal security concern. In this regard researchers attempted to use AI based anti weapon model detection algorithm along with CNN to achieve 98.03% accuracy [25].

Challenges in AI Embedded AM

Although, AI techniques are gradually being integrated with AM and reverse engineering (RE), there are some open challenges in both the technologies and in their integration [25]. Notable challenges are:

Computational cost	High adoption cost
Knowledge gap	Environmental factors
Complicated intellectual property rights	Hardware and software compatibility issues
Standardization	Quality data collection & systems obsolescence

On the other hand product fabricated through AM may sometimes have to compromise on the following accounts also, i.e., it is reported that there are some quality issues of 3D printed objects, such as:

a) Mechanical properties and microstructure
b) Dimensional accuracy
c) Surface roughness
d) Building speed
e) Energy consumption
f) Droplet shape and
g) Heat transfer related phenomena.

It is acknowledged that the integration of AI and AM is happening but it is a long way for the advanced manufacturing sector accepts through transition in AI embedded manufacturing per se.

OPPORTUNITIES IN AI EMBEDDED AM

Artificial Intelligence (AI) embedded Additive Manufacturing (AM) platform give away various opportunities across different domains of manufacturing. Some significant areas where the integration of AI and AM can create major opportunities are [26, 27]:

Design Optimization	Process Optimization
Materials Innovation	Tissue Engineering
Quality Control	Material Selection
Workflow Automation	In-Process Monitoring
Computer Vision Inspection	Supply Chain Optimization
Inventory Management	Security and Intellectual Property Protection
Customization and Personalization	Autonomous 3D Printers
On-Demand Manufacturing	Energy Consumption Optimization
AI-Driven Robotics in 3D Printing	Mass Customization

CONCLUSIONS

This paper presents the concept of AI embedded AM with the perspective of current state of the art AI integrated 3D printing, challenges involved in realizing the full potential of such integration and opportunities these emerging technologies in manufacturing. The review suggest that , during the walk of AI integration into AM, AM first needs to address certain challenges within its decision-making process, as AM suffers from limited information, large uncertainties, and high-dimensional design spaces. The key objective of AI embedded AM is manufacturing quality products by availing the best feature of AM i.e., the design freedom in terms of materials, structures, and processes. This paper refers to the need of development newer AI algorithms for design automation, intelligent sensing, intelligent process control and decision making. However, the full implementation AI embedded AM concept needs sustained Reports works suggest that, as of now all cases reported are in proof-of-concept level. Embedding AI technologies in AM bring new opportunities to build effective, efficient, and economically viable quality products. This integration of AI and AM will help in decision-making at various stages from designing to end product which in turn enhances the product innovations and process conditions.

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Investigating Lead Time Reduction in Customized Healthcare Product Supply Chains

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Abstract *: The study examined the influence of customization by Additive Manufacturing (AM) on the production customized hearing aid buds and foot insoles. The results of questionnaire surveys and a review of the literature gave insights into consumer expectations and preferences regarding foot insoles and hearing aid buds. In addition to data from manufacturers of foot insoles and hearing aids, lead time data for analytical and simulation modeling came from experimental AM production of custom foot insoles and hearing aid buds. The supply chains for conventional manufacturing and AM integrated manufacturing were assessed for overall lead time performance using analytical and simulation methods. In the simulation analysis, the Traditional Manufacturing Supply Chain Network (TSCN) and Additive Manufacturing integrated Supply Chain Network (AMSCN) evaluations of the overall lead time, patients served, and total production time were conducted.*

Keywords: *Additive Manufacturing; Health Care Supply Chain; Customization; Hearing Aids; Foot Insoles*

INTRODUCTION

Additive Manufacturing (AM) is a rapidly growing technology transforming the healthcare industry by enabling the production of complex, personalized items, enhancing patient care, reducing inventory costs, and facilitating quick prototyping. The primary driver of changes in the digital manufacturing practices used in the healthcare sector is customer demands (Hanelt et al. 2020). AM produces better-quality products, it is now used in many industries, such as manufacturing, aerospace, and biomedicine (Dilberoglu et al. 2017). According to Minvielle et al. (2014), AM facilitates prompt communication between clients and businesses in order to expedite the delivery of customized goods. Among the obstacles to the effective adoption of AM practices are the requirement to guarantee appropriate unit collaboration and the requirement to close the gap between technological competency and the clinical field (Tayade. 2020).Several case studies have demonstrated the need for affordability, usability, resourcefulness, sustainability, and innovation (Agarwal et al. 2018). They described a possible product that can meet customer expectations and offer businesses cost-effective manufacturing options. Decentralization of supply chains may be able to reduce the vulnerability of customized healthcare products to defects and recalls. This is because it would allow for decentralized information sharing among supply chain participants while maintaining network track and trace capabilities (Jayaraman et al. 2018). AM technology can help with decision-making, cost reduction, on-demand delivery, and product customization. It can also make supply chains more sustainable (Ageron et al. 2020).In fast developing south-east Asian countries like India, China, and Indonesia generally, AM is mostly used by the healthcare industry to make orthodontics or dental prosthetics (Rodríguez-Salvador and Garcia-Garcia. 2018). AM can be used to create dental implants that precisely match a patient's natural teeth, such as crowns and bridges (Bhargav et al. 2018). Conventional manufacturing is still a viable technique because it provides higher performance and quality, but most research supports AM when it comes to clinical outcomes, indicating faster recovery times and less invasive treatments (Zanetti et al., 2022). AM can enable closed-loop material flows, which can improve resource efficiency (Ford and Despeisse. 2016). The primary obstacles to the widespread adoption of AM are the high initial overhead costs and the dearth of industry knowledge (Calignano et al. 2023). polymers and polymeric composites in AM have emerged as promising materials for a variety of research projects and commercial applications because of their unique physicochemical properties and characteristics, such as light weight, cost effectiveness, ease of process, and variability of compositions (Yuan et al. 2019).Studies have employed triangulated time intervals to measure the transportation times between different supply chain partners (Macchion et al. 2016). They also measured the production performance using simulation models that predicted the influence of variation in supplier behavior in the overall lead time. Supply chains for 3D printing services will likely go through stages akin to those seen in the early stages of pharmaceutical sector breakthroughs and drug discovery (Rogers et al. 2016).According to Chiu and Lin's (2016) simulation investigation, the supplemental nature of additive manufacturing (AM) technology can improve the performance of an AM integrated supply chain.Dispersed spare parts manufacturing would, however, become possible when AM machines become more autonomous, less capital-demanding, and have shorter production cycles (Khajavi et al. 2014).

These findings also demonstrated the increasing competitiveness of early adopters of AM in supply chain networks. The literatures drawattention to the lack of supply chain solutions for customization by AM and resilience, as well as the necessity for more research on the effects of customization on consumer goods. The study aims to assess user preferences and customization needs for foot insoles and hearing aids by utilizing questionnaire surveys and collect lead time information for analysis from manufacturers and the experimental AM manufacturing of customized hearing aid buds and foot insoles. The study employs analytical and simulation modeling methods to evaluate the lead time performance of the respective supply chain models.

METHODOLOGY

Collecting Customer Preferences and TSCN Lead Time Data for Analysis

The study aimed to assess consumer preferences for product customization in the healthcare industry through the use of questionnaires. Likert scale surveys were employed to collect demographic information, evaluate dependability, investigate needs, assess the significance of customization, and measure awareness. The hearing aid survey (Survey I) received 200 responses from various forums, with 181 deemed useful, while the foot insole survey (Survey II) received 122 responses, of which 100 were considered useful. These responses were assigned Likert scores and assessed for reliability using Cronbach's Alpha. The results demonstrated good reliability, with Cronbach's Alpha values of 0.819 for Survey I and 0.959 for Survey II. The findings highlighted the need for improved designs in foot insoles and hearing aids, with participants showing receptiveness to the potential benefits of additive manufacturing (AM) customization. The study also involved interviews with executives from hearing aid and insole manufacturers, investigating the supply chain networks of TSCN for these products.Data encompassed various aspects, including patient measurements, transit times, material logistics, processing and assembly durations, product transport, and trial fitting times, and was collected from manufacturers and audiology specialists.

Collecting AMSCN Lead Time Data forAnalysis by Experimental AM Fabrication

In the experimental production of custom hearing aid buds and foot insoles, Vat Photopolymerization (VPP) and Extrusion-Based Additive Manufacturing (EBAM) were utilized to gather lead time data for simulating AMSCNs of these items. The primary findings from the surveys, emphasizing the importance of a personalized fit for hearing aid buds and the demand for flexible, snug-fitting insoles, guided the experimental fabrication process. During this phase, participants' foot structures and precise ear canal measurements were obtained through digital scanning techniques., UV-curable Photopolymer Bioresin was selected for the hearing aid buds because of its biocompatible properties (**Figure 1a**) while Thermoplastic polyurethane (TPU) was chosen for crafting custom foot insoles due to its flexibility and durability (**Figure 1b**).

Building TSCN and AMSCN Models for Case Study Analysis

Analytical and simulation models were developed for both TSCN and AMSCN, utilizing lead time data gathered from manufacturers and experimental manufacturing. For customized hearing aid buds in TSCN, the process involved four key components: audiologist measurement and order placement, material transportation from suppliers to the manufacturer, product manufacturing, assembly, and delivery to the audiologist, and finally, the patient's test fitting. Mathematical models for both TSCN and AMSCN were created using Integer Linear Programming (ILP), with the objective function focused on lead time. Equations were solved using a Python compiler within the Integrated Development Environment (IDE), Visual Studio, by Microsoft Ltd. In the USA. Additionally, discrete event simulation software, Arena Simulation by Rockwell Automation Ltd. in the USA, was used to build and run the simulation models for the supply chain analysis.

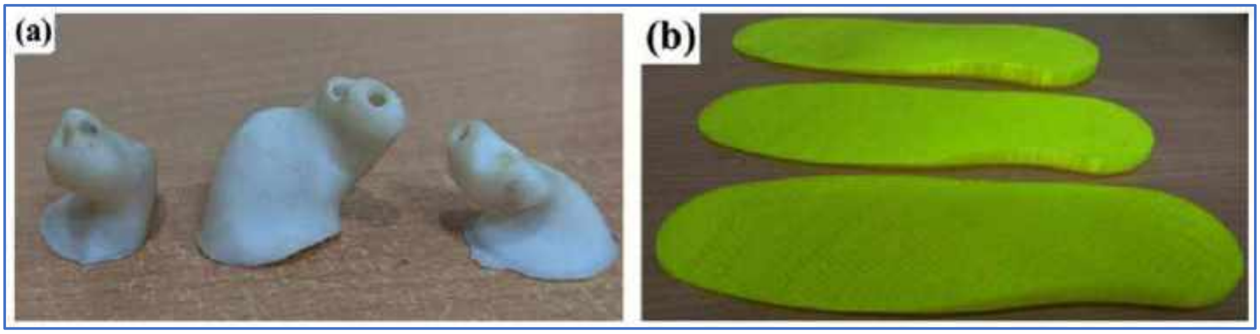

Figure 1 Customized AM made (a) hearing aid buds; (b) Foot insoles.

RESULTS AND DISCUSSIONS

Case Study I: Analyzing Lead times of TSCN and AMSCN of Customized Hearing Aid Bud

The minimum and maximum lead times for the customized hearing aid's first and second trial fittings during TSCN were 18.20 and 25.80 days and 19.62 and 29.20 days, respectively, according to the analytical models (**Figure 2a**). In contrast, the AMSCN models had significantly shorter lead times of 2.08 and 2.52 days, demonstrating that AM significantly reduces lead times, particularly in the first trial, by at least 88%. This is attributed to AM's ability to provide highly accurate customizations. However, overall client service was somewhat lower in both trials for the AMSCN. The TSCN had longer lead times, averaging 20 days with a range from 15 to 25 days. In contrast, the AMSCN technique had a notably shorter average production time of 2.2 days (**Figure 2b**).

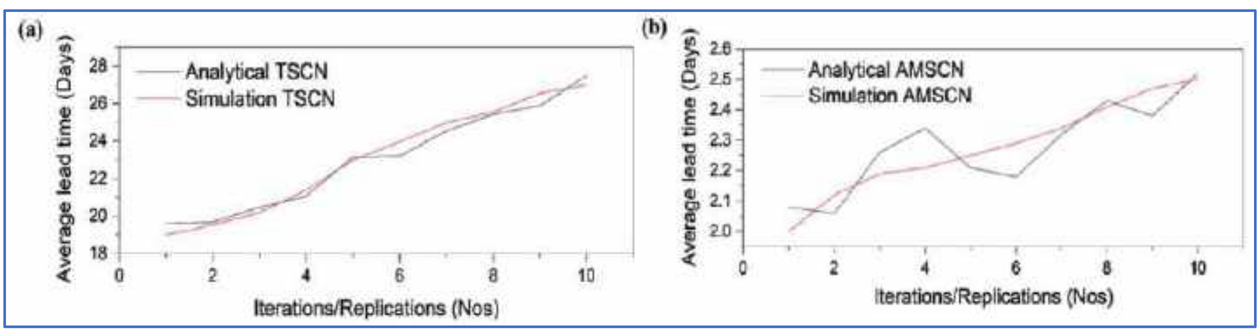

Figure 2 Lead times of customized hearing aid bud production (a) TSCN; (b)AMSCN.

Case Study II: Analyzing Lead times of TSCN and AMSCN of Customized Foot Insole

The TSCN model for customized foot insoles utilizes a three-level supply chain, including a manufacturer outlet, two manufacturers with warehouses, and five suppliers. TSCN uses materials like polyurethane, foam, and cork for its customized insoles, while AMSCN employs Thermoplastic Polyurethane (TPU). Analytical models for TSCN showed lead times of 15.20 days and 20.60 days for the first and second trial fittings of custom foot insoles (**Figure 3a**). In contrast, the AMSCN analysis recommended lead times ranging from 2.35 to 3.25 days. Simulation results revealed a significant lead time difference, with TSCN having a 14-day lead time compared to AMSCN's 2.5 days. Production time for TSCN varied from 13.5 to 16.5 days (**Figure 3b**).

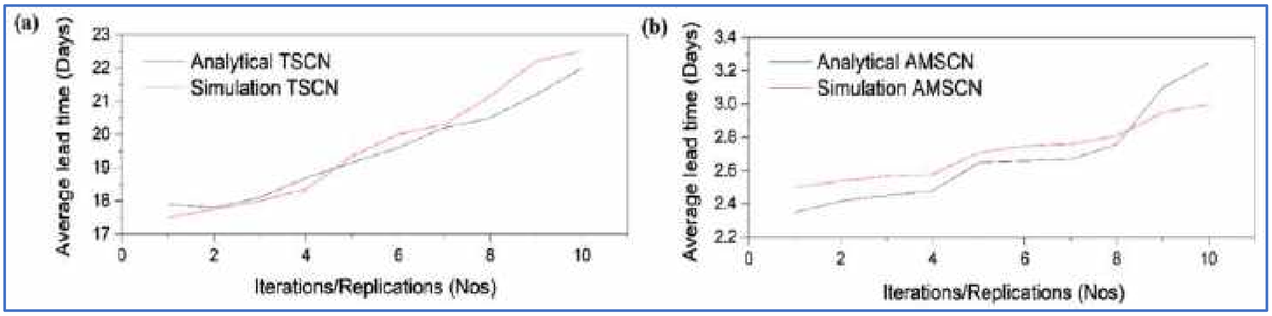

Figure 3 Lead times of customized foot insole production (a) TSCN; (b)AMSCN.

CONCLUSIONS

The study explores the impact of personalization on custom foot insoles and hearing aid bud production, highlighting the need for improved designs prioritizing personalized fit and flexible insoles.

The simulation models demonstrated that in the production of customized hearing aid buds, the lead time in AMSCN was significantly shorter, reduced by approximately 89.53%, compared to TSCN models. Furthermore, AMSCN effectively served 66.10% more clients during the entire simulation period and achieved an impressive 89% reduction in total production time when compared to the TSCN model.

The AMSCN model forecasted a lead time that was 82.94% less than the TSCN model for custom foot insole fabrication. Through simulation, the AMSCN model showcased a lead time that was 82.26% reduced compared to the TSCN model for custom foot insole fabrication.

The simulation and mathematical models for customized hearing aid bud production revealed varying lead times, while AM demonstrated shorter lead times compared to traditional methods. The inherent complexities in production processes contributed to the longer lead times in traditional manufacturing, which involves manual labor and specialized equipment. In contrast, AM offers advantages like rapid design iterations, on-demand customization, and reduced reliance on complex tooling.

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TEXTILE ENGINEERING DIVISION

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Smart Wearables: Advancement in Health and Safety Management System

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***Abstract**: Wearable technologies have been gaining popularity in recent years, and their applications in safety management are becoming increasingly important. These devices are electronically operated. They can be worn on the body, which will collect and transmit data. This equipment can improve the safe working conditions at our works. Personal Protective Equipment, Smartwatches, Fitness Trackers, Smart Glasses, Augmented Reality (AR) Devices, Smart helmets etc. are examples of such wearable units. Helmets, goggles, gloves, and respirators are essentials to be worn at worksite to protect workers from hazards arising out of work activities. Recent advancements in technology, makes the personal protection equipment capable of identifying and warning workers about potential hazards that can affect the health of the workers. Smartwatches are nowadays used by many which give details of our body fitness. These are worn that monitor our body movements and give details about our health and fitness. This will enable us to know about our wellness state. These devices also provide details on our heartbeats, pulse rates and fatigue levels which can caution the people to take appropriate steps from causing accidents and injuries. Wearable technology provides employees to monitor their health conditions. From these observations, they can make arrangements for improving the health conditions which may include preventing fatigue and stress-related illnesses. Once the employee is free from fatigue, their spirits will run high which can make the people focus more on the job activities. This will improve employees to work in groups and turn out better productivity. These advanced technologies reduce the number of accidents in worksites which in turn brings in more revenue to the organisation. The devices warn the employers and employees to be more cautious against any unsafe acts that may lead to accidents and prevent before they occur. Additional benefits in the form of reduced insurance premiums and improved workplace efficiency are the outcomes of using this technology. Wearable devices can be used for detecting hazards and thus injury can be prevented. Well-coordinated efforts by the management are able to identify workers with some sort of disabilities or discomforts while at work. This can be due to a few challenges associated with privacy concerns of the individual's health data. These information about health and family history can be disturbing to the employees and it may lead to breaches of confidentiality agreement between the company and the employees. It may also pose data security and vulnerable to hack. Another impending hurdle can be the costs to procure these wearable units for individual employee. The growth in the global market for personal wearable units is projected to grow at the rate of 21.5% from 2023 to 2028. This clearly demonstrates the acceptability of wearable devices. This can improve safety management in worksites with a definite back up of devices that can monitor and predict health particulars.*

***Keywords**: Wearable Technology, PPE, Smart Watches, Fitness Trackers, Smart Glasses*

WEARABLE TECHNOLOGY – AN OVERVIEW

Wearable technology involves electronic devices designed to be worn on the user's body that may include jewellery, accessories, medical devices, and elements of clothing [1]. Wearable technology functions by incorporating microprocessors, batteries and connectivity to the internet to synchronize the data with other electronics, such as mobile devices or laptops. Nowadays, the people have become more aware of wearable technology that can track and receive notifications for their heart rate and blood pressure, watch their calorie intake or manage their fitness programme.

Eyeglasses were first invented in the 13th century. In the 15th century, timepieces were created -- some of which were small enough to be worn -- but it was not until the 1960s that modern wearable technology came into existence.

Wearable technologies have given rise to human–computer interaction with the rapid development of information and communication technologies. This technology not only allows the consumers mobility and connectivity, but also allows access for exchange of information. Based on IDTechEx [2] analysis report the market of wearable technology will see threefold growth from over $24 bn in 2017 to $70 bn by 2025.

Application of electronic based technology using accessories and clothing on wearable units are consumer friendly with internet of things (IoT) connectivity. While these devices are used to improve health and well-being in personal fitness, innovative applications for monitoring occupational safety and health risk factors are becoming more common. Many of these devices have reached the market while others are still in development. As more wearables become available, they will positively impact and alter the landscape of society and work.

VARIOUS TYPES OF WEARABLES:

As the size of a wearable device [3] is comparatively small, it is very comfortable for people to use them anywhere, be it for jogging or while working. By using fitness trackers, people can count the exact number of calories they burned, the distance they have walked, and can analyse the sleep trend. Wearing mini wearable devices can also detect the exposure to hazardous activities in the work locations like vibration or noise etc.

Smart Watches and Bands

Smart watches and bands are most likely the most well-known and widely used fitness trackers in the workplace today. When a smart watch is linked to a mobile device, the wearer can read and send new messages directly from their watch, eliminating the need to hold and view one's phone. The smart watches and smart bands track vital health metrics such as step count, heart rate, calories burned, fall detection, sleep tracking, blood pressure, blood oxygen monitoring, emergency SOS, and many more. Designers of smartwatches and bands are constantly looking for new ways to innovate.

There are a plethora of smart watches and smart bands available in the market. Furthermore, leading tech companies such as Apple, Samsung, Oppo, Sony Corporation, Fitbit, Huawei Technologies Co., Fossil, Garmin, and many others are developing more smart watches and smart bands with more advancements. In addition, Meta/Facebook is also looking to compete with these companies by launching its smart watch in the market, in the near future.

Smart Clothing[4]

Smart clothes are high-tech garments that include built-in technology that extends their functionality beyond their usual application. These smart wearable clothing can communicate with phones and computers via particular apps, allowing users to keep track of their active metrics and crucial biometrics. These smart wearable clothing also enable the user to monitor their health and performance, which is critical for staying healthy.

There are various types of wearables that come under smart wearable clothing, such as Smart shoes, Smart work clothes, Smart sleepwear, Smart activewear, Smart casual wear, Smart socks, and many more. Currently, many smart wearable clothing is available in the market, including Siren Socks (smart socks that detect growing foot ulcers).

Furthermore, Samsung undertakes substantial research in this field and has filed a number of interesting patents; if these patents are commercialized, Samsung may soon deliver smart shirts capable of diagnosing respiratory problems and smart shoes that monitor running form.

Smart Helmets

Most individuals are bored and sometimes fed up with wearing normal helmets. But now there are smart helmets with built-in speakers and GPS. These helmets employ capacitive coupling, which transforms sound into vibration and allows users to listen to music while riding.

Technology has advanced further on helmets that helmet users can measure calorie burn, stamina, route and pace. The market for smart helmets is promising as many individuals are turning to smart helmets to have fun while staying safe. We can witness many novel products in the smart helmets category very soon.

Smart Glasses

Smart glasses, also known as wearable computer glasses, are among the most interesting wearable technology trends in 2022; they're an exciting experiment that will improve productivity and working capacities. AR (augmented reality), VR (virtual reality), a camera, Bluetooth, built-in headphones, noise cancellation, facial recognition, health sensing, audio recording, and other functions are included in these smart glasses.

These spectacles carry out the functions of a phone. The available smart glasses include Google's Glass, Microsoft's Hololens, Snap's Spectacles, and Facebook's Ray-Ban Stories glasses.

Furthermore, Apple is also looking beyond phones and will soon launch its smart glasses in the market.

HEALTH AND FITNESS WEARABLES [5]

There are a variety of devices that are well connected with the health and wellness areas. People are wearing such smartwatches to measure their exposure to hazardous tasks like vibration and noise. Vibration is an occupational disease that can cause severe pain on the fingers and can lead to vibration white finger. This is caused due to regulated supply of blood to the fingers. Such irregular flow of blood can be detected through these smart devices that are worn by workers in the industry. In the field of occupational safety and health, it has become of paramount importance to save the lives of employees from any occupational illness or injuries. Vibration white finger can cause chronic issues to the affected person and sometimes even the fingers may have to get amputated. This can be avoided through timely intervention of preventing exposure to such hazardous activities and usage of machines. Wearing these wearables can help to identify such irregularities and workers can get immense benefits.

Life Insurance Wearables [6]

To enjoy healthy life styles is everyone's wish. In order to achieve this, many promotions do take place and it has become the practice to utilise life insurance companies to provide assistance in the form of advices as well as materials to the needy ones. They also have found the issuance of wearable devices to their valued customers to identify about their health conditions and data. These data reveal the customers' activities, health particulars and concerns that may lead to serious health effects. This information is being used to evaluate the insurance premium prices. These wearables provide more or less accurate information on the health of customers and prepare a policy depending on the age and sickness details.

Fashion Wearables

Smart shirts and body suits provide data related to pulse rate, temperature, heart beats and physical movement, and these data are transmitted through Bluetooth to an app in real time. It is an intelligent system that senses and reacts to the changes in the environment and the wearer reacts to such changes. These applications are also able to automatically cool or warm the body based on body temperatures taken from sensors. Smart fabricsare woven fabric that contains a digital component like batteries, sensors, or an electronic chip that enable various functions through these applications. There are also other wearables like smart rings that can measure one's sleep habits. In this manner, if the technology advances further, the day is not that remote when our trousers or shirts become so smart that they can produce thermal energy even to charge our mobile phones.

Logistics Wearables

Another beneficiary of wearables is the logistics industry, which relies on wearable tech to develop more efficient operations. Smart glasses like Google Glass [7] enable warehouse workers to quickly scan barcodes, pull up information from a database and make updates along the way. This process eliminates the need for workers to return to computer, which can save time while they organise packages.

Some VR glasses go as far as to help workers finding the quickest and most quick and cost-effective route to reach their location in a large warehouse. These glasses can also identify different options to organize packages for maximized storage without crushing lighter items.

APPLICATIONS OF WEARABLES IN CONSTRUCTION INDUSTRY

Construction sites have dynamic environments involving activities that are unique and often hazardous working conditions that can change daily and throughout the life of a project. Nearly 20% of all work-related fatalities occur on construction sites every year. These environments frequently expose workers to extreme temperatures, loud noises, poor air quality, encounter with equipment and vehicle operations and job-related tasks like working at height, confined space working, hot works like welding, gas cutting etc. Heavy construction equipment is operated by workers and they work very close and near to other workers exposing them to potential hazards of collisions and get knocked over. The movements of vehicles can be detected through these devices and monitors and workers can move away from getting vehicles.

Wearable technology is beginning to be developed, tested, and used in a wide range of applications in construction industry. For example:

- Proximity detection and warning alarm systems [8], are reliable and effective and can alert people to move away from the hazard zone of moving vehicles and equipment.
- Physiological status monitors can reliably collect worker data in the outdoor environment and warn about the potential for heat stress.
- Monitor air quality, including carbon monoxide, hydrogen sulfide, gas leaks, temperature, humidity, and noise can improve the health of workers.
- Exoskeletons [9]enable workers to reduce pain and stress and can prevent musculoskeletal disorders. Forward bend lifting using an exoskeleton reduces fatigue. It can also reduce shoulder pain which can improve fitness in workers to increase productivity and work quality.

Advantages and Disadvantages of Wearable Technology [10]

Advantages of Wearable Technology

- Society has benefited from the technological advancement in devices for monitoring health particulars of humans. The pacemaker has saved thousands of lives since its invention in 1960. A great and more modern example is the Apple Watch.
- These advancements can help increase productivity. When the device is attached to your wrist, details can be obtained by lifting and pressing a button. Wearable technology can get things quicker thus saving time.
- Employers facilitating to implement a company wellness program, wearable technology enables to track employee health information and activity.
- Wearable technology can help keep people safe. People can trackexact location even in the middle of the ocean. how wearable technology can help keep people safe in many ways.
- A worker wearing a proximity sensor can be notified if a piece of heavy equipment is approaching him. Likewise, smart vehicles can monitor workers in their vicinity

- Active monitoring of physiological data with wearable technologiesallows for the measurement of heart rate, breathing rate, and posture. This information can help workers actively monitor their bodies' response to the work environment and its demands.

Disadvantages of Wearable Technology

- Wearable technology is expensive and not accessible to everyone.
- It is not a stand-alone device. They need to be connected to a second or multiple devices to send information and communicate with another piece of technology to reach full functionality.
- Risks regarding your personal safety as the device is attached to your body, someone may be able to access data like your location, health information, etc.
- Wearables will track and report all of your health information, not just what you pick and choose. This may raise concerns about privacy if this information gets into the wrong hands.
- Because of its highly accessible and "always on" nature, wearable technology can be distracting and time-consuming.
- The disadvantages of wearable technology have more to do with the mental effects on society and perceptions people have about how evolving technology is taking away from the "human" parts of humans.
- Cost, maintenance, and privacy are all issues that could affect how widely these technologies are adopted. Many of these systems require infrastructure spending, such as an IoT mesh network, in addition to the cost of the wearable devices.

CONCLUSION

Wearable technology has come here to stay for a long time. Technologies are changing at very high pace that unless the companies also adopt to the new innovations taking place, there is a possibility that they would be marginalised in a competitive world. Wearable technology has already established it footing for the past decade and it has found its usefulness among its users. Employers also have found various advantages in using the wearable technology to comply with the well-being of their employees. The workers have identified that they are able to monitor their health particulars and thus identify any ill-health symptoms and they can go for medical attention without aggravating their ailments. So, wearable technology has made a stamp of its own in the engineering and technological field and the world is moving with advancements befitting the human kind.

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Towards a Circular Fashion Industry: Effective Waste Management

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***Abstract**: The textile and fashion industry, known for its environmental challenges, grapples with issues of waste generation, resource consumption, and a substantial carbon footprint across the entire supply chain. This paper explores waste management in the textile industry towards achieving sustainable fashion. It addresses the industry's environmental impact, challenges of waste generation, and the positive consumer shift towards eco-friendly products. Case studies of brands like Patagonia and Nike highlight recycling efforts. Effective waste management can reduce costs and environmental impacts while promoting circularity in fashion. By implementing effective waste management strategies, the fashion industry can reduce costs, minimize environmental impacts, and contribute to a more circular and resource-efficient model of production.*

***Keywords**: Circular Fashion, Waste Management, Textile Industry, Recycling Practices*

INTRODUCTION

The fashion and textile industry has garnered significant criticism due to its adverse environmental impact, which encompasses issues such as waste generation, resource consumption, and carbon footprint, all of which are present throughout the supply chain operations [1]. The manufacturing of textiles and apparel is known to consume considerable amounts of energy, water, and other natural resources, leading to the rapid generation of substantial waste [2,3]. In response to the challenges faced by the textile and apparel business, there has been a growing focus on sustainable practices to mitigate the climate crisis and reduce the industry's environmental burden [4]. The combination of increasing demand from fashion-conscious consumers and the rise of fast fashion has resulted in a significant surge in apparel production and consumption [5], which, in turn, contributes to a substantial volume of waste at various stages of manufacturing, including spinning, knitting/weaving, dyeing, apparel making, and finishing [6]. According to several studies, it has been estimated that the global textiles industry produced around 92 million tons of waste in 2014. Unfortunately, only a small portion of this waste is reused or recycled, while a significant amount finds its way into landfills or is incinerated [7]. This has been noticed that maximum focus always given to water & energy in textile industry rather than the solid waste management and make it a vital problem for textile industry [8]. In 2015, the textile and apparel industry held a substantial value of USD 1.3 trillion. Throughout that year, approximately 53 million tons of textile fiber were consumed, with a staggering 73% of it ending up in landfills or being incinerated. Regrettably, less than 1% of the material was recycled for the production of new clothing, resulting in a loss of over USD 100 billion worth of materials annually [9]. Various types of waste generated in textile industry during production has been depicted in **Table 1**.

These types of waste as presented in table I, represent the various stages of textiles and apparel manufacturing where waste is generated, highlighting the need for effective waste management and recycling practices to reduce the environmental impact of the industry.

Impact of Waste in Industry and Environment:

The textile industry faces significant challenges related to the generation and management of waste throughout its manufacturing processes. These problems have far-reaching implications for both the industry and the environment. Here are the key issues associated with improper waste management in the textile industry as described here.

Table 1 Various types of waste in Textile industry

Waste Type	Description
Fibre Waste	Waste generated during the processing and production of fibres used in textiles and apparel. This includes trimming waste, short fibres, and by-products.
Yarn Waste	Waste generated during the spinning and twisting processes of yarn production. This includes broken or unusable yarns, leftover yarn ends, and manufacturing defects.
Fabric Waste	Waste generated during the cutting and sewing processes of fabric production. This includes fabric scraps, offcuts, and rejected or flawed fabric pieces.
Apparel Waste	Waste generated during the manufacturing of apparel, such as garments that do not meet quality standards, samples, prototypes, and damaged or unsold products.

Increased Production Costs: Waste generation leads to increased production costs due to the disposal of valuable raw materials as waste. This loss of materials represents a financial burden for textile manufacturers.

i) Wasteful Handling and Resources: Dealing with waste requires additional time, effort, and resources. Reworking, replacement production, and inspection consume valuable time and add unnecessary costs to the manufacturing process.
ii) Energy Loss: With waste generation increases, energy loss also increases. The transportation, disposal, and management of waste require additional energy inputs, contributing to overall energy inefficiency [9].
iii) Legal, Environmental, and Social Problems: Inadequate waste management practices can lead to legal, environmental, and social issues for textile institutes or factories. Failure to handle waste properly can result in legal repercussions and harm the reputation and social standing of the organization [10].
iv) Water Pollution: The textile industry consumes vast amounts of water for processes like fibre washing, bleaching, dyeing, and cleaning. Wastewater containing synthetic dyes and chemicals is often discharged into water bodies without appropriate treatment. This contributes to water pollution, disrupting aquatic ecosystems and posing a threat to aquatic life [11].
v) Air Pollution: Gaseous waste containing solvent vapours, such as ammonia and formaldehyde, is released into the atmosphere from textile manufacturing activities. In addition, emissions of cotton dust and carbon dioxide contribute to air pollution. These pollutants can harm human health, damage animal and plant life, and contribute to global warming and climate change [12].
vi) Noise Pollution: Textile manufacturing operations generate excessive noise levels, which pose a threat to the well-being of workers and residents in surrounding areas. High noise levels can have adverse effects on physical and mental health, causing irritability, concentration difficulties, anxiety, and other health issues [13].

Addressing these problems requires implementing effective waste management strategies in the textile industry. By maximizing resource reuse, improving wastewater treatment, reducing air emissions, and promoting recycling practices, the industry can mitigate the environmental impact of solid waste while also improving its operational efficiency and sustainability.

Circular Fashion

There is a growing movement towards achieving a circular fashion value chain, which involves a shift from the current linear system of take-make-waste to a closed-loop or cradle-to-cradle design principle. Making fashion circular requires a fundamental transformation, and designers play a crucial role in driving this change. The decisions made during the design phase have significant environmental impacts and costs. Therefore, designers need to adopt a circular fashion mindset. The Make Fashion Circular initiative focuses on three key pillars as depicted in table II, establish a circular system in the fashion industry:

Table 2 Three pillars of Circular Fashion Initiatives

Promoting business models that extend the lifespan of clothes. This includes implementing practices like clothing resale, organizing clothing swaps, offering store take-back schemes, facilitating garment repair, and encouraging upcycling.	Emphasizing the use of renewable and safe materials. This involves utilizing high-quality renewable fibres that are produced in a safe and non-toxic manner, reducing the environmental impact associated with the production of textiles.	Creating solutions that transform used clothes into new garments. This includes innovative approaches such as upcycling waste materials into new products through thoughtful design, as well as recycling waste textiles through mechanical and chemical processes to produce new fibres.

By embracing these principles, the fashion industry can move towards a circular economy, where clothes are kept in use for longer, sustainable materials are prioritized, and used clothing is given new life through creative recycling and upcycling methods. The fashion industry's current production and consumption patterns are unsustainable, with over 100 billion garments being produced annually and consumption projected to increase by 63 percent by 2030.

New Business Thinking

A circular economy approach in the fashion industry aims to create a sustainable and closed-loop system by extending the lifespan of garments and preserving the value of products and materials. This involves designing products with multiple lifecycles, promoting the flow of materials within the system, and collecting and recycling waste as valuable resources. Policy measures, such as Extended Producer Responsibility (EPR) principles, can drive this transition towards circularity. Adopting a system perspective, the fashion sector can involve various stakeholders,including designers, producers, manufacturers, suppliers, business professionals, and consumers. A model proposed by the RSA's "Great Recovery"[14] program as shown in Fig. 1 illustrates this approach with four levels. The first level focuses on consumer behavior, aiming to extend the use phase of products. The second level involves companies and new business models, such as Product-Service Systems (PSS), to enhance product use. The third level challenges manufacturers to extend product lifespan through remanufacturing. The fourth level emphasizes material recovery, using textile waste to manufacture new fibres and yarns.

This model recognizes the importance of collaboration among key stakeholders to drive the transformation towards circularity. Designers, researchers, industry players, users, and policymakers must come together to create a new network and system that promotes circular fashion practices. Notably, significant efforts are being made to explore innovative ways of utilizing textile waste as a source for new fiber production.

Extending the use of clothing is a critical aspect of sustainable development. By doubling the use-time of garments, we can significantly reduce the resources required for production and decrease waste rates associated with consumption [15]. This would be a substantial improvement compared to the current unsustainable fashion [16] practices that lead to early disposal of clothing. There are already successful examples of initiatives that promote extended use of clothing. Some brands offer rental or leasing services, allowing customers to access garments for a specific period instead of purchasing them outright. Others provide free mending services to extend the lifespan of garments, not only meeting customer needs but also enhancing brand value. For instance, Mud Jeans, Lena Fashion Library, and Vaatepuu are brands that offer rental or leasing options, while Nudie Jeans provides free mending services. Eco-spun (Welspun Inc.) is a brand that specializes in selling recycled fabrics made from discarded plastic bottles with approximately 9 million plastic-based wastes being disposed of in landfills each year. It was found that just 200 PET bottles are sufficient to cover a standard-sized sofa [17]. For Days, a Los Angeles-based brand, is dedicated to producing sustainable clothing. They specialize in organic cotton T-shirts, tanks, and sweaters. Their unique business model involves a monthly fee that grants consumers access to a set number of products. When a garment is sent back, For Days replaces it and recycles the returned item by transforming it into new fibre for creating new T-shirts, while European brand Filippa K offers its upmarket women's and menswear garments to lease for a one-off fee. G-Star RAW, a renowned brand, has been actively working towards achieving circularity in denim production. As early as 2012, they introduced the pilot for Renewed Denim, which is made from recycled G-Star RAW jeans. These jeans are blended with new organic cotton and do not contain any added polyester. In their efforts to enhance recyclability, G-Star RAW has eliminated rivets and replaced zippers with eco-finish metal buttons. As a result, these jeans are 98 percent recyclable, further promoting sustainability and reducing waste in the denim industry [18]. These initiatives not only contribute to the circular economy by keeping garments in use for longer but also fulfil customers' emotional satisfaction and strengthen brand reputation. They demonstrate the potential for alternative business models that prioritize sustainability and customer value in the fashion industry.

Figure 1 Four models of Design in Circular Economy

DEALING WITH AND RECOVERING WASTE

There exists the pre customer and post customer textile waste. The type of pre customer textile wastes, impact and how to achieve an environmentally sustainable way to minimize that type of waste generation already discussed in previous section of the paper. Post-consumer waste from the fashion industry can be recycled through mechanical, thermal, or chemical methods as shown in **Figure 2.**

Mechanical recycling involves sorting, cutting, shredding, carding, and spinning the material into new yarns. Although the yarn quality may not be as high as virgin materials, some virgin materials are often added to maintain sufficient quality. Chemical or thermal recycling dissolves the material and returns it to the polymer level, allowing for fibre regeneration. Significant progress has been made in developing technologies for different waste fibres in the recycling process, requiring technical and system innovations to effectively utilize waste as a valuable resource in manufacturing. The T2C Trash-to-Cash project as shown in **Figure 2** is an excellent example of interdisciplinary collaboration and an example of post customer waste handling [19]. This process aims to reduce the use of virgin materials, enhance material efficiency, decrease landfill waste and energy consumption, and promote design for recycling. The ultimate vision is to close material loops and create new material and product opportunities through creative design using textile waste and process by-products.

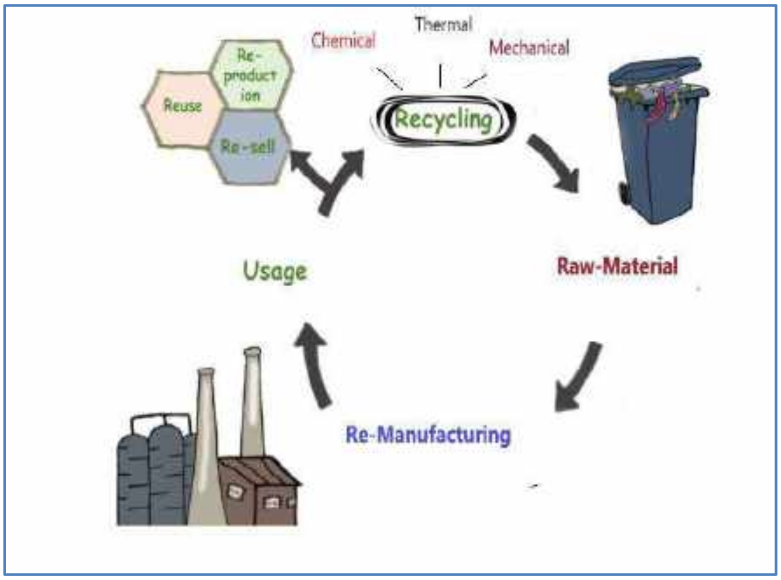

Figure 2 Post-consumer waste handling

CONCLUSION

The fashion industry is facing significant environmental challenges due to its linear take-make-waste model. However, there is a growing momentum towards adopting a circular economy approach, which offers a promising solution for sustainable waste management in the fashion sector. In the pursuit of sustainable fashion, waste management must be prioritized as a key element. It is not only an opportunity to reduce the environmental burden but also a pathway towards a more circular and resource-efficient industry. The key principles of circular fashion involve keeping clothes in use, using renewable and safe materials, and creating solutions to turn used clothes into new ones. This approach emphasizes extending the lifespan of garments, reducing resource consumption, and minimizing waste generation. Several innovative brands and initiatives, such as For Days, G-Star RAW, and Christopher Raeburn, have already demonstrated their commitment to circularity by implementing practices like clothing rental, recycling denim, and reworking surplus fabrics. To achieve a fully sustainable clothing item, it is essential to consider all aspects of the production process, from using natural and organic fibres to renewable energy-based manufacturing and zero-waste fabric cutting. By adopting a cradle-to-cradle design approach, products can be designed for multiple lifecycles, and materials can be efficiently recycled to create new fibres and yarns. Not only the pre customer waste handling but also post customer waste handling i.e., recycling play a crucial role towards circular fashion. Encouraging collaboration among stakeholders, including designers, manufacturers, suppliers, consumers, and policymakers, is crucial to transitioning towards a circular fashion industry successfully. Implementing policy measures like Extended Producer Responsibility (EPR) can facilitate the transformation and encourage businesses to adopt circular practices.

As the global consumption of textiles continues to rise, the urgency to address textile waste becomes more apparent. Embracing circular fashion not only presents a viable solution to reduce environmental impact but also holds immense economic potential. The shift towards circularity requires a collective effort from the entire fashion value chain, and the rewards include reduced resource consumption, diminished waste generation, and a more sustainable and resilient fashion industry for future generations.

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Multilayered Protective Clothing for Protection against Low Pressure Steam

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***Abstract**: Protective clothing offer protection against different thermal hazards such as hot surfaces, flame, radiant heat, hot water, molten metal etc. However, risk evolved in case of steam exposure is mostly ignored at the workplace. Very few studies have addressed the threat of steam exposure in industry and at workplace.*

An effort was made to study the effect of steam exposure on different multilayered protective clothing and in line with this a steam exposure test set-up was developed. Different Samples were developed by utilizing high performance fibres such as meta-aramid, para-aramid, para-aramid filament etc. Three layers were utilized for developing the protective clothing. The outer layer was developed with meta-aramid, para-aramid, para-aramid filament and antistatic. Whereas, middle layer was developed with recycled fibres and light weight fabric was utilized for inner layer.

It was observed that the time to second degree burn against the exposure of steam was increased by incorporating moisture barrier before middle layer as well as by incorporating coated outer layer. However, the comfort parameter may get compromised by utilizing the coated outer layer. Additionally, the coated outer layer is recommended where the exposure time of the wearer is less in the extreme environment.

INTRODUCTION

Thermal hazards such as flame, hot surface, radiant heat etc. are present in industries having high temperature working environment. Thermal protective clothing is developed by utilizing different flame-retardant fibres, that can protect them from these high temperature hazards. Also, along with these thermal hazards, Industries such as oil, gas, steel, power plant, food processing, garment manufacturing,textile, chemical, leather, paper, food, gold, foundry and molten metal to name a few can pose serious threat of steam leakage to the personnel working in such environment. The steam penetrated through protective clothing (single or multilayered) get condensed over the wearer's skin after or during the exposure. The latent energy gets transferred to the wearer's skin during the time steam condensation. Skin burn can be observed in the wearers' skin due to this latent heat. Thermal protective clothing can protect the wearer from different high temperature hazards but they fail to provide protection against low pressure steam. Therefore, life of workers and professionals working in these fields are always at risk [1]

The firefighters have to work in an environment very much similar to the extreme working condition of industries therefore, Firefighters are also exposed to the steam while firefighting. The steam may get generated from water in hose pipe, dew, rain and even from the moisture trapped within the clothing [2] The water used for extinguishing fire may convert in to steam [3]and in structural firefighting the water pressure pipeline may burst and eventually generates steam[4]. Exposure of the aforesaid conditions may result in fatal and non-fatal injuries such as burn, strain, bruise, toxic gas inhalation[5]. Extensive research has been carried out to improve the performance of firefighter's suit against flash fire and high intensity thermal radiation but ignored the threat of steam. However, study revealed that penetration of hot water and steam through the protective clothing caused 65% of the skin burn injuries [6]. To determine the performance of protective clothing in firefighting, various studies were carried out and test-rigs were developed [7]. Multiple tests were conducted at varying pressure and it was observed that pressurized steam compresses the protective clothing.Due to the compression, entrapped air gets released thus increasing the heat transfer rate to the wearer [8]. Further, it was observed that thickness, density, air-permeability, water infusibility, thermal insulation have vital effect on the performance of protective wear [3], [9], [10].

The transfer of steam through the different layers of protective clothing is complex phenomena and it involves condensation, diffusion, and absorption of water condensed during the steam exposure. Also, impermeable membrane can prevent steam burn by restricting the mass transfer of steam and proved efficient when compared with permeable and semi-permeable membrane. It was also observed that structural orientation of layers in multi-layered protective clothing would produce different results. Some practical situations were addressed by researchers where combined effect of radiation and steam exposure was studied and similar to this test, steam exposure test was conducted after radiant heat exposure. The steam exposure test was also examined where protective clothing get affected (abraded) by multiple use [11].

After accessing the researches on steam protection performance of thermal protective clothing, different fabrics were developed and the performance of those fabrics was evaluated in multi-layered assembly. The multi-layered assembly was exposed to different thermal hazards along with the steam exposure. The time to second degree burn was observed for different samples for differentiating their performance against the steam exposure.

MATERIAL AND METHOD

Different inherent flame-retardant synthetic fibres were procured and processed in High Performance Textiles Pvt. Ltd. Panipat i.e; meta-aramid, para-aramid, FR viscose and modacrylic was procured from Toray, Kolon, Lenzing and Kaneka. These fibres were blended in appropriate ratio to develop the yarns and fabrics. Some fabrics were coated with neoprene by utilizing knife edge coating technique in Udaipur. The specifications of developed fabrics are given in **Table 1**. The fabrics were subsequently tested for its physical properties and thermal performance. All the samples were conditioned at (20 ± 2)°C temperature and (65 ± 2) relative humidity prior to the testing.

The multilayered combinations of developed fabrics, that were used for evaluating their performance are given in **Table 2**.

Table 1 Details of developed samples

S. No.	Sample code	Composition	Specification	GSM (g/m^2)	Thickness (mm)
1	A	93//5/2 meta-aramid	4/40 yarn, twill weave	265	0.80
2	B	93/5/2 meta-aramid with para-aramid filament	2/40 93/5/2 yarn with 300 denior para-aramid filament, Double fabric	277	0.68
3	C	FR vicose/Para-aramid/chorofibre (60/25/15)	30s Savesplash® yarn, knitted	290	0.83
4	D	Coated Savesplash® fabric	Knife edge neoprene coating on Savesplash®	550	1.13
5	E	Coated para-aramid SS wire	Knife edge neoprene coating on core yarn woven fabric	325	1.08
6	F	Modacrylic/para-aramid (50/50)	nonwoven, thermal barrier	180	1.92
7	G	Neoprene coated fabric	moisture barrier	150	0.89
8	H	Para-aramid/FR viscose (60/40)	Plain weave	160	0.55

The samples were tested for their steam protective performance by exposing them to steam. The time to second degree burn was evaluated for differentiating the performance of samples. There is no international standard for steam exposure test on protective clothing therefore, the steam test was performed on developed test-rig (Figure 1) by assuming the practical working condition. The test-rig was able to generate the steam at different pressure (ranging from 0 to 6 bar) and temperature (ranging from 100 to 200°C). The test was conducted at 3 bar, steam pressure and 120°C, steam temperature. The sample was placed 5 cm above from the steam nozzle.

Table 2 Multilayered assembly of developed fabrics

S. No.	Multilayer assembly	GSM (g/m^2)	Thickness (mm)
1	AFH	605	3.27
2	AGFH	755	4.16
3	BFH	617	3.15
4	BGFH	767	4.04
5	CGH	630	3.30
6	CGFH	780	4.19
7	DF	730	3.05
8	EF	505	3.00

Figure 1 Developed steam test-rig

Additionally, the samples were tested for flame spread, contact, convective and radiant heat transmission test and multilayered assembly were formed before conducting the tests. The flame spread test was conducted as per ISO 15025:2016. In this test, bottom edge ignition method wasadopted for evaluating after flame and afterglow.The contact heat transmission testing was conducted in accordance with ISO 12127-1:2015 where the samples were placed on aluminium calorimeter (sample holder) and heated cylinder was made to contact with the sample at 250°C. The performance of test sample was evaluated by calculating threshold time which is the time required to raise the temperature of back side of the sample by 10°C. The thermal characterization of the samples was carried out further by exposing them to 80 ±2 kW/m^2 heat flux under direct flame as per ISO 9151:2016. The performance evaluation under direct flame was based on calculating heat transfer index (HTI 24), which is the time required to raise the temperature of the test sample by 24°C. Likewise, the samples were tested against the radiant heat exposure as per ISO 6942:2022 after exposing to heat flux of 20 kW/m^2.

RESULTS AND DISCUSSION

The thermal performance of samples against different exposures was discussed first and steam exposure test is explained in details. The behavior of individual layers under the exposure of flame was observed as per ISO 15025. In this test the fabrics were vertically oriented and bottom edge ignition was performed on them. There was no hole formation, no flaming debris and flame was self-extinguished after the removal of burner. All the fabrics were inherent flame retardant and the observed after flame & afterglow time was ≤ 2 seconds. However, the burnt area was different for different fabrics, that basically depends on the fibre constituents used in preparing the fabrics.

The test results obtained in contact, convective and radiant heat transmission test are given in **Table 3**.

Table 3 Thermal performance of samples against contact, convective and radiant heat

Samples	**Convective heat transmission (HTI_{24}, s)**	**Radiant heat transmission ($RHTI_{24}$, s)**	**Contact heat transmission (T_t, s)**
AFH	37	118	13.9
AGFH	45	132	16.8
BFH	45	119	16.1
BGFH	53	135	21.8
CGH	44	118	16
CGFH	52	134	20.9
DF	40	132	11.7
EF	26	118	12.8

Further, the performance of multi-layered assembly against hot surface contact was evaluated at 250° C under 49 N weight. The threshold time for multi-layered assembly having A as outer layer was less than the multi-layered assembly having B and C as outer layer. The improved performance sample having B as outer layer was corelated with para-aramid, weight and thickness that increases the thermal resistance of fabrics. Similarly, due to the presence of high shrink clorofibre in sample C, produces good results as sample B.

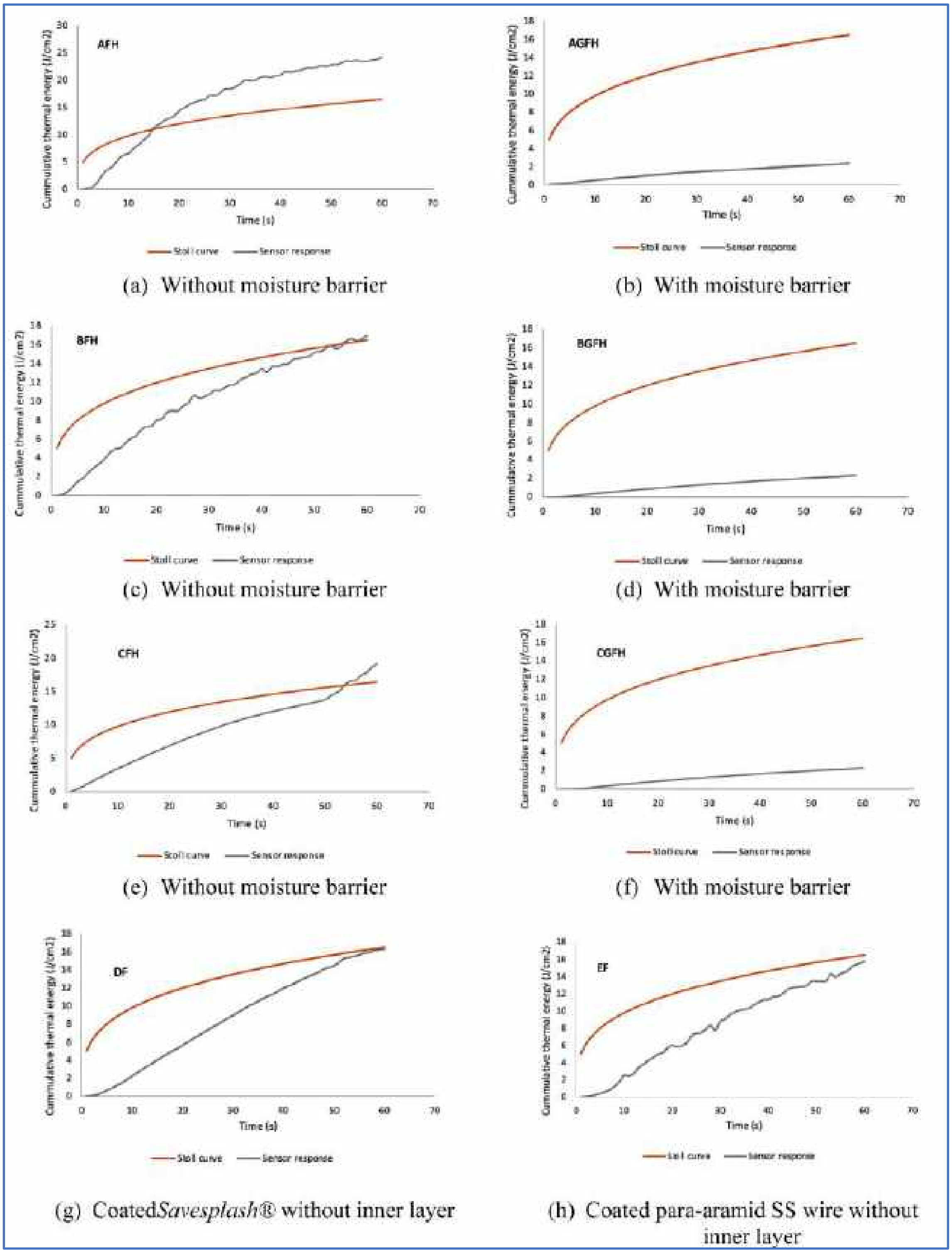
Due to the coating of neoprene in Savesplash® and para-armid fabrics, the wight and thickness were increased & the performance was comparable to the multilayered assembly having A as outer layer. Moreover, the performance of multi-layered assembly having B as outer layer and having C as outer layer were comparable, slight variation in results were observed due to the weight of the fabric. It is worth mentioning here that the SS wire reinforcement in fabric E may induce conductive nature in the fabric and the heat get passed through the fabric quickly when compared with fabric D. This behavior may reduce the performance of fabric E slightly when compared with sample D on same weight basis.

Similar to the test results of contact heat transmission, the performance of multi-layered assembly having B, C as outer layer was more than the multi-layered assembly having A as outer layer against direct flame and radiant heat exposure. The reinforcement of para-aramid filament helps in retaining the fabric structure of multilayered assembly BFH and BGFH under the exposure of direct flame and radiant heat. Also, more shrinkage was observed for 93/5/2 meta-aramid when compared with other multilayered assembly. However, the performance of multi-layered assembly having B and C as outer layer was comparable.

Steam Exposure Test

The steam was made to strike on the samples placed on a sample holder at 3 bar and 120°C. A nozzle was used through which steam passes and strikes the sample.

The second-degree burn was observed for samples having no moisture barrier and no coating against the exposure of steam. The second degree burn time for multilayer assembly AFH was 15 seconds (**Figure 2a**) whereas the second degree burn for multilayered assembly BFH and CFH were 56 and 54 seconds respectively (**Figure 2c, 2d**). This result can be corelated with the results of other thermal hazards where para-aramid presence, weight and thickness played an important role in thermal performance of samples. Further, employing moisture barrier before the thermal barriers results in improved performance of samples and no second-degree burn was observed for these samples. It was also observed that GSM also increases by utilizing neoprene coated rubber-based moisture barrier thus improving the performance. Also, this moisture barrier was impermeable and double side coated on glass-based substrate and because of this, steam was not able to get transferred through the multilayer assembly, thus, resisting the mass transfer of steam. Whereas, breathable membrane-based moisture barrier can resist water transmission but proved insufficient in case of steam exposure. The steam gets infiltrated through the layers of multilayered protective clothing and get condensed over the wearers' skin and produces second degree burn.



(a) Without moisture barrier

(b) With moisture barrier

(c) Without moisture barrier

(d) With moisture barrier

(e) Without moisture barrier

(f) With moisture barrier

(g) Coated*Savesplash*® without inner layer

(h) Coated para-aramid SS wire without inner layer

Figure 2 Sensor response of different multilayered samples against steam exposure

Neoprene coating is preferred protective clothing such as gloves, apron and suit because of high heat resistant, water, chemical resistance and lower cost than silicon-based coating. For the preferable properties of neoprene coating, two fabrics D and E were developed and their multilayer assemblies were exposed to steam. Similar to the behavior of neoprene coated moisture barrier, the coated assemblies DF and EF did not produce second degree burn for 60 s exposure of steam. Coating can significantly improve the performance of protective clothing against steam exposure because of restricting the mass transfer of the pressurized steam. However, impermeability in protective clothing can induce heat stress to the wearer thus discomfort in prolonged work.

CONCLUSION

The performance of multilayered protective clothing is affected by their weight, thickness and numbers of layers. In addition to this, the fibres blended in the fabrics also affect the performance irrespective of their weight and thickness as observed in EF assembly. It was also observed that employing impermeable moisture barrier or coated layer in multilayered protective clothing can improve the thermal performance of the clothing against steam exposure. Second degree burn to the wearers' skin can be avoided in case of low pressure and low temperature steam by utilizing coating based protective layer. However, heat stress caused due to the wearing of these fabrics is another study area and coating thickness can be optimized for this purpose. Another point can be addressed in future study where performance difference can be observed for coat outer layer and impermeable moisture barrier placed before the thermal barrier.

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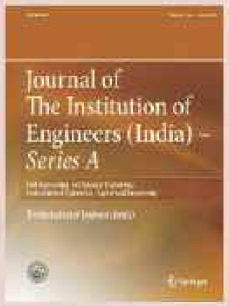

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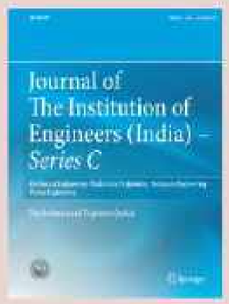

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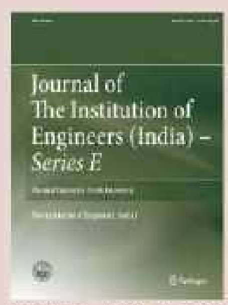

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