IEI Centenary Publication

Dr S P Luthra Memorial Lecture

A Compilation of Memorial Lectures presented in

National Conventions of Mechanical Engineers

35th Indian Engineering Congress

December 18-20, 2020

The Institution of Engineers (India)

8 Gokhale Road Kolkata 700020

Background of
Dr S P Luthra Memorial Lecture

Dr S P Luthra, born on April 01, 1912, after a brilliant academic career in India was awarded a Government of India Overseas Scholarship for higher studies and research at the Imperial College of Science and Technology, London and obtained the Ph.D. Degree in Mechanical Engineering in 1949. Earlier, he had received the B.Sc. (Engineering) Degree of Punjab University in 1937 and worked at the North-West Railway Mechanical Workshop at Lahore; Punjab PWD, Hydro Electric Branch; Shaw Wallace and Co Ltd; Siemens India Ltd and VDJH Technical Institute, Lahore.

In 1949, Dr Luthra joined Delhi Polytechnic (now known as Delhi College of Engineering) as Head of the Mechanical Engineering Department. He was also Visiting Professor at the University of Wisconsin, USA, under the Technical Co-operation Mission. Later, he joined the Indian Institute of Technology, Delhi, as Professor and Head of the Department of Applied Mechanics and held the positions of Dean of Students, Dean of Examination, Dean of Faculty of Engineering, and Dean of Administration and finally became its Director. During his professional career, Dr Luthra was connected with various professional, educational and scientific organizations. He was member of the Board of Governors, IIT, Delhi; Chairman, Board of Governors, Gorge College for Women, New Delhi; Chairman, World Conference in Industrial Tribology, New Delhi; and President of the Indian Society for Industrial Tribology.

Dr Luthra was also a recipient of the President of India Award for Best Teacher in Technical Education in 1979 and the prestigious award by the Prime Minister of India for meritorious service rendered to the IIT, Delhi, on the occasion of its Silver Jubilee in 1986, and a silver medal by the President of India for meritorious services rendered to the Indian Institute of Science, Bangalore, on the occasion of its Diamond Jubilee in 1986.

Dr Luthra had long association with The Institution of Engineers (India) having joined it as Corporate Member in 1944. He had served on the Council for twelve years and was Chairman of the Delhi State Centre of the Institution. He expired on July 24, 1993.

In memory of his dedicated service, The Institution of Engineers (India) instituted an Annual Memorial Lecture in his name during the National Convention of Mechanical Engineers.

Dr S P Luthra Memorial Lecture

presented during **National Conventions** of **Mechanical Engineers**

Computers in Vibrations and Noise Engineering **1**
Prof B C Nakra
(Delivered during the Tenth National Convention of Mechanical Engineers on 'Computers in Mechanical Engineering' organized by Andhra Pradesh State Centre, November 5-7, 1994)

Tribology for Energy Conservation in Industries **11**
Shri A Srinivasulu
(Delivered during the Eleventh National Convention of Mechanical Engineers on 'Tribology for Energy Conservation in Industries' organized by Madhya Pradesh State Centre, November 25-26, 1995)

Renaissance in Aviation Design and Manufacturing Technologies — An Indian Experience **16**
Dr Kota Harinarayana
(Delivered during the Thirteenth National Convention of Mechanical Engineers on 'Modern Trends in Manufacturing System' organized by Delhi State Centre, November 06-08, 1997)

Composite Pistons for Improving Two Stroke SI Engine Performance **22**
Dr R Mahadevan
(Delivered during the Fourteenth National Convention of Mechanical Engineers on 'Advances in Thermal Engineering' organized by Tamil Nadu State Centre, October 23-24, 1998)

Information Technology for Engineering Applications: A Roadmap to the 21st Century **27**
Dr S S Iyengar
(Delivered during the Fifteenth National Convention of Mechanical Engineers on 'Role of Information Technology in Mechanical Engineering' organized by Andhra Pradesh State Centre, December 16-18, 1999)

Safety in Automated Factory Environment **37**
Prof A Mubeen
(Delivered during the Eighteenth National Convention of Mechanical Engineers on 'Emerging Trends in Mechatronics for Automation' organized by Rourkela Local Centre, November 9-10, 2002)

Manufacturing Competitiveness: Issues and Challenges **42**
Prof S G Deshmukh
(Delivered during the Twenty-fifth National Convention of Mechanical Engineers on 'Challenges for Manufacturing in the Next Decade' organized by Delhi State Centre, November 06-07, 2009)

Engineering Solutions to Combat Climate Change **56**
Prof R S Agarwal
(Delivered during the Twenty-seventh National Convention of Mechanical Engineers on 'Advances in MEMS and Robotics in Manufacturing Industries' organized by Rajasthan State Centre, September 03-04, 2011)

Industrial Laser based Manufacturing Technologies for Sustainability and Safety in Mobility **59**
Dr G Padmanabham
(Delivered during the Twenty-eighth National Convention of Mechanical Engineers on 'Emerging Technologies in Product Development for Safe and Sustainable Mobility' organized by Coimbatore Local Centre, September 03-05, 2012)

Super Critical Technology — Mitigation of Environmental Impact **70**
Dr S Sekar
(Delivered during the Twenty-ninth National Convention of Mechanical Engineers on 'An Insight into Supercritical Technology-Concept to Commissioning' organized by Tiruchirapalli Local Centre, September 06-07, 2013)

Respice, Prospice Mechanical Engineering: Look Behind, Look Ahead **73**
Dr Souvik Bhattacharyya
(Delivered during the Thirtieth National Convention of Mechanical Engineers on 'An Green Technology in Power Sector' organized by Uttar Pradesh State Centre, September 20-21, 2014)

Maturity of Advanced Coal Combustion Technologies and the Indian Priorities **75**
Mr M S Unnikrishnan
(Delivered during the Thirty-second National Convention of Mechanical Engineers on 'Indian Manufacturing Industries – Challenges and Opportunities' organized by Jharkhand State Centre, December 10-11, 2016)

Modeling of a Manufacturing System: An IT Perspective **78**
Dr Rajat Bhagwat
(Delivered during the Thirty-third National Convention of Mechanical Engineers on 'Advances in MEMS and Robotics in Manufacturing Industries' organized by Udaipur Local Centre, September 01-02, 2017)

New Vistas of Mechanical Engineering for Industry 4.0 **84**
Prof (Dr) P B Sharma
(Delivered during the Thirty-fourth National Convention of Mechanical Engineers on 'Mechanical Engineering and Emerging Challenges for Manufacturing' organized by Delhi State Centre, September 07-08, 2018)

Study of Performance, Combustion and Emissions of Biodiesels and Diesel Additive (2-EHN) Blends in DI-Diesel Engine and Calibrations of NOx-SOOT-BTHE Trade-off Characteristics through Taguchi-Fuzzy based Multi-objective Optimization Technique **86**
Dr Swapan Bhaumik
(Delivered during the Thirty-fifth National Convention of Mechanical Engineers on 'Recent Trends and Development in Automotive Industry' organized by Hosur Local Centre, September 04-05, 2019)

Computers in Vibrations and Noise Engineering

Prof B C Nakra, *Fellow*

Professor, Indian Institute of Technology, Delhi

In this Memorial Lecture, the need of using digital computers for both theoretical and experimental analysis of machines and structures is outlined. Some of the work carried out recently, especially by the author and his co-workers, is included. This covers the use of transfer matrix and finite element method for vibration and noise engineering studies and approaches for dynamic optimum design using digital computers. The experimental studies relate to modal testing and analysis, sound intensity analysis, signature analysis and condition monitoring, all needing extensive use of digital computers.

INTRODUCTION

The author deems it an honour to have been invited by the organizers to deliver the First Dr S P Luthra Memorial Lecture. The author had the privilege of having worked with Prof S P Luthra at IIT, Delhi, since 1962 till the latter's retirement. It was during his tenure as Head of Department that young faculty members including the author received guidance and encouragement from Prof Luthra, to pursue academic work and aim at achieving excellence. He helped one and all as a true grind, guide and philosopher and made it a point to keep in touch with all his former colleagues even after his retirement till his sad demise. It was during his tenure at IIT Delhi that the use of digital computers gathered momentum for research work and he was greatly instrumental in creating facilities for this purpose.

The work on the 'use of digital computers for both theoretical and experimental work in the field of vibrations and noise engineering is highlighted with special reference to some of the work of the author and his co-workers.

The field of vibrations and noise engineering has been studied by physicists and mathematicians since long, to name a few: Newton, Lagrange, Hamilton and Rayleigh. The engineering significance, however, was realized much later. The failures of engine shafts and steam turbine wheels were explained as being due to fatigue caused by vibrations. The same is true of the field of noise engineering, though the subject of acoustics has been of interest to physicists since long though the consequences of noise pollution have been appreciated relatively recently. The trend in engineering practice for an increase in speed and power of mechanical systems and structures and the use of light weight and continuous construction without joints, eg, prefabricated buildings and welded construction, are some of the factors causing increased vibrations and noise.

The problems of vibration and noise arc inter-related. A vibratory surface creates noise and there may be acoustically induced vibrations in structures. Both vibrations and noise are undesirable from the point of view of comfort and reliability of systems. These can, however, be used to advantage to indicate any fault or malfunctioning of the system, if monitored and interpreted properly.

THEORETICAL STUDIES

The analysis of problems in vibrations and noise requires mathematical modelling, simulation and solution of the governing differential equations. Since real-life problems are complex; often simplified models are attempted for theoretical analysis. Lumped parameter models are used for approximate analysis in such cases. For complex continuous systems, numerical solutions have to be found since classical solutions are possible only in idealized cases. Approximate analytical solutions are attempted wherever possible and techniques like Rayleigh Ritz, Galerkin, etc are fairly accurate.

Numerical Solutions

For numerical solutions, use of computers is absolutely essential. An engineer, however, does need simpler techniques or experimental results to check the results obtained from computer solutions using techniques like finite different method, Runge kutta method, etc. In case of vibration problems, natural frequencies and mode shapes and response to a given excitation have to be determined while for noise engineering problems, one is interested in sound pressure, power or intensity values. Transfer matrix method and finite element methods, as described below, have been widely used in the past two decades.

Transfer Matrix Method

In this method, a relationship-is obtained between variables like displacements, forces, pressures, velocities at neighbouring stations. The system is broken up into a number of stations as in Fig 1 (a) and the relations are used to cover all stations for solution. Results have been obtained for torsional natural frequencies and response due to dynamic torques in an engine compressor system[1] using the transfer matrix method and digital computers for solving the resulting equations. The method has also been used for evaluation of sound in a muffler with mean flow.[2]

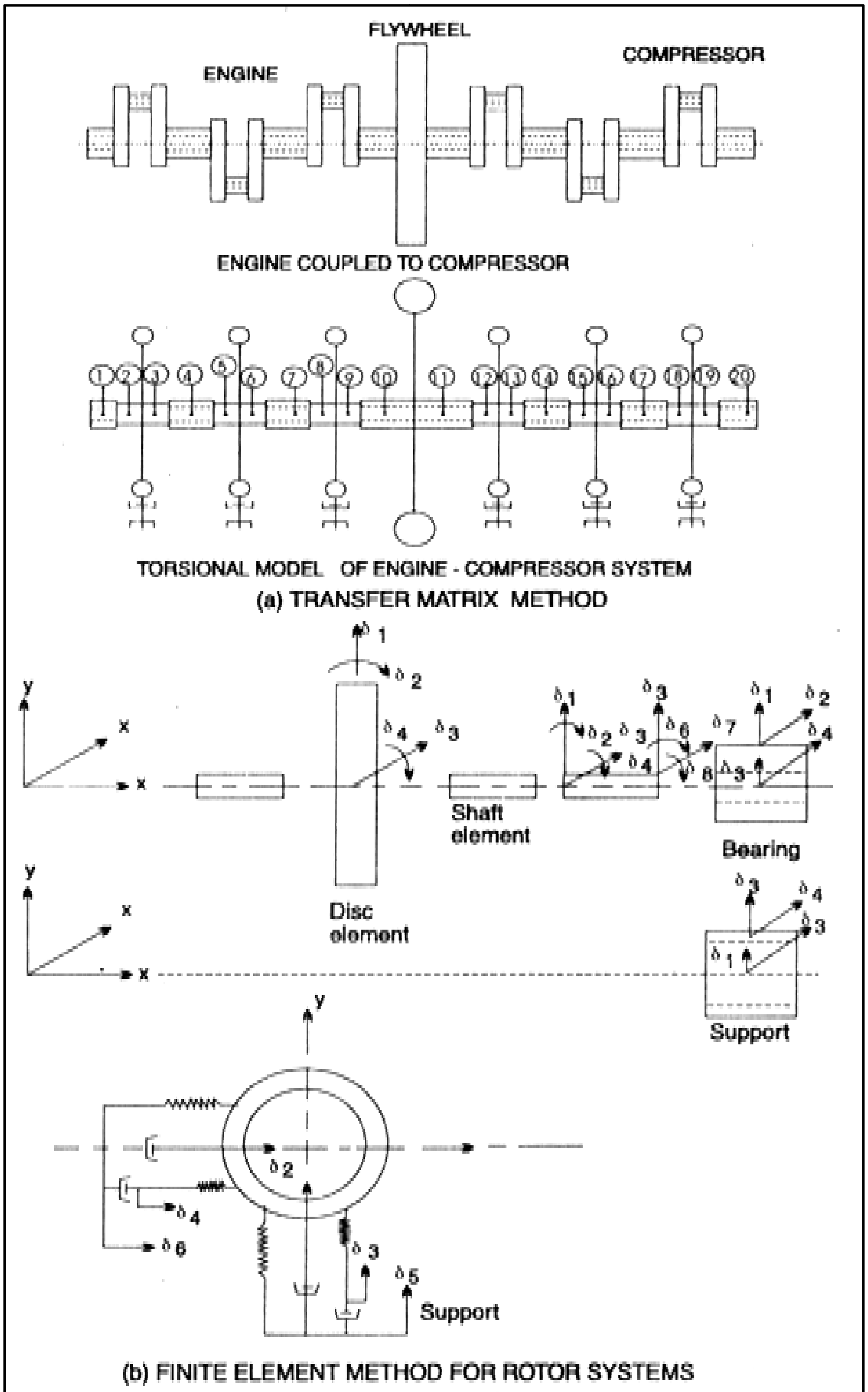


Fig 1 Computer aided analysis

Finite Element Method

The finite element method is quite a versatile method in that any combination of elements forming a system, may be analyzed using digital computers, eg, as in Fig 1 (b), the method has been applied[3] for dynamic analysis of a rotor system mounted in rolling element or fluid film bearings, supported on viscoelastic supports, using FEM, where the governing relationship for shaft element, disc element, bearing and support elements are derived separately and the elements are assembled for solution of the resulting matrix equations on a computer. The method has been applied to several situations including determination of eigne values of heat exchanger tubes as in Fig 2.[4]

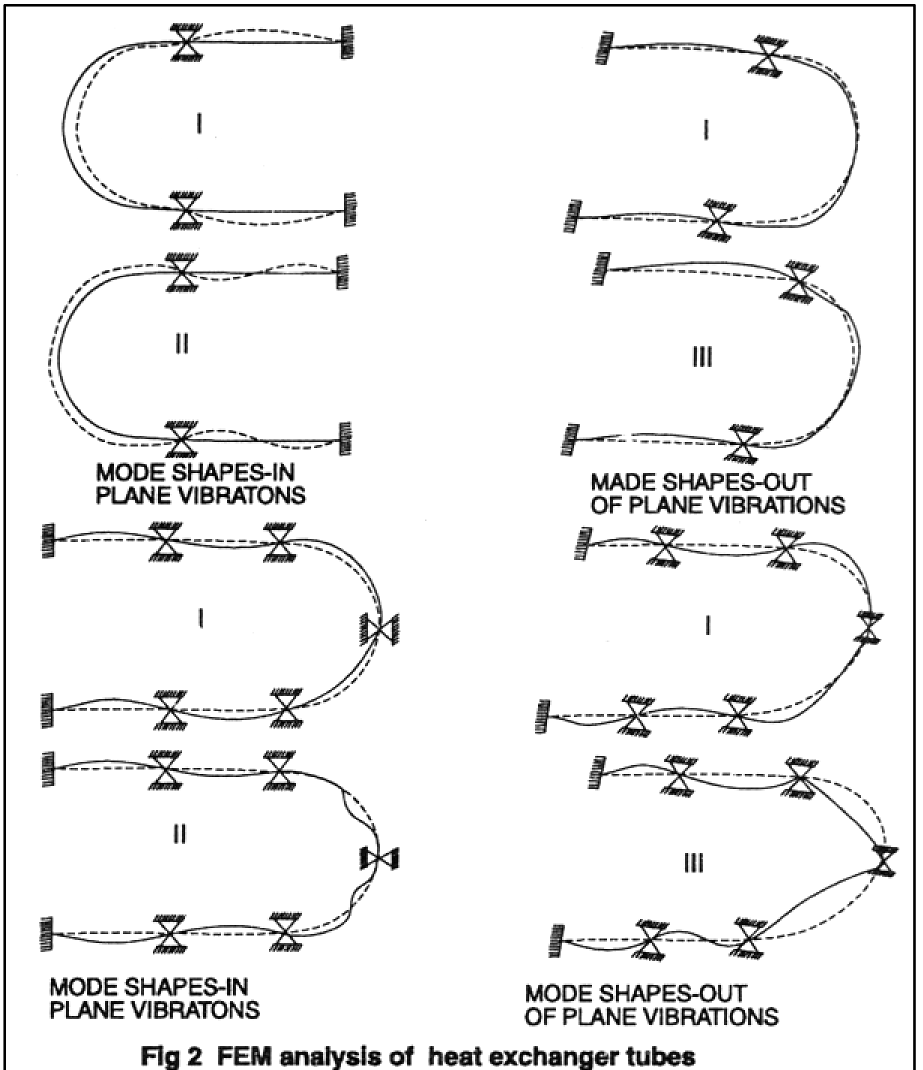


Fig 2 FEM analysis of heat exchanger tubes

The method has also been applied to acoustical problems[5] covering sound attenuation in an expansion chamber, lined duct, bends in ducts, etc.

Dynamic Optimum Design and Analysis

Multi-parameter optimization techniques subject to given constraints have been used for obtaining an optimum design of a dynamic system, eg, vibration damping obtainable from a viscoelastically damped structure has been optimized with regard to several geometric and physical parameters, with specified constraints on weight, size and static stiffness.[6]

In dynamic system modification or reanalysis;[7] the basic premise is that once a complete analysis has been performed for a particular design, there is considerable information available that can be recycled so that the influence of modifications can be economically carried out on a computer shown in Fig 3 (a) and (b). Fig 3 (c) also shows the technique of adding a damped absorber to a structure like that of a machine tool and results can be obtained giving the influence of using various types of absorbers at different location,[8] Similarly, the influence of adding constrained damping treatments, to a structure has been studied[9] using perturbation techniques. In order to determine the trend in dynamic characteristics as a result of parametric changes, dynamic sensitivity analysis involving rate of change of eigen values or response is carried out and the same has been reported[10] for response of rail vehicle dynamic as in Fig 4.

Dynamic optimum design using a combination of sensitivity analysis and dynamic system modification has recently been carried out for application to a complex structure like a machine tool structure.[1] Application of such techniques is not possible without the use of a powerful digital computer.

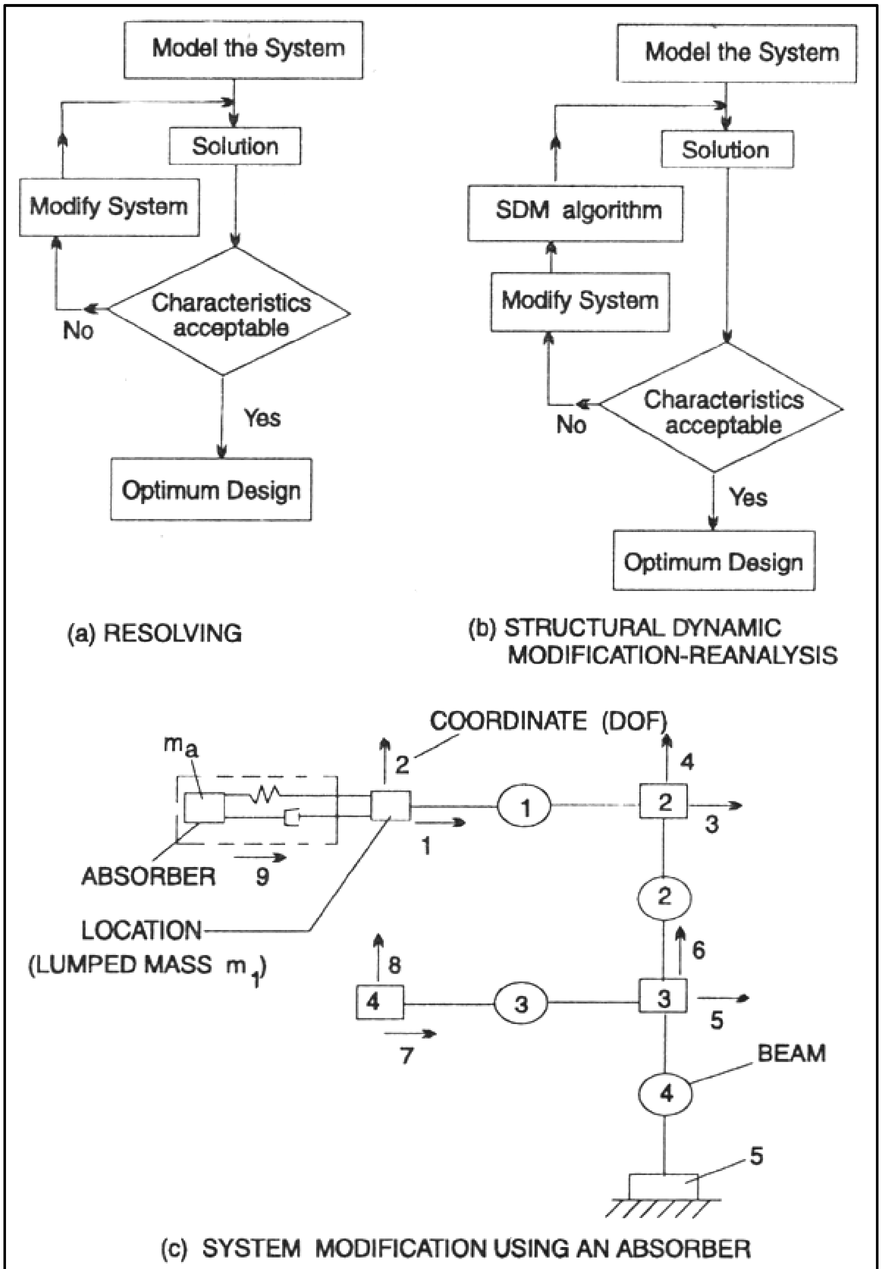


Fig 3 Dynamic modification

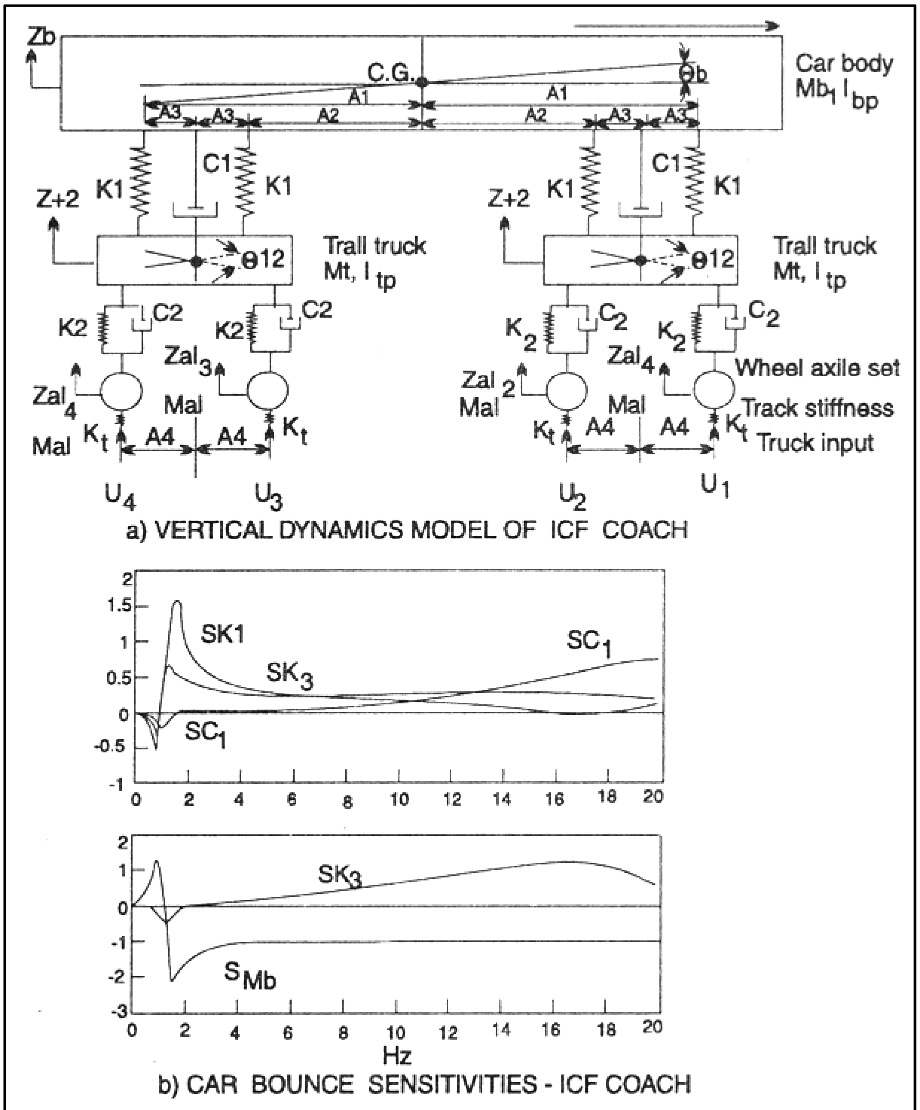


Fig 4 Response sensitivity analysis

EXPERIMENTAL STUDIES

Experimental work in this field is meant to supplement the theoretical work, with a view to verifying the latter and also is needed where theoretical studies are tedious due to complexity of the physical system. Techniques like modal analysis and sound intensity analysis have acquired considerable importance, of date, due to availability of low cost microprocessors for data recording analysis and carrying out complicated mathematical operations. Due to the availability of graphics soft- ware, much of the operations for vibration and noise testing and diagnosis can be automated.

Modal Testing and Analysis

A new branch of vibration engineering was developed during the 1970's covering aspects of both experimental and analytical techniques known as experimental modal analysis or modal testing.[12] It has been made possible by advanced developments in digital signal processing through use of PCs and FEM analysis and is useful for real structural vibration problems. We can (i) measure mode shapes and frequencies and derive a mathematical model from measurements, (ii) correlate with analytical model leading to the correction of the latter (model updating) for situations otherwise difficult to model like machine joints, (iii) predict effect of modifications in mass, stiffness and damping, etc, and (iv) test complex sub-systems and integrate the results with the analytical results of other sub-systems for a total system analysis.

Vibration testing for determination of natural frequencies, mode- shapes and response analysis may be done by:

(a) Computer controlled measurement system[13] as in Fig 5 where the excitation frequencies for harmonic testing are changed by use of the oscillator. The excitation force supplied by an electrodynamic exciter is measured by a force transducer and responses at various locations on the test structure are sensed by motion transducers like piezoelectric transducers. The computer is used for data storage, analysis and computations.

(b) Impulse method as in Fig 6[14] where the excitation is provided by an instrumented hammer, which is used to strike the test structure, for exciting the various modes of vibrations. Vibrations are sensed by a piezoelectric accelerometer. The force transducer, usually of piezoelectric type is located on the hammer. The hammer is used to strike at various locations and measurements of force and response signals, after conversion from time to frequency domains, are stored and processed in a desk-top computer. With the use of modal analysis software, it is possible to get

— natural frequencies and damping at various modes,
— mode shapes of vibrations,

which can be displayed on the computer screen or may be printed using a printer, connected to the computer. Prior to the testing, pre-processing involves storing in the computer the geometrical data regarding the shape of the test structure. This is a very powerful technique for testing machine structures like pump compressor casings, machine rotors, automotive structures, etc.

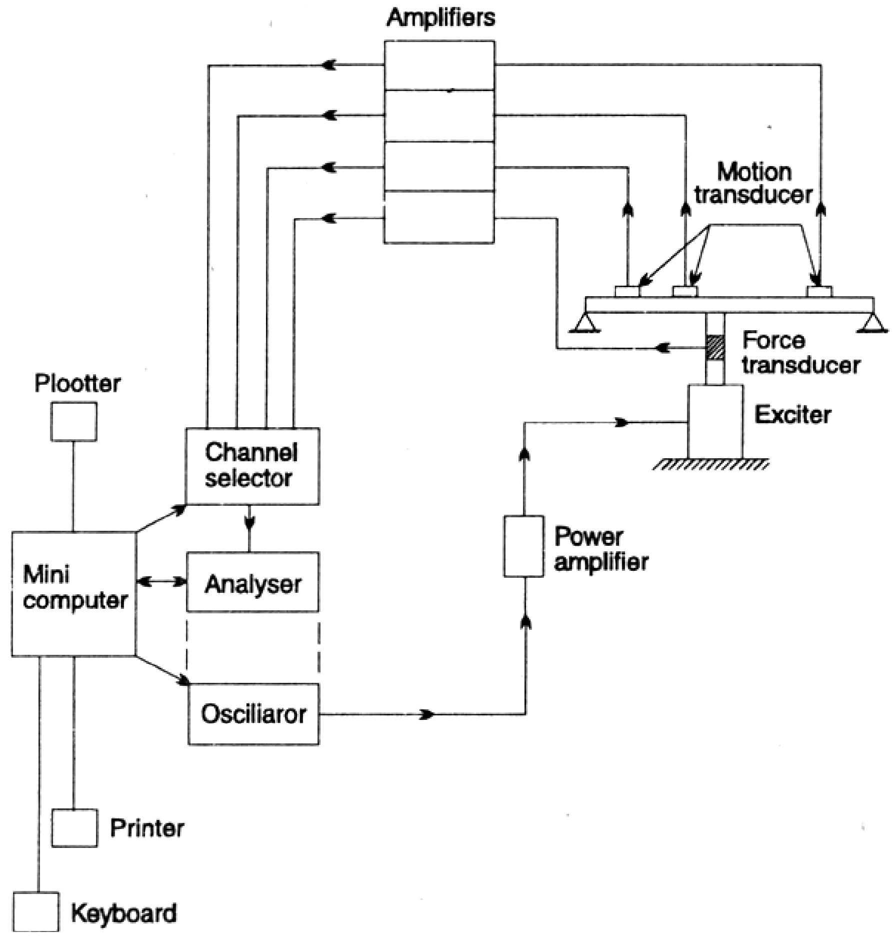


Fig 5 Computer controlled measurement system

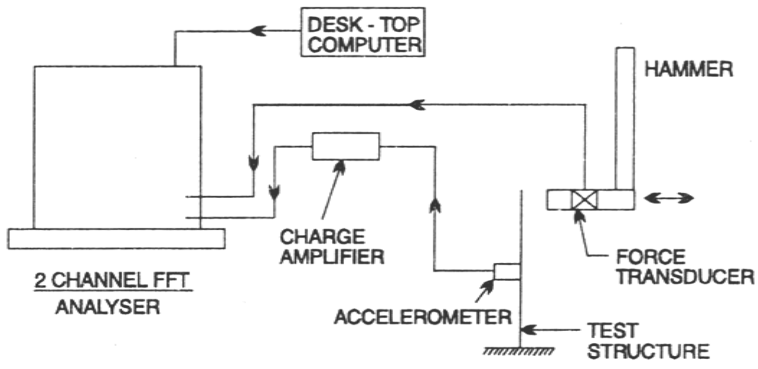


Fig 6 Modal analysis by impulse method

Sound Intensity Analysis

Sound intensity is a measure of the acoustical energy flow per unit area of a sound wave and is a vector quantity unlike sound pressure. The instrumentation used for measuring sound intensity has only been developed in the last decade. The sound intensity is measured from the imaginary part of the cross spectrum between the signals of two closely spaced microphones as in Fig 7 (a)[15] and the instrumentation used includes a computer as in Fig 7 (b) and the signals have to be processed through a two channel FFT analyzer.

The technique involves sound ranking and intensity mapping. Scanning is used by sweeping the sound intensity probe over the components or sides of a machine to rank the contribution of various components or sides, while intensity mapping is done by use of a measurement grid over the machine. Analysis of the measurements at various points on the grid using a suitable computer software gives 3-D intensity maps which indicate the high noise sources which are useful for noise control.

Fig 8 gives results of sound intensity analysis on a refrigerator[16]. Fig 8(a) gives the various sides or surfaces for sound power ranking. Results in Fig 8 (b) show that the two sides which produce most sound power are back and front sides. Detailed sound intensity contours were obtained by conducting measurements close to a grid formed on the surfaces. Distribution of noise on these surfaces is shown in Fig 8 (b). It is seen that on the back side, the major noise source is near the bottom right comer, viz, the location of pipes connected to the compressor while on the front side, the locations of major noise sources are the top side and bottom left comer, the fanner due to liquid flow in the tubes and the latter from the compressor tubes.

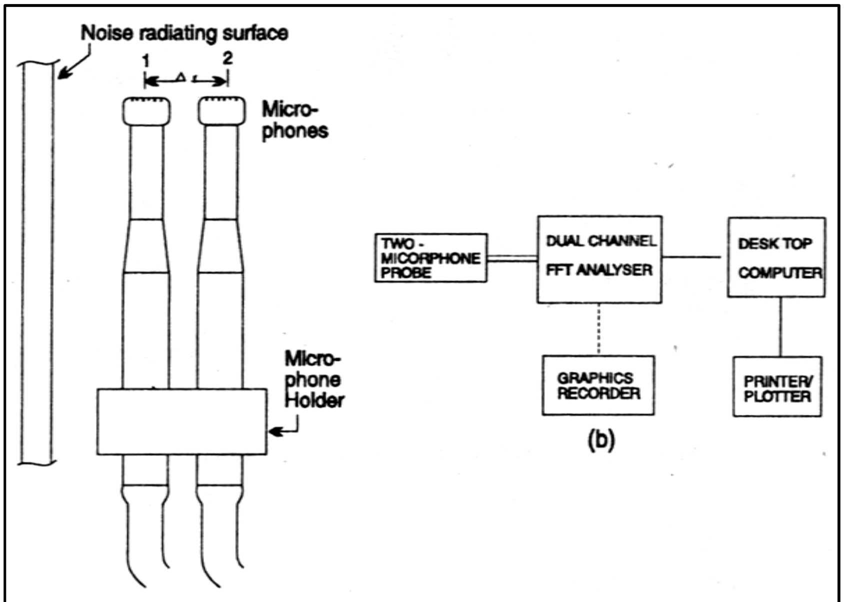
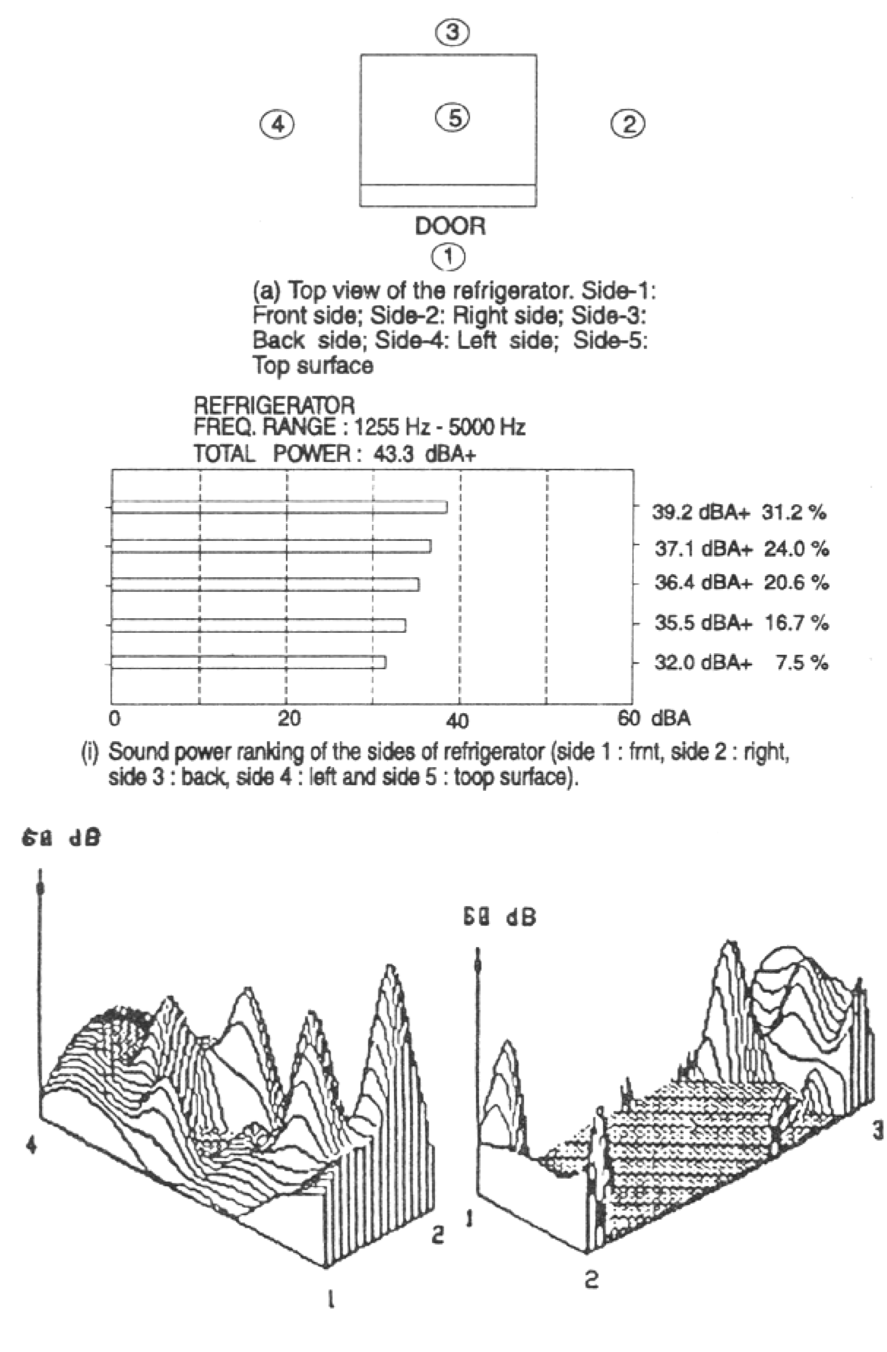


Fig 7 Sound intensity measurement set-up



(a) Top view of the refrigerator. Side-1: Front side; Side-2: Right side; Side-3: Back side; Side-4: Left side; Side-5: Top surface

(i) Sound power ranking of the sides of refrigerator (side 1 : frnt, side 2 : right, side 3 : back, side 4 : left and side 5 : toop surface).

(ii) 3-dimensional sound intensity map of the back side of the retrigerator (line 1-2: bottom and line 3-4 : top of back side)

(iii) 3-dimensional sound intensity map of the front side of the retrigerator (line 1-2: bottom and line 3-4 : top of front side)

Fig 8 Results of sound intensity analysis

Condition Monitoring and Diagnostics

Since vibrations and noise have special features under normal or abnormal conditions of a machine, monitoring and interpretation of these signals or signatures, may be used to provide indication of various machine faults like unbalance, misalignments, bearing problems, etc. By comparison of the frequency spectrum of signals of a machine in healthy condition with that obtained after machine operation, one can diagnose impending problems, likely failures and can thus take timely maintenance action. This strategy of maintenance is called condition based maintenance or predictive maintenance. Signals of vibration, noise, temperature and other performance parameter of an important machine like a gas turbine, may be recorded and analyzed using a computer, as in Fig 9.[13,14]

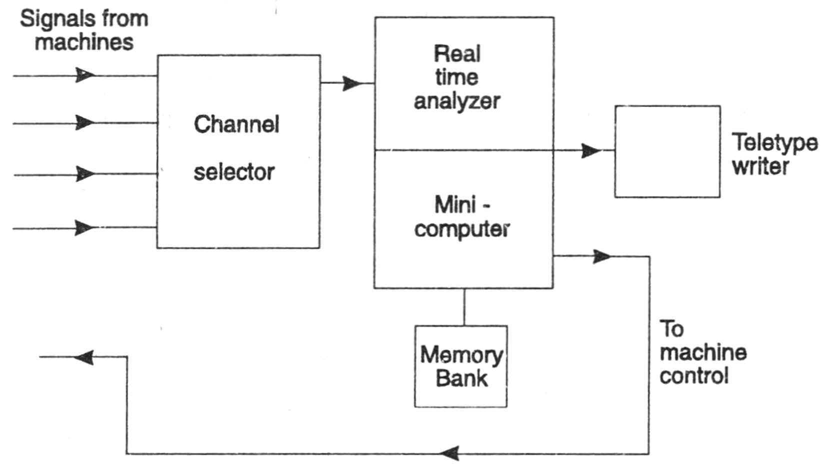


Fig 9 Use of mini-computer for vibrations signature analysis

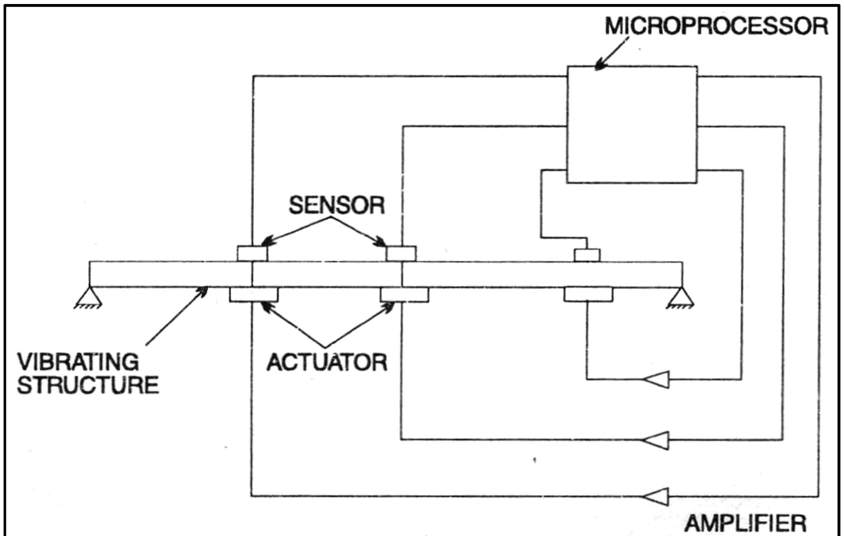


Fig 10 Active control of vibrations

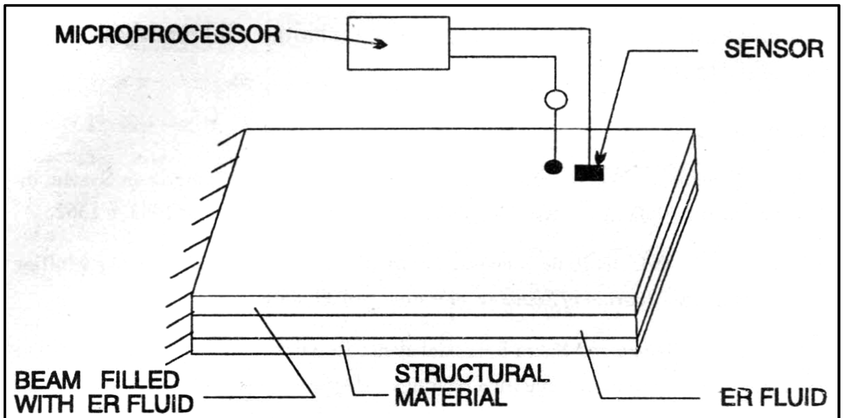


Fig 11 Use of ultra advanced intelligent composite material

CONCLUDING REMARKS

Current trends in vibration engineering are to use active control as in Fig 10 whereby sensors sense vibrations and after a microprocessor modifies the signal according to a control strategy, controlling forces are applied using actuators to control the vibrations. The use of magnetic bearings based on similar principle, for controlling stiffness and damping at rotor supports, is acquiring importance for vibration-free running at all speeds. Noise control, using similar technique involves use of microphones as sensors and loud-speakers as actuators and has been used for noise control in ducts and other applications. Current research is on the use of ER (Electro-rheological) materials as in Fig 11[17] whose stiffness and damping properties can be controlled by feedback devices using a microprocessor. These use structures of composite materials containing ER fluids and form the ultra-advanced intelligent composite materials. The developments in optimum dynamic design of machines and structures using both analytical and experimental techniques have been made possible due to availability of computers. Another emerging area is the development of expert systems software for trouble free operation and predictive maintenance of vital machines. Finally, modal testing and sound intensity analysis techniques are powerful techniques for vibration and noise analysis respectively and these techniques inherently need the use of a digital computer.

References

1. R P S Gahlaut and B C Nakra. 'Torsional Response of Engine Compressor System by Transfer Matrix Method.' Proceeding oftheSixthIFIOMM Congress, 1983, p 1362.

2. M L Munjal. 'Velocity Ratio cum Transfer Matrix Method for Evaluation of a Muffler with Mean Flow.' Journal of Sound & Vibration, vol 39, no I, 1975, P 105

3. P Kulkarni, S Pannu and Nakra B C. 'Unbalance Response and Stability of a Rotating System with viscoelasticity Supported Bearings.' Mechanism & Machine Theory, vol 28, no 3, 1993, P 427.

4. A K Kohli and B C Nakra. 'Natural Frequencies of Vibrations of Heat Exchanger Tubes.' Proceeding of the 11th National Conference on Fluid Mechanics & Fluid Power, Hyderabad, 1982, p FV65.

5. L Cederfeldt. 'On the Use of Finite Element Method on Some Acoustical Problems.' Report D4: 1979, Swedish Council for Building Research, Stockholm, 1979.

6. A K LaB, B C Nakra and N T Asnani. 'Optimum Design of Viscoelastically Damped Sandwich Panels.' Engineering Optimization, vol 6, 1983, p 197.

7. J A Brandon. 'Strategies for Structural Dynamic Modification.' Research Studies Press Ltd,1990.

8. T K Kundra and B C Nakra. 'Structural Modification with Tuned Absorber Attached to a Complex Structure via Identification Models.' ASME DE, vol 3, 1987, P 37.

9. S SA Ravi, T K Kundra and B C Nakra. 'Eigne Value Reanalysis of Sandwich Beams with Viscoelastic Core Using Perturbation Method.' International Journal of Analytical & Experimental Modal Analysis, vol 9, no 3, 1994, P 203.

10. B C Nakra and M Deshpande. 'Sensitivity Analysis of Rail Vehicle Dynamic Systems.' Proceedings of the Indo-Britisn Workshop on Railway Vehicle Dynamics, RDSO Lucknow, March 11·13,1993, P IV-I.

11. S S A Ravi. 'Structural Dynamic Modifications and Design Sensitivity Analysis of Structures with Viscoelastic Damping Treatment.' Ph D Thesis, lIT Delhi, 1994.

12. D J Ewins. 'Modal Testing: Theory and Practice.' Research Studies Press Ltd, 1986.

13. B C Nakra and K K Chaudhry, 'Instrumentation, Measurement and Analysis.' Tata McGraw-Hill,1985.

14. B C Nakra, G S Yadava and L Thuestad. 'Vibration Measurement and Analysis.' N PC Publications, 1989.

15. T E Reinhart and MJ Crocker. 'Source Identification on a Diesel Engine using Acoustic Intensity Measurements': Noise Control Engineering, vol 18, no 3, 1982, P 84.

16. N Tandon and B C Nakra. 'Sound Intensity Technique for Noise Source Location in Machines': Journal of Acoustical Society of India, vol 21, 1993, P 89.

17. S B Choi, et al. 'An Experimental Investigation on the Active Damping Characteristics of a Class of Ultra-Advanced Intelligent Composite Materials Featuring Electro Rheological Fluids': Proceeding of Damping, 89, Florida, February 1989.

Tribology for Energy Conservation in Industries

Shri A Srinivasulu, *Fellow*

Director (Engineering, R&D)
Bharat Heavy Electricals Ltd, New Delhi

INTRODUCTION

During recent years, in the mechanical engineering nomenclature, the term 'Tribology' has progressively gained in significance and, today, occupies a place amongst the front-line mechanical engineering sciences. Tribology, derived from the word 'Tribes' ie, rubbing, deals with the interacting surfaces in relative motion. All the related phenomena in mechanical engineering covering friction, wear and lubrication have been brought under this engineering science head 'Tribology'. Thus, tribology broadly encompasses the fields of physics, metallurgy, material science, chemistry, mathematics, mechanical and chemical engineering, fluid dynamics, and very closely interacts with the field of computational science and engineering.

With advancement in industrialization, the levels of mechanization and automation have risen considerably. On account of this, maintenance breakdowns and mechanical failures in industry have become increasingly expensive. Efforts to prevent such maintenance breakdowns and mechanical failures due to various causes, particularly tribology (due to friction and wear), have led to not only scientific solutions of these problems but also, to a certain extent, realization of energy conservation through tribology. However, in spite of best efforts, tribological problems and challenges persist in machines used in power sector equipment including steam and gas turbines, nuclear turbines, turbogenerators, hydroturbines and hydrogenerators.

TRIBOLOGICAL CAUSES LEADING TO FAILURE OF MACHINES

Industrial equipment in operation, in the power sector or in any allied industry, may breakdown or fail due to various causes including tribological. Some of the factors responsible for the tribological causes of failure are broadly classified as:

1. Hostile environment	: Causing corrosion, creep, hydrogen embrittlement.
2. Improper material of construction	: Improper material having inherent weakness causing fatigue, and inadequate friction and wear characteristics of the material used.
3. Improper operating practices	: Notably overloading of equipment, neglect of lubrication and improper selection of lubricant.
4. Incorrect operation/ malfunctioning of equipment	: Causing wearing-out.

These causes lead to unscheduled breakdown of the equipment, resulting in loss of man hours, money, energy. Such untimely breakdowns can be avoided by adopting the correct tribological practices.

ECONOMIC ASPECTS OF SAVINGS THROUGH CORRECT TRIBOLOGICAL PRACTICES-A GENERAL VIEW

It is well known that tribology can conserve (save) energy directly by minimizing friction and wear of the interacting surfaces in relative motion. However, it is not such a common knowledge that significant energy savings can be effected, indirectly, through correct tribological practices. The Department of Education and Science Working Group in Britain estimated that through correct tribological practices, the British industry could save about £ 340 million per annum (1970 estimate). Although no such study has been conducted in the industry in our country, the saving is expected to be much higher. The reported figures in respect of savings effected by British industry, through correct tribological practices, under various heads, are given in Table 1.

It is thus clear that in view of the present energy crisis and asymptotic increase in energy consumption, tribology plays a very significant role in the overall industrial scenario. Directly as well as indirectly, tribology can help industry to save energy through the following practices or developmental efforts:

(i) Developing lubricants which allow longer drain periods;

(ii) Proper selection of lubricants for a given application;

(iii) Reducing storage and handling losses of lubricants;

(iv) Recycling of the used lubricants;

(v) Avoiding unnecessary leakage through seals joints and fittings in general (20%-30% oil is lost from poor quality fittings);

(vi) Correct design of bearing to minimize power loss; and

(vii) Developing new cost-saving materials with better wear and friction characteristics.

TABLE I
SAVINGS EFFECTED BY BRITISH INDUSTRY THROUGH CORRECT TRIBOLOGICAL PRACTICES

Particulars	Amount saved, £ million
Reduction in energy consumption through lower friction	14
Reduction in manpower	7
Saving in lubricant costs	7
Saving in maintenance and replacement costs	155
Saving in losses consequential upon breakdowns	77
Saving in investment due to higher utilization and greater mechanical efficiency of machinery	15
Saving in investment through increased life of machinery	65
Total	340

ENERGY CONSERVATION IN POWER SECTOR THROUGH TRIBOLOGICAL SOLUTIONS

It has been estimated that a considerable fraction of the worlds's energy generation is lost by various means through friction and wear. In fact, as early as 1966, ie, when the science of tribology was in its infancy in the United Kingdom, it was stated that in the case of 500 MW turbine sets, then being built, the frictional loss could be up to 5 MW, on bearings not designed to correct tribological principles. At least 35%-40% of this friction at loss would not have occurred had the bearings been designed on the correct tribological basis. Furthermore, the additional steam required to overcome such unnecessary friction led to an equally unnecessary capital expenditure of over £ 1 million on the generating equipment.

In our country, power generating machines of ratings ranging from 1.5 MW to 500 MW have been designed and installed. Considering the importance of these machines in terms of speed, mass and physical size, the tribological problems are extremely significant and closely related with energy conservation during operation and maintenance. The equipment which need close monitoring for tribological problems during design and operation and can yield energy saving through tribological solutions have been studied. Some of the tribological problems relating to these equipment, and solutions to overcome them, are discussed hereunder.

Steam Turbine Generator Sets

The high-pressure casing of turbo sets is allowed to slide on the pedestal and the low-pressure casing on the foundation, to provide differential movements. These supports and guides are subjected to a combination of sliding motion, pressure and differential temperature induced stresses, which create tribological problems, like misalignment due to unsymmetric friction forces. Also, rubbing or malfunctioning of bearing occurs due to wear, causing changes in the internal clearance between the rotor and the stator.

The degree of wear has been controlled by judicious selection of material pairs, lubrication, pressure and speed. Also, by the use of hard material coating on valve spindles of governing systems, various tribological problems have been resolved. Tribological problems of turbogenerators have been overcome to a large extent, with proper selection and assembly of laminations of the core. This has minimized relative rubbing between the adjacent laminations, consequentially leading towards saving of energy and increase in life of the laminations.

Rotor

In the steam turbines, erosion in the blades of LP stages is caused by water droplets impinging on the tip of the leading edge of the last-stage blades. Flame hardening and hard coating are in use to reduce the erosion. However, the most popular design is to braze a shield made of cobalt-based alloy or tool steel to protect the blade from erosion-wear-a tribological solution for the extension of blade life.

Wear is a common phenomenon in the end-windings and slip ring brushes. Cyclic loading due to self-weight causes wear in the end-windings and results in fretting. This problem has been overcome by selection of proper insulation material-a tribological solution. Slip ring transmits current through brushes to the rotor windings. This results in brush wear and temperature rise due to high surface speeds. To overcome this problem in a most optimum manner, a tribological measure using graphite impregnated with synthetic lubricant has been developed.

As a parallel measure to eliminate this problem, BHEL has developed brushless exciter.

Bearings

Based on the science of tribology, various bearings which are required to be used depending on load, speed, clearance and stability criterion have been developed. As a result, partial arc-cylindrical bearings, two-lobe, three-lobe, four-lobe, tilting-pad and off-set bearings are nowadays commonly used. The precise optimum design of bearings based on tribological consideration has enabled operating the bearings in super-laminar regime to minimize the power losses. Such energy efficient bearings can be considered as one of the outstanding contributions to the industry by tribologists.

Most of turbomachines having flexible rotors operate .above the first and the second critical speeds. These systems are subjected to oil whirl instabilities and parametric instabilities. To avoid the bearing instabilities to reduce power losses and make the bearings energy efficient, various tribological techniques have been developed to determine precisely the dynamic coefficients of the bearings. A new approach, using electrical analogy, has been developed by BHEL to determine dynamic coefficients of bearings.

Seals

Steam seal problem mainly occurs in HP turbines where the pressure drop is more. To overcome this problem, the glands are constructed on 'tribological principles in six segments and spring-backed so that during misalignment and shaft run-out, hard contract is prevented and life of the seals is thereby extended. Also, if the shaft is whirling synchronously with running speed, the temperature at the contact point rises as compared to the other side of the shaft and produces thermal bending. This may cause catastrophic failure. Proper seal design based on tribological principles is the only solution for such problems.

Milling Equipment in Thermal Power Plants

The modern thermal power plant boiler utilizes pulverized coal combustion for generation of high pressure/temperature steam. These boilers, in the present market scenario, are required to attain the efficiencies of the order of 90%. For this purpose, the coal is fine-ground in milling equipment and air transported to the boiler furnace for subsequent combustion in the boiler. The finenss of the pulverized coal is of the order of 70% through 200 mesh, which corresponds to -7511 size of the coal particle.

This requirement poses several serious tribological problems for the Indian coals due to the presence of a high percentage of alpha quartz ash in these coals. Because of the high ash-content, not only do the elements of the milling equipment wear out fast, but also the power required by these equipment to achieve coal finenss of 70% through 200 mesh size increases significantly. This is so because not only the carbon particles have to get ground to the prescribed fineness, but also the ash particles which are very hard and much denser than the carbon particles. Getting the ash particles ground to the prescribed size, thus results in the carbon particles getting ground to still finer sizes. Consequently, it has been observed that pulverized coal of a much finer size than specified enters the boiler, with practically no gain in the combustion efficiency of the boiler. This problem has been studied and analyzed in detail in BHEL, and the following important conclusions have been arrived at to overcome the problem:

1. It is possible to lower the coal size fraction limit to about 60% through 200 mesh instead of 70% through 200 mesh without sacrificing combustion efficiency. These coarser coal particles do attain the size required for complete combustion even with this modified size fraction limit.

2. For Indian high ash-content coals, it is necessary to redesign the aerodynamics of the mill (originally designed to deal with the low ash-content coals typically mined in the USA), so that the ash particles, on account of their high density, do not return to the mill.

BHEL has already demonstrated coarser firing at Raichur and Tuticorin thermal power stations. This has been further taken up as a CBIP project to cover more utilities. Additionally, the modifications required for improving aerodynamic of the mills have been designed, and will be implemented in the near future.

With these modifications, BHEL hopes not only to solve the problem of wear in the milling equipment but also effect considerable reduction in their power consumption.

Hydro Sets

Thrust bearings, guide bearings, brakes and seals are the important tribological components used in hydro sets. These components govern primarily the functional performance of the hydro sets and can bring about energy conservation in the hydro sets.

Thrust Bearings

The thrust bearings in hydro sets support the dead weight of the rotor and the hydraulic thrust. The total load on the thrust bearings ranges from a few hundred tonnes to 4000 tonnes in large machines with a surface speed of 30-40 m/s. Under these conditions, distortion plays a very significant role. Under high bearing temperature, large thermal distortion leads to increase in gap between the runner and the bearing at the edge. As a result, oil film in these areas does not contribute to load carrying capacity. Oil film thickness at the central zone gets reduced because of non-uniform distribution of load on the pad, causing higher load at the central zone. This results in metal-to-metal contact, causing bearing failure. Hence, analysis of both thermal and elastic distortion is very important for satisfactory operation of the bearings and reduction of power losses in them.

The recent tribological developments in respect of thrust bearings are using PTFE as the bearing material and development of bimetallic bearing.

PTFE-based bearing is a tribological break-through towards achieving energy conservation. PTFE has a coefficient of friction of 0.07 as against 0.3 for the conventionally used babbitt material. Thus, in the case of PTFE-based bearing, during start/stop regime, much smaller torque is required for rotation and the heat generated is reduced substantially. Furthermore, jacking up operation, used in the conventional bearings, is eliminated. This adds to the saving of energy effected by using PTFE-based bearings.

Bimetallic bearing consists of segments made into two separate parts. The top part is made of babbitted bronze, and the lower part of steel containing machined grooves for flow of oil beneath the pad surface. This results in adequate cooling of bearing, reduction in operating temperature and, consequentially, in the power loss.

Guide Bearings

The vertical rotors are inherently unstable. Hence, guide bearings used for the vertical rotors of both hydro turbine and generator are of tilting pad type. These bearings are very stable in operation. However, sometimes, fretting is observed between the bolt and the guide bearing pad, which results in increase in the bearing clearance and subsequently higher vibration levels and power loss. This problem has been overcome by a tribological solution which entails providing hard coatings on the mating surfaces.

Brakes

Brakes are used for stopping the hydro set. These brakes are hydraulically operated and act against the collar made of mild steel or medium carbon steel. The brakes minimize the distance travelled by the rotor in the absence of adequate oil film. Thus, wear of bearing is reduced and the service life is not affected by stopping the machine. Based on tribological principles, the pressure is selected such that the heat generated due to contact does not cause plastic thermal deformation and damage to the brake track.

Seals

The hydro turbine seals used for preventing entry of water into the guide bearing housing are made of fibre-reinforced plastic material with asbestos fibres and resins as ingredient. The seal is designed and the seal material is selected on the basis of tribological principles to take into account the performance characteristics and frictional losses during operation.

Guide Vanes and Turbine Blades

Hard quartz particles in silt-laden water erode the guide vanes and turbine blades, drastically reducing their service life. This problem has been overcome by applying a hard and tough coating on the vanes and blades-a tribological solution. The same tribological solution can be applied for other areas where this erosion problem persists.

ENERGY-EFFICIENT ROLLING-ELEMENT BEARINGS

Rolling-element bearings are widely used in different rotating machines. The life span of these bearings depends upon the operating conditions, ie, load and speed, and, in general, bearing failure is caused by surface stress. To increase the load-carrying capacity of these bearings, efforts are being made towards development of much harder materials without changing the basic design and configuration of the bearings. Parallelly, efforts are being made to achieve the increase in load-carrying capacity through surface coating and improving the lubricant characteristics. Towards this end, BHEL has developed and patented the design of a Double Decker High Precision Bearing, an energy-efficient bearing, which has higher safe load carrying capacity than the basic load-carrying capacity of an equivalent conventional bearing operating at the same speed. Also, under identical operating conditions, the bearing developed by BHEL has low power loss as compared to a conventional bearing." These new bearings are, at present, undergoing long-range endurance tests at Electric Loco Shed (Ghaziabad), Kirloskar Motors (Hubli). Naval Dockyard (Bombay), Pumping Station at R C Puram (Hyderabad) and the Corporate R & D Division of BHEL (Hyderabad).

CONCLUSION

Tribology plays a very significant role in upgrading industry, and in bringing about energy conservation in industry. However, there is scope for achieving higher levels of energy conservation through tribological solutions. A considerable amount of work still requires to be done in the area of wear phenomenon, to avoid under and overdesigning of machinery. Design criterion which relate and identify the type of wear - abrasive, adhesive, corrosive and fatigue wear – with the operating conditlons -load, speed, temperature, environment and material properties - are required to be developed. Tribology in the electrical environment is another area which may govern wear of machinery by the surface phenomenon of physics and chemico-absorption. Development of energy-efficient magnetic bearings is one of the outstanding contributions of tribology in the electrical environment.

Renaissance in Aviation Design and Manufacturing Technologies — an Indian Experience

Dr Kota Harinarayana

Aeronautical Development Agency, Bangalore

Introduction

Aviation is one of the most significant technological influences of our time. Worldover, Aviation has been the prime engine for development of technology leading to wealth generation. Aviation also provides the military might ensuring not only national security but also dominant voice in the international relations.

Aviation demands continuous improvement in technology to streamline design process, achieve break through in production and create fundamental advances in manufacturing processes.

In India, in the last one decade, as a part of our new fighter development programme, significant work has been done to improve the traditional design processes and manufacturing technologies. Work is also in progress to improve assembly process by adopting virtual prototyping techniques.

The results have been quite encouraging. Significant improvement in product quality with attendant reductionjn cost of development has been achieved.

Design and Development Process-The Traditional Route

For many years, 2D engineering drawings have been used to convey geometric information and supporting tolerance process and material data (Fig. 1). This was once considered as "state of art" in representing 3D objects in a 2D medium and has been the basis for engineering design and manufacture during that period. The problems that continued use of this method can bring to a modern engineering operation are fare greater than would be immediately apparent. As designs become more complex and congested, the medium of drawing for design communication breaks down. The effect of this is that the product design increasingly becomes invisible to the design team.

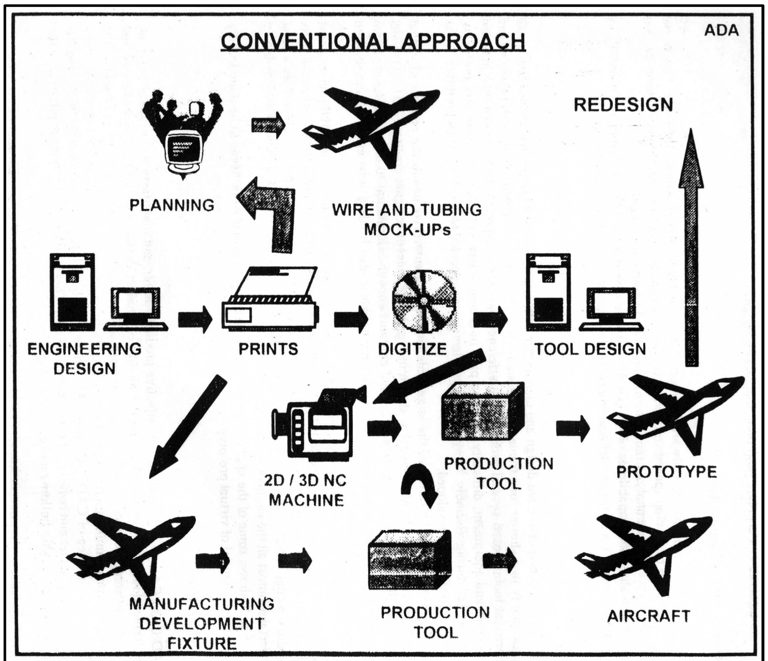


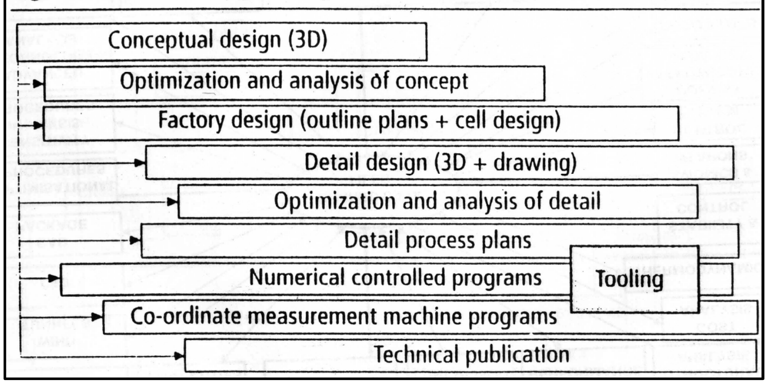
Fig 1

In this traditional approach, the design is parcelled out to various engineering groups. The product definition becomes fragmented. All of the above leads to an excessive amount of problems discovered later in the design and manufacturing cycle leading to costly rework resulting in cost and time escalation.

Integrated Product Development Process

The problems of traditional design and manufacturing process can be reduced significantly by the radical application of concurrent engineering and 3D product modelling (Fig. 2). The modern fighter aircraft is a complex machine with very advanced technologies needing state of art design and analysis tools (Fig. 3). A large number of advanced computer tools are a prerequisite to assist the modern design and manufacturing process. Experience in our aircraft development programme has shown that significant improvements in quality, time and cost are achieved with judicious application of CAD/CAMICAE tools in an integrated environment.

Figure 2 Concurrent engineering



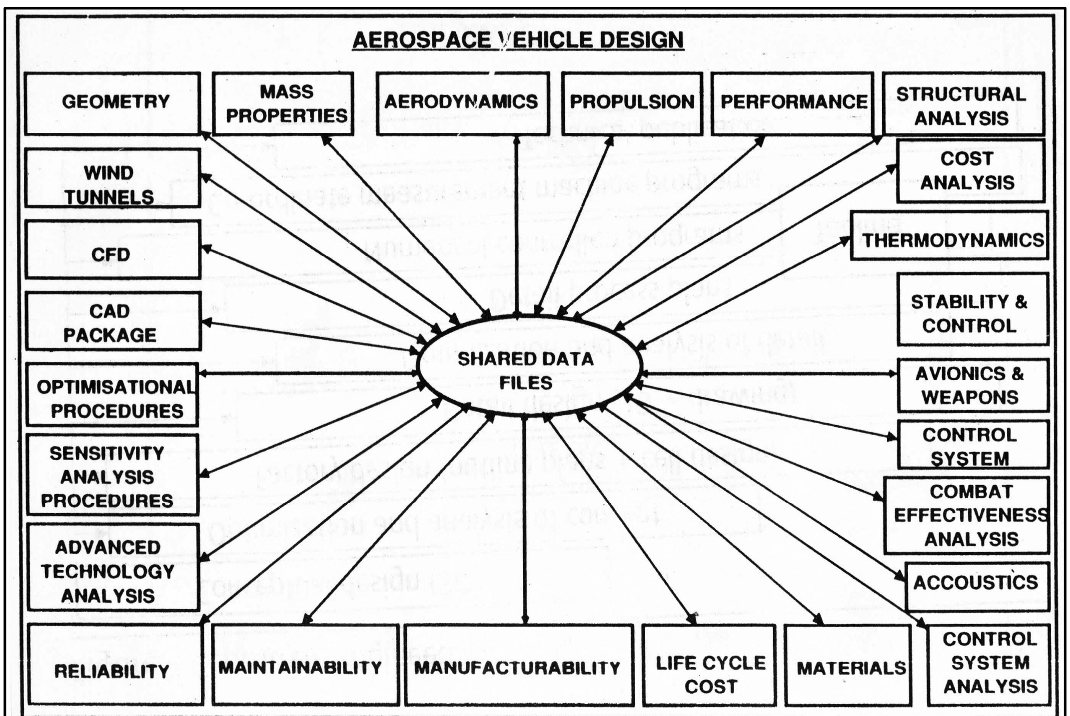


Fig 3

Tools for Component Design and Fabrication

Mechanical parts are mostly either machined components or sheet metal components or made out of composite materials. Assessment of commercially available CAD/CAM tools showed that while CAD packages such as CATIA and CADDS, availabe in the market fulfil the detail design requirements of machined and sheet metal parts, they had no capability to design the composite parts. Even for metal components, software for design of jigs and fixtures, computer aided process planning, computer aided inspection, were not readily available. Even for sheet metal components, the available CAD packages were not adequate to handle highly contoured parts typical of aircraft and automobiles. To bridge this gap, at ADA, a number of software packages were developed. These software packages were integrated together to create computer integrated manufacturing environment (Fig. 4).

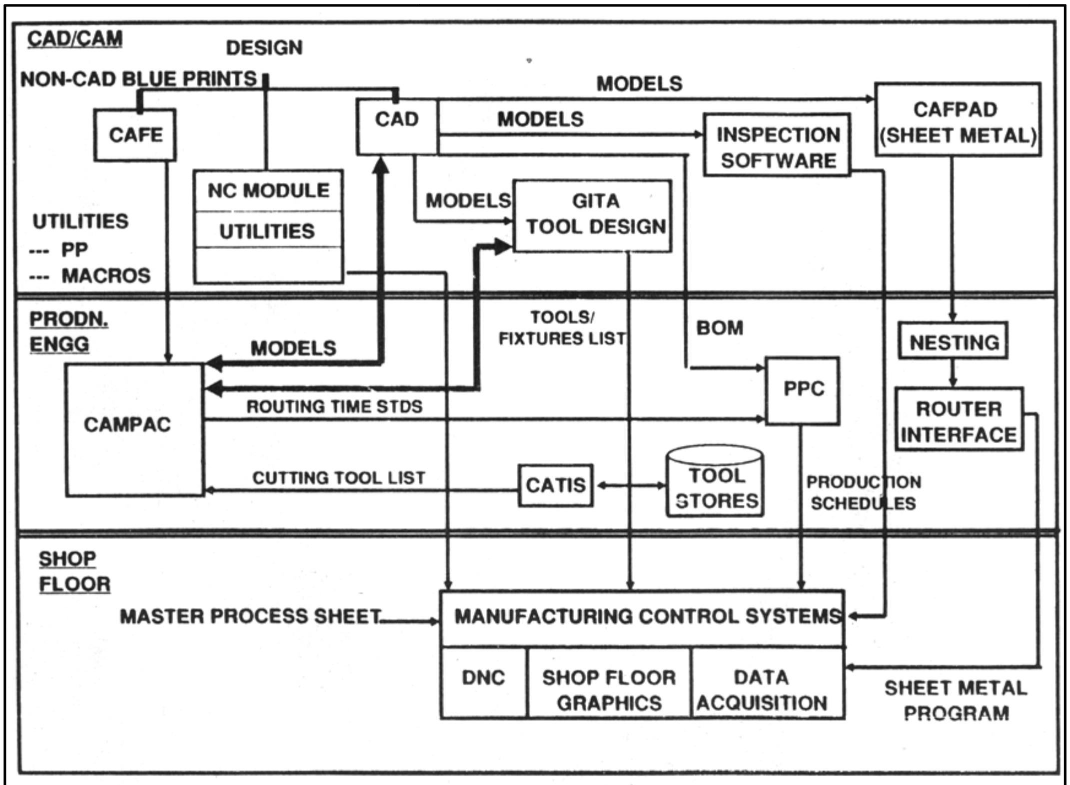


Fig 4

Machined and Sheet Metal Components

The major packages developed are:

(i) GITA-CAD package developed initially for design of jigs, fixtures and/other tools. The softwar is now a full-fledged CAD package (Fig. 5).

(ii) Sheet Metal CAD/CAM-Three packages have been developed for the following tasks:

(a) Automatic and interactive generation of flat patterns from CAD models (CIFPAC).

(b) Automatic Nesting of sheet metal components on the blank sheet (NESTING).

(c) Automatic generation of NC programmes for route machines from CAD models and interfeced with NESTING and CIFPAC (CARIF).

(iii) Shop floor Support

(a) DNC:

— High speed network between shop floor and CAD/CAM centre
— Bi-directional CNC programme flow
— CNC programme management system

(b) Graphics

— Graphics at the shop floor level.
— Provides display of components generated in CAD/CAM on shop floor.
— Cutter path display.

(iv) Process Planning

(a) CAFE

- Feature based modeller.
- Automatic generation of machining operations from the model.
- Logical sequencing and generation of route card.

(b) CAMPAC

- Large data bank.
- All resource information readily available.
- Complete shop floor document generation.

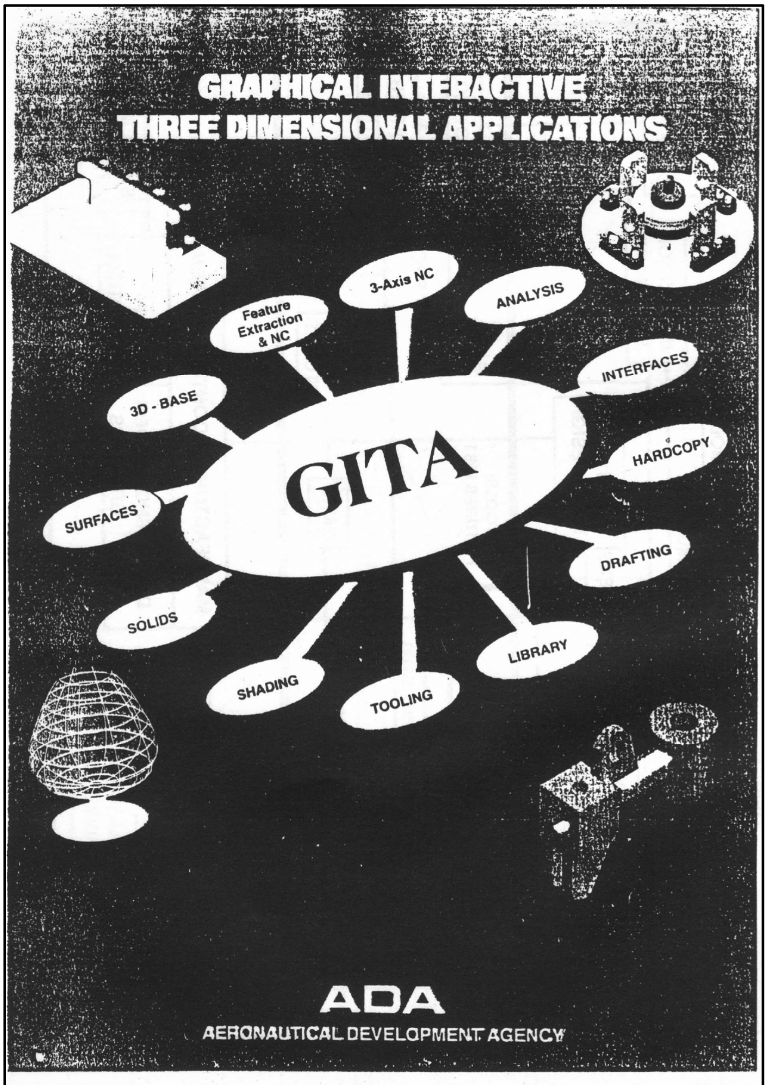
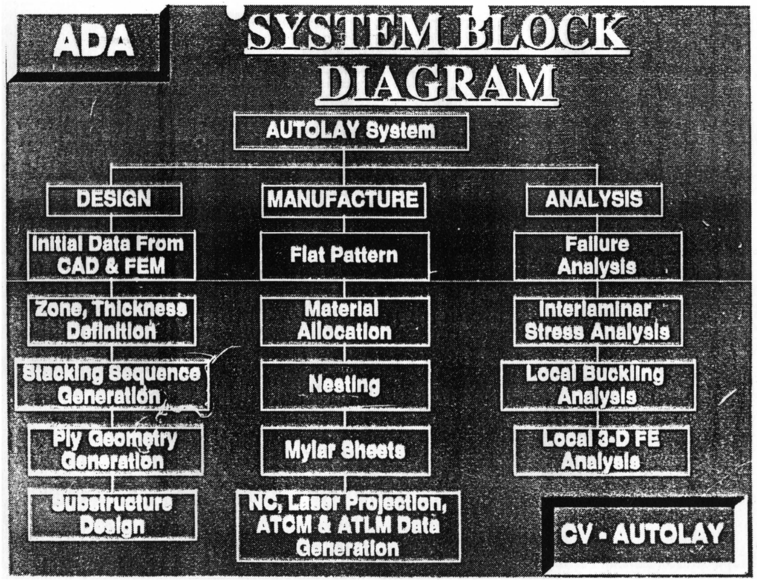


Fig 5

CAD/CAM for Composites

In the area of composite, no software packages were available for design and manufacture. This forced the ADA team to develop special software packages that enable designer to develop component designs taking into account the analysis requirements and manufacturing constraints.

Fig 6 shows the capabilities of AUTO LAY software developed at ADA to design and manufacture composite parts. It is a unique package, one of its kind available anywhere in the world.



Virtual Prototype

While use of computer aided design and manufacture software tools helped in producing components of high quality in a shorter time frame, the assembly of systems and equipment along with pipelines and electrical looms posed several problems. Interference between equipment, lack of clearance between structure and equipment, difficulty in laying pipe lines and looms and many such interface problems, were noticed during assembly. To avoid such problems, it was decided to develop virtual prototype of the fighter aircraft being developed.

The key to the integration of the large scale engineering enterprise lies in the concept of virtual prototyping and of the product model as shown in Fig. 7. The concept designer creates a 3D CAD model which is full representation of the product and contains enough information to drive the down stream processes. The model is created to mean dimensions while also holding tolerance information and allowing interference checking.

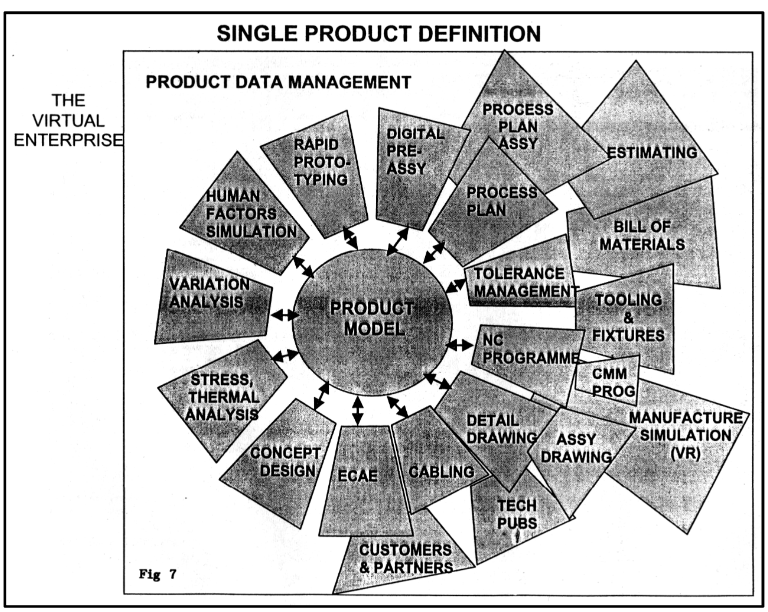


Fig 7

The implementation of virtual prototyping is a very significant factor in achieving concurrent engineering. Solid modelling is regarded as the only unambiguous way to. represent 3D mechanical parts and assemblies for design analysis and manufacturing. The virtual prototyping is created as a total product model which is an electronic definition of the product. With this model, it is feasible to undertake almost all the engineering functions.

Fig. 8 shows some of the applications of virtual prototype. Further work needs to be done to fully exploit the potential of virtual prototyping.

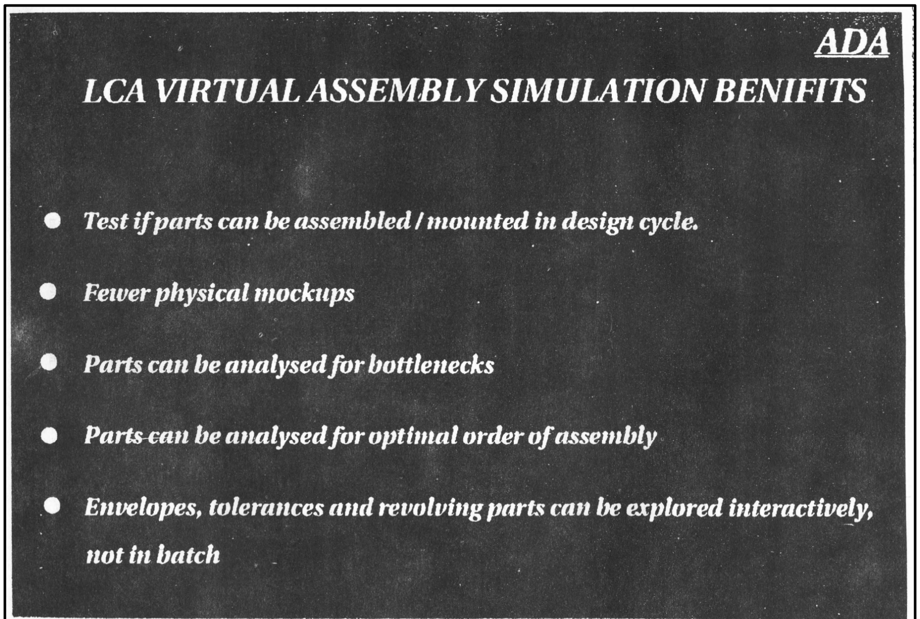


Fig 8

CONCLUSIONS

CAD/CAM/CAE are essential for cost effective products design and manufacture. Virtual prototyping has tremendous potential in enhancing the quality of product design and enabling manufacture and assembly of complex systems with minimum rework and resultant time and cost benefits. Thanks to the new fighter programme undertaken in the country a large number of software packages have been developed in the area of CAD/CAM and CAE. These tools have helped in significantly improving the quality of the product and reducing the developmental cost. These packages have wide application in the automobile sector, ship building and general industry.

Delivered during the Fourteenth National Convention of Mechanical Engineers on 'Advances in Thermal Engineering' organized by Tamil Nadu State Centre, October 23-24, 1998

Composite Pistons for Improving Two Stroke SI Engine Performance

Dr R Mahadevan

Director, India Pistons Ltd. Chennai

1. INTRODUCTION

The most striking feature of the transportation scene in recent years is the proliferation of 2-wheeler (Scooters, Motorcycles & Mopeds) on our roads. India is probably the largest producer and user of 2-wheelers in the world. This segment is growing at a healthy rate of over 20% even in the present depressed economic situation.

Most of the two wheeled vehicles are powered by two stroke spark ignition engines. These engines are less expensive, simple in design and operation than the 4 stroke counterparts which is why they have been so popular.

The problem with the two stroke engine, however, is that there is no separate exhaust stroke. The fresh incoming mixture of air, and fuel is expected to sweep out combustion products through the exhaust port and therefore unavoidably, there is always loss of fresh mixture. This results in reduced efficiency and increased exhaust pollution due to unburnt fuel. This is the most significant factor that has influenced the major two wheeler manufacturers to develop and launch 4 stroke engines to power their new models of two wheelers. Even so, there would still be a large number of 2 stroke vehicles on the road and significantly large numbers will continue to be produced with the earlier engines for some more years. Some solution that would provide an answer to this problem would, therefore, be a welcome attempt.

One solution, however, is to induct air only into the combustion chamber and inject fuel separately. Such systems, however, make the engine more complicated and expensive and therefore not very popular. A simple addon device to the existing engines is fitting of two additional reed valves to the engine, which allow the air from the atmosphere to flow into the inlet passages when the piston moves up without allowing the air to escape into the atmosphere. When the piston moves down during the expansion stroke, the pressure in the crank case forces the air that came in first, into the cylinder. This delayed entry of the fresh mixture reduces the mixture loss through the exhaust port.

2. PRESENT WORK

This paper presents two attempts at modifying the piston in order to improve the performance of the two stroke engine. In the first attempt the aluminium alloy piston of the engine is provided with a cap made of niresist. This cap is fixed to the top of the piston with 0.5 mm air gap. The cylinder head of the engine was also similarly constructed with niresist insert, which would reduce the heat transfer to the cylinder head. The construction of the piston and cylinder head is shown in figure 1.

In the second case, a thermal insulation coating was provided on the piston top and the cylinder head. The coating was made up of Partially Stabilized Zirconia (PSZ) ceramic material, OAmm thick. applied by Plasma spraying technique.

3 EXPERIMENTAL PROGRAMME

Both types of insulated combustion chambers were tested in a single cylinder, two-stroke spark ignition engine of 55cc displacement volume developing 1.7 kw at 5000 rpm. This type of engine is very widely used in light two wheelers in India. This engine was coupled to an eddy current dynamometer (Vibrometer, WB 5.6) for torque and speed measurements. Standard instrumentation was employed for fuel flow measurement. An infrared gas analyzer (Horiba, Mexa 324 FB) was used to measure HC and CO emissions in the exhaust. Tests were carried out at different constant speeds (3000 & 4500 rpms) with variable load using gasoline as the fuel. In the case of the niresist components, a limited endurance test of 50 hours was also carried out to asses its durability.

4. RESULTS AND DISCUSSION

The variation of brake thermal efficiency with brake output at a constant speed of 3000 rpm for composite, ceramic and normal combustion chambers are presented in the fig.2. It is evident that with the composite combustion chamber there is a significant improvement in fuel economy compared to normal combustion chamber (CC) for the entire range of load at this speed. The maximum brake thermal efficiency increases from 17.7 to 20.43% (15.4% improvement) for composite combustion chamber compared to normal CC at an output of 0.8 kw, 3000 rpm. This is due to better vapourisation of the fuel-air charge and reduced heat transfer losses during the combustion and expansion processes. However, the maximum brake thermal efficiency improves from 17.7 to 19.3% only (9% improvement) at the same operating point for the ceramic coated CC compared to the normal CC. The performance of the ceramic CC is less significant compared to the composite CC due to the thermal inertia of the ceramic coating surface which responds slower to the gas temperature transients than the composite CC.

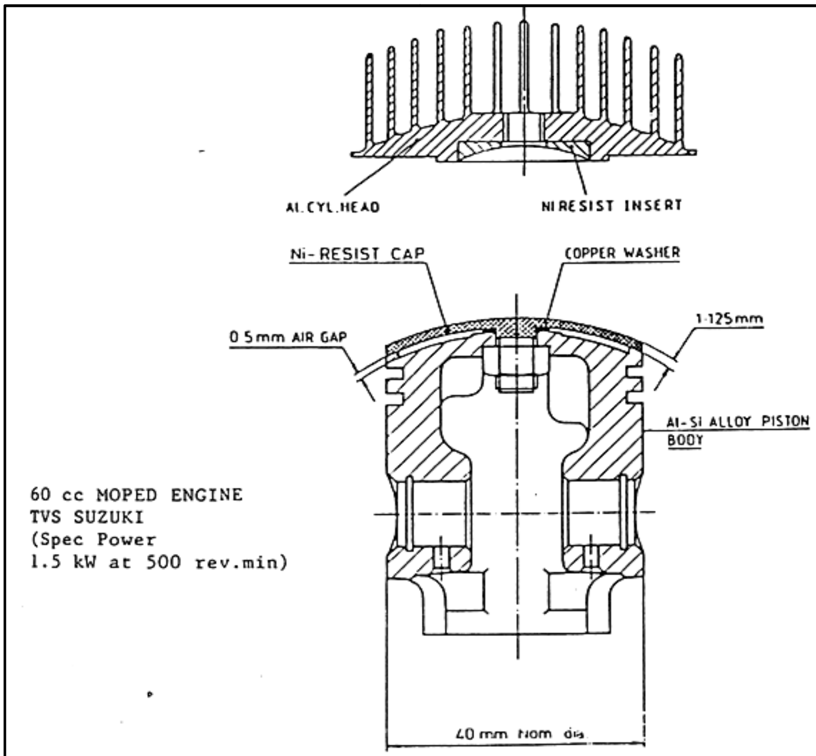


FIG. 1. PISTON TOP AND CYLINDER HEAD INSLUATED BY NIRESIST INSERTS

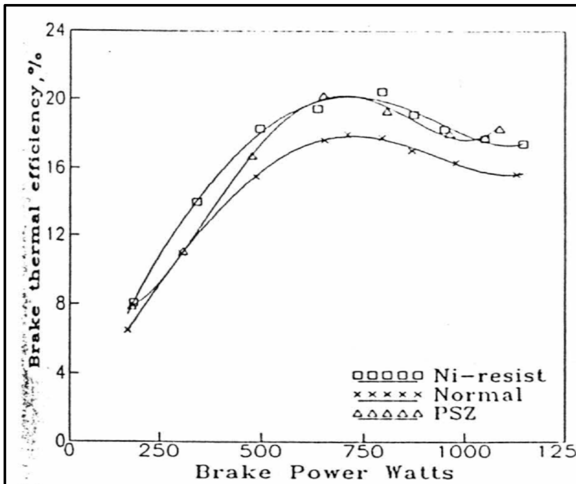


Fig 2 Variation of brake thermal efficiency with brake power for composite and ceramic coated combustion chambers at 3000 rpm

Two-stroke SI engines are normally supplied with rich mixtures to compensate for the exhaust dilution of the fresh mixture. This results in a mixture which is heterogeneous and much of the fuel is carried to the engine in the form of large droplets. Under these conditions, a considerable quantity of heat is required to completely vapourise the fuel. External heating of the fuel-air mixture improves vapourisation but it affects the volumetric, efficiency (3). Providing a hot CC will result in complete vapourisation of the rich fuel-air mixtures. This hot CC can be obtained by providing thermal insulation in the CC, which retains the heat generated from combustion. A thermally insulated combustion chamber reduces the heat transfer losses to the surroundings, thereby helping to improve the thermal efficiency (2). But one should be cautious while providing insulation since excessive insulation will lead the problems associated with high temperatures such as drop in volumetric efficiency, pre ignition and knock. Hence, only the judicious application of thermal insulation will result in a more complete and faster burning of the fuel-air mixture.

Figures 3 and 4 show the variation of HC and CO emissions with brake output respectively for the three types of combustion chambers. The composite CC produces relatively lower concentrations of HC and CO emissions over the entire load range at a constant speed of 3000 rpm compared to the other two types of combustion chambers. At an output power of 0.8 kw, 3000 rpm, HC emissions are reduced from 4150 to 3400 ppm with the composite CC and from 4150 to 3750 ppm with the ceramic CC compared to the normal CC. CO emission decreases from 2.1% to 1.4% vol for the composite CC. With the ceramic coated CC, the differences in CO emissions are marginal at part loads and slightly higher outputs compared to the normal CC.

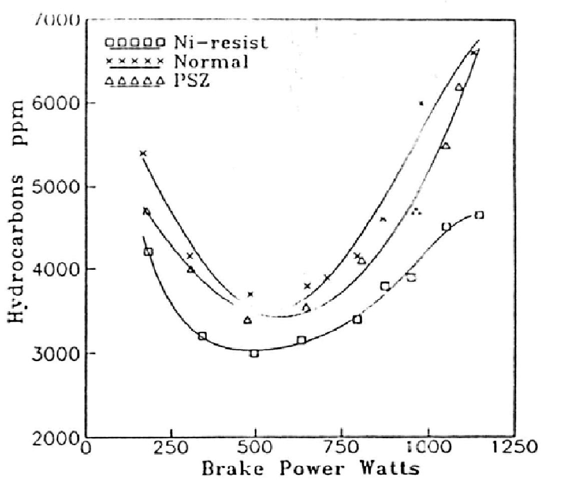


Fig 3 Variation of HC emissions with brake power for composite and ceramic coated combustion chambers(3000 rpm)

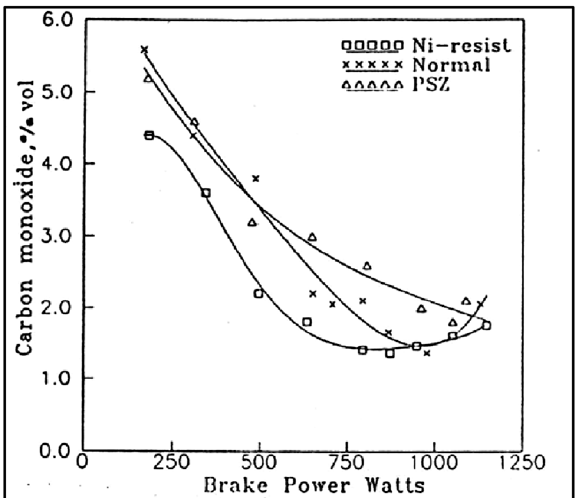


Fig 4 Variation of CO emissions with brake power for composite and ceramic coated combustion chambers(3000 rpm)

No, emissions are expected to be higher with insulated combustion chambers due to higher combustion chamber temperatures. Since two stroke engines emit generally lower NO, emissions due to large exhaust dilution. Even the increased NO, emissions due to insulation may be much lower than that of their four-stroke counter parts.

Figure 5 indicates the variation of brake thermal efficiency with brake output at a constant speed of 4500 rpm. The composite CC shows consistent improvement in the brake thermal efficiency compared to normal CC over the entire load range and the improvement is quite significant at part loads. The maximum improvement in the brake thermal efficiency is about 11.4% (from 18.8 % to 20.9%) at a brake output of 1.1 kw, 4500 rpm for the composite CC compared to the normal CC.

Ceramic coated CC shows a marginal improvement in the brake thermal efficiency. The niresist cap in the composite CC provides uniform insulation and there is also a possibility that the nickel in cast iron is acting as a catalyst promoting combustion [4], whereas in the case of the ceramic coated CC uniform insulation could not be attained. Hence the better performance is obtained with the composite CC.

Figures 6 and 7 illustrate the exhaust emission characteristics for all the three types of combustion chambers. It is evident from these figures that the composite CC exhibit lower levels of HC and CO emissions compared to the normal and ceramic CCs over the entire load range. The reduction in HC emissions is about 575 ppm at 1.1 kw output. With the ceramic CC the reduction in HC emissions is significant at part loads and marginal at higher outputs compared to normal CC. CO emission decreases by about 1.0% vol at part load with composite CC compared to normal CC. But at higher outputs, the reduction in CO emissions is not much with both the types of insulation.

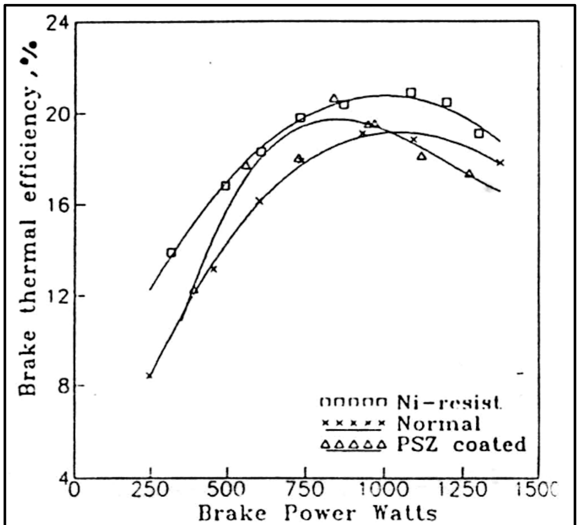


Fig 5 Variation of brake thermal efficiency with brake power for composite and ceramic coated combustion chambers at 4000 rpm

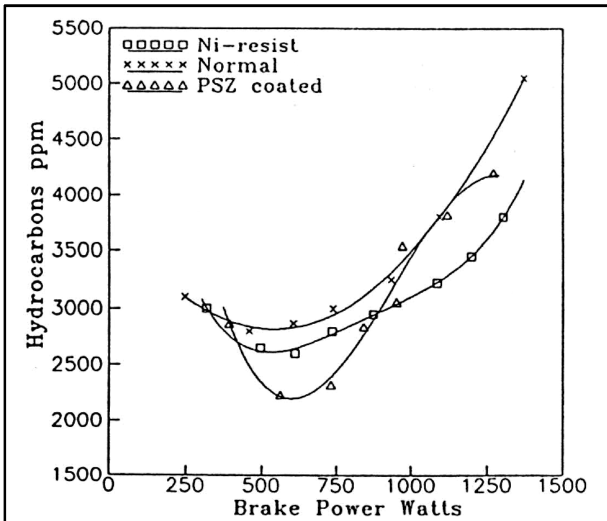


Fig 6 Variation of HC emissions with brake power for composite and ceramic coated combustion chambers(4000 rpm)

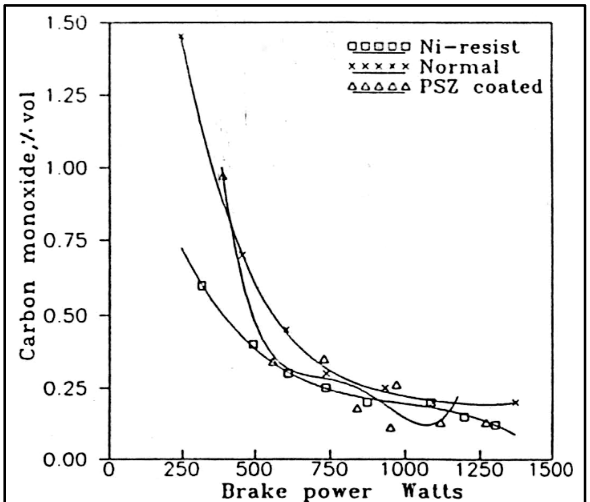


Fig 7 Variation of CO emissions with brake power for composite andceramic coated combustion chambers(4000 rpm)

5. TENDENCY FOR KNOCK AND DEPOSIT FORMATION

One would expect the insulated combustion chamber to promote knock or preignition due to the elevated temperatures. However, neither of these phenomena was observed during testing range with both the types of insulation. This is possibly due to moderate insulation (thin ceramic coating, 0.4 mm thick, in the case of ceramic coated CC and 1.125 mm niresist cap in the case of composite CC).

A limited 50 hours endurance test which was carried out also revealed that the insulation provided through composite CC was stable. There was no appreciable wear or deposit formation. Durability of ceramic coating is less satisfactory than that of composite components. The advantage of the ceramic CC however, is that it is easier to coat ceramic in the combustion chamber than to produce composite components.

6 CONCLUSIONS

Based on the above experimental investigations the following conclusions are drawn.

• A moderate insulation of the CC improves brake thermal efficiency significantly and reduces HC and CO emissions considerably due to better vapourisation of fuel-charge and reduced combustion heat transfer losses.

• Composite CC has a superior performance compared to ceramic coated CC over the entire test range due to better and more uniform insulation.

• The maximum improvement (over the base value) in the brake thermal efficiency is about 15.4% at 0.8 kw, 3000 rpm for the composite CC whereas, with the ceramic coated CC the improvement in the brake thermal efficiency is only about 9% at the same operating condition.

• HC emissions are reduced by about 750 ppm at 0.8 kw, 3000 rpm and about 575 ppm at 1.1 Kw, 4000 rpm for the composite CC. The ceramic coated CC exhibits lower HC emissions only at part loads compared to the normal CC.

• Co emissions are lower with the composite CC over the entire test range but for ceramic coated CC CO emissions are slightly higher at higher outputs.

Information Technology for Engineering Applications: A Roadmap to the 21st Century

Dr S S Iyengar

Professor and Chairman, Dept. of Computer Science, Luisiana State University, Baton Rouge, LA-70B03, USA

INTRODUCTION:

Information technology has redefined every aspect of our lives, creating a new measurement of wealth based not on possession or power, but on knowledge. Efficient development of high-tech products is a key for the competitiveness of many industrial enterprises. The support with information technology becomes more and more important to effectively improve the quality of the development process.

Over the last two decades, the world has been caught up in what is the greatest transformation recorded in history, The Information Revolution. Remember that history shows that a tenfold increase in technology leads to a revolution. The automobile was ten times faster than the horse; the aeroplane is ten times faster than the automobile. In fact the quantum leap in our ability to process, understand, store and mine information has so altered our lives that we're just beginning to understand the full consequences of this.

Engineers have always been on a quest to reshape reality in its own image, and now the products of the information age allow us to do exactly that. We have ability to represent almost everything in the universe as an endless string of zeros and ones. Any given string of digits could be easily manipulated, and that particular string could contain the medical record include a key ingredient in a chocolate souffle, which very few people understand how to make. Data that would formerly have filled an entire building can now be fitted into a single device fitted into your own hand.

In recent years, knowledge of data mining, data warehousing, a-commerce, and ERP, has given an opportunity to manufacturers to take back the direct customers whom have been long since lost to distributors.

DEFINITION:

Before proceeding further, it would be wise to analyze the strict and applied definitions of information technology. Strictly speaking, the standard interpretation of the term states that information technology means "all computerized and auxiliary automated information processing, telecommunications, and related technology, including hardware, software, firmware, vendor support, and related services" (GITA). Although in its widest interpretation, information technology can be meant to encompass all forms of digital processors and circuitry, the role of the applications regarding advanced economic performance lends itself to the most interesting discussions. Only in the last five years have managerial and organizational scholars realized the economic benefits afforded by efficient databases and networks. As an official definition expressed by the government of the United Kingdom, "Information technology is the acquisition, processing, storage, and dissemination of vocal, pictorial, textual, and numeric information by a microelectronics based combination of computing and telecommunications" (Dept. of Trade and Industry 1998).

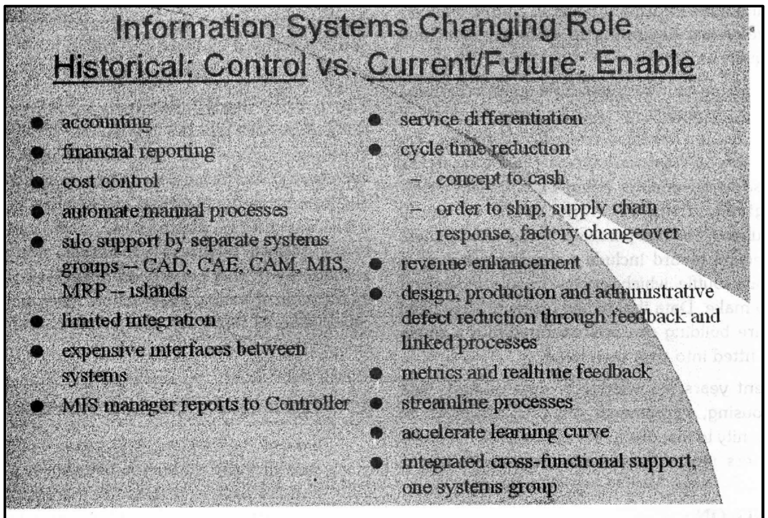
The proper implementations of information technology have resulted in increased productivity; improved customer service; reduced cycle times; decreased costs and increased revenue; the creation and improvement of internal and external linkages with suppliers, customers, and workers; reengineered business processes; improved management and control of information; the exploitation of leading-edge technologies; enhanced organizational flexibility; and better responses to the competitive pressures that have been complicated by the information explosion.

1. Challenges of The New Millennium :

One of the challenges we have is to make sure that the difference between the haves and the have-riots does not increase. In the information age, those who control the flow of information and knowledge will have the advantage. The architecture and infrastructure of that information will be valuable for Engineers. Staying ahead of the competition, whether it's in business or national security, will become more and more difficult. Information will be available to almost everyone with a minimal effort. So, increasingly, the utility of information is measured by its timeliness, as well as its accuracy.

The information age is not the only sweeping change to overtake us in the past few years. India is dealing in a time of global economic realities. And the next several years are going to continue to present major enormous challenges to industry, to government, to academia to any activity that's engaged in operations and business in domestic as well as global economy. Engineers will search for ways to manage this complexity as it is forced upon them, at the same time reducing cost and risk. This is going to replace the jobs of a lot of people as we have seen that throughout the last few decades by introduction of automation. An ideal engineer would be a hybrid of Technical, Management and IT skills.

We have done studies that allow us to look at the impact of this on individual lives. Let's look at the internet. We know you know it's growing rapidly. In 1996, one had access to seventy million pages on the internet. By the end of the next decades, it's possible that we will see the internet expose us to the entire total of human experience of recorded history. In 1996, spending on the internet was less than three billion; in the year 2000, we expect it to exceed easily two hundred billion dollars? Quite obviously, dramatic changes in the way in which we conduct business are going to be required. And I'll also point out to you — and I'll come back to this also — with almost unlimited opportunities for new business.



Source : Information Technology in manufacturing, Motorola Lightning Inc.

2. Information Fusion:

Contrary to popular belief, digital communications have not yet evolved into a smooth running multimedia network. Significant barriers still exist which weaken the effectiveness of current information technology systems. As research continues, however, the successful fusion of raw information into an accurate, diverse, and efficient networking paradigm becomes inevitable.

Important examples of recently improved information technology include the State Hermitage Museum in St. Petersburg, Russia, as well as unfinished developments at India's Centre for Development of Advanced Computing, where applications have been focused on preserving the multilingual cultural heritage of the Saraswati Mahal Library in Tanjour, India. Such examples highlight the effectiveness of information technology as well as emphasize the reality of nagging barriers with regards to language, image processing, network performance, and widespread accessibility. Using a three-tier computer environment based on a fusion of web technology with direct RDBMS connections, researchers have made extensive use of object technology to facilitate the dissemination of materials through a web database, Internet media, and XML tools.

2.1 The Road Map of Information Technology

With the advent of the World Wide Web at the beginning of the decade, information technology has since blossomed into a rapidly developing field of innovation. Starting from static web pages, computer research soon produced developments such as the search engine, dynamic web pages, and operational database integration. With ever increasing complexity and usefulness, Internet technology how offers a variety of new commercial, academic, and work related systems, which allow millions of users to interact dynamically with other Internet entities.

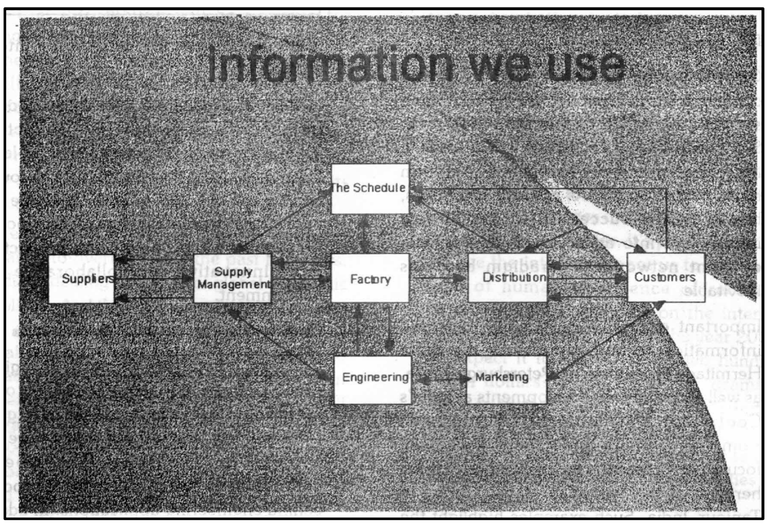
In turn, this dynamic interaction produces tremendous real gains in productivity. Through a more efficient division of labour , links to valuable interdisciplinary resources, and the use of object oriented portable code; information technology has made it possible for engineers to produce better products in a more innovative and collaborative work environment.

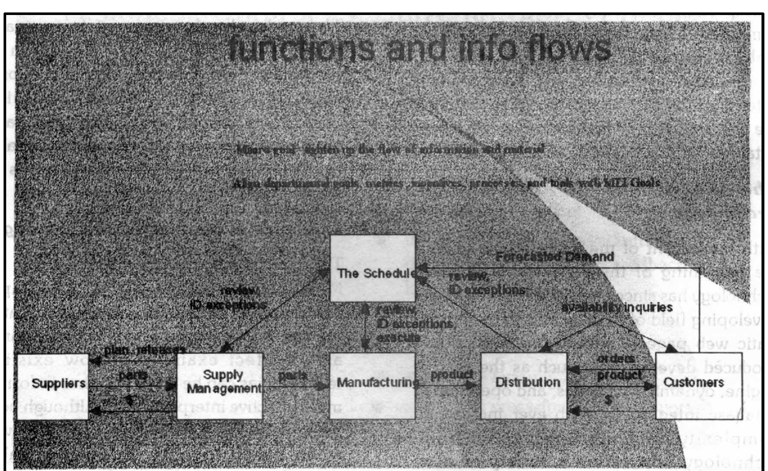
3. Engineering Process Applications:

Changing the work environment of engineers necessarily results in the development of new methods of accomplishing goals. Consequently, the last few years have been witness to a surprising number of improvements in the fundamental processes behind engineering applications. In addition to linking workers into a more effective organizational structure, which affords greater productivity and division of labor, information technology also creates innovative solutions to the engineering algorithms themselves. These developments have been made possible through the implementation of technology that has increased computational capacity, created affordable high performance computing networks, and produced experimental equipment better able to manipulate and analyze large stores of sensitive analog data results in real time.

3.1 Examples in Mechanical Engineering

The concurrent use of DFMA (Design for Manufacture) software with RP (Rapid Prototyping), which has lately generated interest among mechanical engineers, stands as a perfect example of how existing technologies can be fused together to form a more effective interpretability. Although both technologies were effective on their own, when linked together through a viable networking system, they produce a synergetic relationship whereby CAD database geometry can immediately be communicated in time to improve algorithmic efficiency.





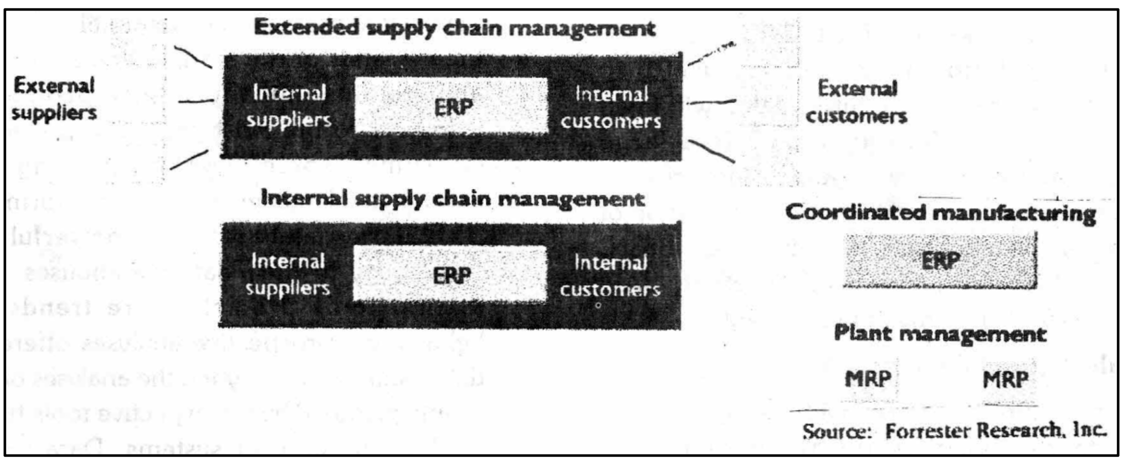
Source : Information Technology in manufacturing, Motorola Lightning Inc.

Dealing more generally with the direct obstacles facing information technology, Lockheed Martin (Missiles & Space of Sunnyvale, CA) recently developed and released the Intelligent Library System Version 1.0. Capable of "disseminating files from a wide variety of sources and formats online," "the interactive digital archiving and analysis solution allows users to manage, retrieve, and distribute more than 10 million gigabytes of imagery and data files from remote-sensing satellites or other sources. The ILS uses an open architecture and automated search tools to streamline retrieval and workflow".

Similary, EELS (the Engineers Electronic Library, Sweden) now provides free access on the World Wide Web to an entire library of academic resource materials, each catalogued by a carefully constructed call number system similar to the Dewey decimal system. Covered subject areas include physics, mathematics, energy technology, nuclear technology, light and optical technology, computer science and engineering, general engineering, polar research, and cold region technology. Although the actual volumes of materials included are still scarce, a convenient skeleton of accessible subject material folders has already been implemented which will ensure a user-friendly atmosphere in the future. Developed by the Swedish Universities Technology, EELS stands out as an excellent non-commercial example of how information technology has the potential to greatly facilitate time-consuming research. Although the fiercely independent business environment of less socialist countries provides for a bit of a problem concerning the open sharing of intellectual property, it is likely that governments will intercede, producing valuable virtual libraries which provide Significant improvements to the general economic welfare to the country at large.

4. Enterprise Resource Planning (ERP) :

One type of software system that aims to serve as the backbone for a whole business is Enterprise Resource Planning, or ERP. Composed by a set of applications that automate financial and human resource departments, ERP helps manufacturers handle jobs such as order processing and production scheduling. Through the integration of key business and management processes, it also provides a sky-level view of much of the various activities in the business organization. ERP tracks company financials, human resource data, and all the manufacturing information, such as whereabouts of stored inventory, and when certain products need to be taken from the parts warehouse to the shop floor.



4.1 Application of ERP in Engineering

A group of applications for planning production, taking orders, and delivering products to the customer are as follows :

• Production planning: it performs capacity planning and creates a daily production schedule for company plants.

• Materials management: controls purchasing of raw materials needed to manufacture products - it also manages inventory stocks.

• Order entry and processing : automates the data entry process of customer orders and keeps track of the status of orders.

• Warehouse management: maintains records of warehoused goods and processes the movement of products through warehouses.

• Transportation management : arranges, schedules, and monitors, delivery of products to customers by various means.

• Project management : monitors costs and work schedules on a project-by-project basis.

• Plant 'maintenance : sets plans and oversees maintenance of the internal facilities in a plant and.

• Customer service management : administers install-based service agreements and checks contracts and warranties upon customers request.

ERP implementation in an organization enhances the communications process and makes the right information available at the right time at the right place for effective decision-making. Furthermore, ERP implementation is immensely useful in enhancing the flow of information within an organization. Although ERP is a large investment for any organization, closely managed implementation and optimization of one of the packages available (e.g., BaaN, JBA, JDEwards, Oracle, PeopleSoft, SAP, SSA) will deliver maximum benefits.

5. Sales Conclusions:

Manufacturers are losing a huge opportunity to gather information about their own customers-data the distributors are feeding on and using to their own advantage. In addition, buying through a distributor rather than buying direct only increases the chance that the customer will buy a product from another manufacturer instead. The largest companies in the world make up the smallest group of direct customers, and manufacturers make the bulk of their profits from them. The other 80% of the customers, on the other hand, typically buy through distributors. As an example, the biggest electronics manufacturers (Motorola, Texas Instruments, etc.) typically have direct relationship with only 20% of their customer base, because they simply do not have the resources to serve all of their customers directly. Ultimately then, manufacturers can reap benefits by utilizing the latest available information technology described above to maximize profits and maintain a healthy customer relationship.

5.1 Data Mining and Business Intelligence:

In addition to the many benefits of the standard Internet technology, which have already been developed, current research in the data, mining of information technology holds the promise of new and better tools for produce delivery. Data mining helps manufacturers in predicting unforeseen marketing trends that will boost sales. (A primary tenet of classical economics is that a more perfect information environment will produce greater economic efficiency-which means that firms will be better able to predict the demands of the market, and thus will be able to dynamically adjust production resources to the most profitable projects of consumer society). Data mining, the extraction of hidden predictive information from large databases, is a powerful new technology in their data warehouses. Data mining tools predict future trends and behaviours, prospective analyses offered by data mining move beyond the analyses of past events provided by retrospective tools typical of decision support systems. Data mining tools can answer business questions that traditionally were too time-consuming to resolve. They search databases for hidden patterns, finding predictive information that experts may miss because it lies outside their expectations. In a recent research it was found that the placing of diapers and beers in close proximity within supermarkets increased the sales of both products.

6.1 Architecture for Data Mining

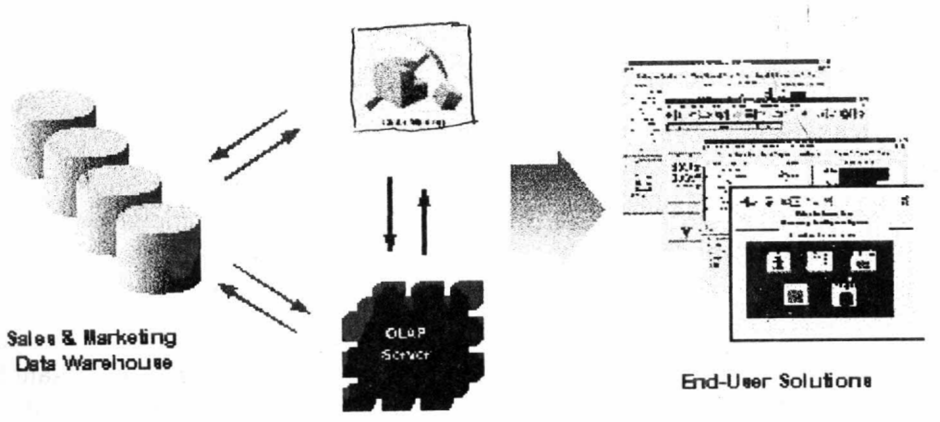
The analytic data warehouse can be applied to improve business processes throughout the organization, in areas such as promotional campaign management, fraud detection, and new product rollout.

The ideal starting point is a data warehouse containing a combination of internal data tracking all customer contact coupled with external market data about competitor activity. Background information on potential customers also provides an excellent basis for prospecting. This warehouse can be implemented in a variety of relational database systems and should be optimized for flexible and fast data access.

An OLAP (On Line Analytical Processing) server enables a more sophisticated end-user business model to be applied when navigating the data warehouse. The multidimensional structures allow the user to analyse the data, as they want to view their business summarizing by product line, region, and other key perspectives of their business. The Data Mining Server must be integrated with the data warehouse and the OLAP server to embed HOI-focused business analysis directly into this infrastructure. An advanced, process centered metadata template defines the data mining objectives for specific business issues like campaign management, prospecting, and promotion optimization. Integration with the data warehouse enables operational decisions to be directly implemented and tracked. As the warehouse grows with new decisions and results, the organization can continually mine the best practices and apply them to future decisions.

7. Intelligent Machines :

At an abstract level, a machine, which integrates these technologies, is an intelligent machine. Perhaps the best description we can give to the question is to cite a few examples of the uses that Engineers see for intelligent machines.



Integrated Data Mining Architecture
(Fig. From http://www.pilotsw.com/dmpaper/dmindex.htm)

• Producers of high value consumer electronic products want production systems, which rapidly and easily accommodate new products.

• Although somewhat overstated, the systems should be able to work with product designers and front-line workers to ensure manufacturability and then to autonomously reprogram themselves for new product designs.

• Smarter automation is needed for the safe dismantlement of the nation's stockpiles of nuclear, chemical and conventional explosive weapons.

• The auto industry wishes to develop a system with human-like dexterity for assembly and material handling.

• Food processors wish to develop RIMS capable of butchery.

• The agriculture, construction and mining industries are beginning to demand mobile, driverless machines with sensor-based control in the field.

• Just In Time manufacturing systems will respond quickly to consumer demand and reduce inventory to near zero.

Importantly, there were a host of examples, in which the intelligent system would be a human being working together with a smart machine.

• In the many industries where heavy objects are routinely and repetitively moved, mechanical assistants for humans-machines which work safely with the human and safely with the package being moved.

• Or to generalize, machines which work with people to reduce the stress and strain of repetitive motion tasks.

• Given the aging demographics of the US population and our desire to remain independent in our golden years, there is growing interest in smart houses and robotic assistants.

• Service robots, which automate the collection of hazardous wastes in hospitals.

• Dexterity enhancing devices, which assist surgeons.

• In an entertainment park, a robotic character that would be smart and safe enough to directly interacts with park visitors.

• Planetary rovers collaborating with earthbound humans for the exploration of Mars.

• Machines, which collaborate with a human to clean up hazardous waste sites, automating repetitive tasks and taking higher, level direction from the human operator.

• The military interest in robotics is reviving, spanning a wise range from soldier's assistants to swarms of small, smart machines autonomously swivelling a battle zone.

There are several themes, which underlie these examples:

• The ability to sense and reason about physical objects

• The ability to respond rapidly to change

— product change over
— products not designed for (dis) assembly

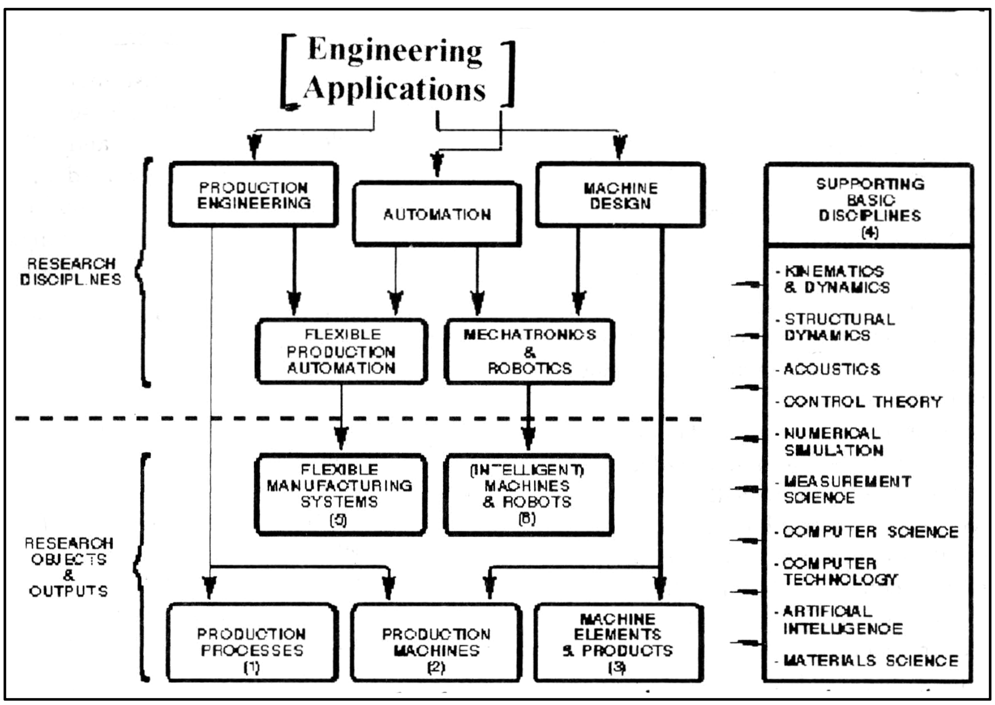
• Safety

— improving the operational health and safety of human operations
— improving the safety of automated or remote operations
— machines, which are inherently safe around humans and can, work in close proximity.

The commonality of themes is one underlying reason that such a diverse group could state and share a common vision. In addition, the attendees believed that there is a common base of technology, which will support all the application areas mentioned above. In short, these technologies are:

• New machines which use sensors to acquire information needed for quick, safe response when the unexpected occurs, and.

• The intelligence to make quick determination of (safe) responses to change or unexpected events.



8. Marketing and Information Technology:

Clearly, information technology carries the potential for vastly transforming the sales operations of diverse businesses around ,the globe. Investors on Wall Street consistently sound warnings, arguing for or against the robustness of Internet stocks, or clamouring against the terrible risks inherent in personal electronic trading. Illegal and off-shore gamblers have developed an exploding empire of electronic bets which have resulted in the ire of several members of Congress. In essence, information technology, when properly' and ubiquitously divided among a large population base of high spending consumers, results in nearly unlimited growth potential for small business, and for more efficient and cost reducing methods of sales distribution for major international conglomerates.

8.1 Data Mining Applications

A large packaging company can apply data mining to its consumer goods to improve its sales process to retailers. Data from consumer panels, shipments, and competitor activity can be applied to understand the reasons for brand and store switching. Through this analysis, the manufacturer can select promotional strategies that best reach their target customer segments.

A pharmaceutical company can analyze its allies force activity and their results to improve targeting of high-value physicians and determine which marketing activities will have the greatest impact. The data needs to include competitor market activity as well as information about the local health care systems. The results can be distributed to the sale force via a wide-area network that enables the representatives to review the recommendations fr.om the perspective of the key attributes in the decision process.

Competition requires timely and sophisticated analysis on an integrated view of the data. Quantifiable business benefits have been proven through the integration of data mining with current information systems, and new products are on the horizon that will bring this integration to an even wider audience of users.

9. Electronic Commerce :

In the market of today, manufacturers face increasing competition to bring their product to the market as quickly as possible, to reduce inventory, and improve bottom line for shareholders. Electronic commerce offers an excellent solution to solve the problem. Describing automated business-related transactions through paperless mechanisms; it encompasses transactions in and between the private and public sector, and in both the domestic and international communities.

It is recognized as essential to reduce, costs, to complete and to meet the demands for speed, accuracy, and business intelligence. One of the most established forms of electronic commerce is the EDI (Electronic Data Interchange). It is a computer-computer exchange of business transactions, such as purchase orders, invoice, and payment advances within large industrial communities.

9.1 Case Study

Cisco Systems has entered the fifth year of its electronic commerce strategy, it is working with large customers to integrate the order application into its purchasing systems and restructuring its own underlying architecture on an object model. The company has become a poster child for electronic commerce. Cisco's industry-leading efforts to adopt an electronic commerce model provide a blueprint for financial benefit to other companies. Across from the revenue side of the income statement, electronic commerce slashes customer service costs. For Cisco, Web-based order status checking alone saves the company from fielding more than 160,000 queries a month. The customer's ability to download software may save Cisco as much as $25 million a month in shipping and administrative costs. More accurate order placement cuts paperwork and results in happier customers.

Electronic commerce can be highly beneficial in reducing business costs and in creating opportunities for new customer services.

Unfortunately, the electronic systems are susceptible to misuse, fraud, and failure in many ways. The risks involved in these systems can be mitigated by use of appropriate security measures in conjuction with the various business legal frameworks.

10. Information Technology at work in your Organization:

As anyone who as ever survived the implementation of an Information Technology system can tell you, it's not about the technology, it's about reinvesting Engineering. And, although your Organization may pay tremendous lip service to people and cultural issues, when it comes to a major IT initiative you ignore them at your peril.

In its brief history, Information Technology is more often identified with out-of-control budgets and questionable returns than with business transformation. Replacing dozens of legacy systems with a single integrated one for managing operations across every discipline-finance, human resources, procurement, materials management, sales and distribution, production, order management-is challenging even for companies with generous IS budgets and a hefty staff. Equally daunting, because IT is so intertwined with business processes, is the task to effectively changing the daily activities and behaviour of many of your employees. For instance, a warehouse worker managing inventory spreadsheets pre-ERP could be forecasting customer demand and making critical business decisions after ERP. Are you confident your workforce is ready for those kinds of changes?

From an Engineering viewpoint, Information technology concepts are especially tricky because they go against the mantra of decentralization, which many companies adopted in the '70s and 80s -to spur innovation among business units. These sophisticated enterprise systems require a switch from a functional to a process orientation because modules often cut across traditional departmental lines. That's tough for companies with myriad independent business units that are unaccustomed to sharing information or coordinating with other divisions.

Finally, the spate of mergers and acquisitions in many industries over the last decade has made the integration problem more vexing. Taking a hard look at your companies unique culture-before you choose a system-is the first step toward preventing resistance in the ranks.

With such extensive online growth in specific research materials and abstract experimental simulation software, it becomes justifiable to raise issue on a possible sinking demand in the job market for mechanical engineers. If research can truly be shared effectively within and between engineering firms, then engineers may begin to worry about the value of their individual skills. Furthermore, engineers engaged in technical sales may feel threatened by the direct and cost-cutting nature of electronic commerce.

11. Information Technology in India: Predictions for the 21st Century:

We would like to briefly look at what one can expect from information technology in the next ten years or so for India. So we're looking at about 2010. However, we want to caution you about predicting, and these are my predictions. There could be a problem, as the noted linguist of the New York Yankees, Yogi Berra, once said: "Predicting is very hard, especially when it's about the future." So you can take that for what it's worth. Some noted individuals have failed. T.J. Watson, who was the founder of IBM, reportedly stated that the total demand for electronic computers was around five machines. The father of Wilbur and Orville Wright said that flight in the atmosphere was a gift reserved for angles, and not man, that it would never succeed.

So now, for our predictions. First of all, we think you can expect the speed in communications to approach that of the speed of light, so if you've tried to log onto one of these very popular sites on the web, you know how frustrating it can be to sit there waiting for a hit. We, of course, have to expand the web, but, with communication at the speed of light, you should be able to overcome a good part of that. Secondly the large majority of all information will be digital. Thirdly, information will move, and most people will not. One can reasonably expect telepresence to be a semi-normal mode of operation. People will decide where they want to live, and they will move there, and it's not going to make any difference where they work. Fourth, there will be global connectivity and global accessibility, and merging intelligent networks and infrastructure will distribute information across the network, normally pushing it all the way out to the end user. Consequently, the power will migrate to those individuals who can access, analyze, and manipulate information. Information, as we stated earlier, will be the source of wealth and power, because, as we said, information will be available to almost everyone. Those people who can get knowledge out of that will be those who have the advantage.

Network-enabled collaborations will be the major way of interacting with others throughout the world. Fifth, continuing advances in network communications technologies, systems software, and systems application will allow a convergence of data, documents, business processes and people processes all into one and probably represented by single strings of zeros and ones.

Systems will possess intelligence and be able to think. Now this usually gets people who are dozing off to come awake, because it creates a fear in some people when you start to think about computer thinking. Computers or microprocessors will be everywhere. In about the year 2010, the processor should be a few cents apiece; you can just extrapolate back in the past twenty years or so, look out to the future, and you can see that they are just going to be a few cents apiece, so they're going to be everywhere. In Paul Sapphos vision, we will be surrounded by tiny, invisible microprocessors, which sense our presence, anticipate our wishes, and even read our emotions. Sappho points out that today's toilets can sense our presence by infrared sensors, but even the most sophisticated computer are totally unaware of who, what, or where the person is located. Now Paul Sappho says, "If a meteor smashed into my house and struck me while I was sitting next to my Pc, it wouldn't have the slightest clue as to what had happened; it would be sitting there waiting for my next instruction? That is going to change by the year 2010.

Most everyone has heard about smart cards, but in 2010 we will not only have smart cards; we'll have smart cars, smart roads. Smart cars will be able to detect when a driver becomes sleepy, or when his breath contains too high a level of alcohol for safe driving. And perhaps this way we can eliminate some of the carnage on US highways that accounts for some forty thousands deaths per year, half of which are associated with truck driving. Sensors will detect foreign obstacles near a vehicle, and alert the driver that is such, and perhaps even take the necessary action to avoid that. Global positioning satellites will be able to track the move of every vehicle; stolen vehicles can be tracked, probably to the local chop shop. All of our homes will be smart homes, not just Bill Gates' home. We assume that you've read something about Bill Gates' home. But smart cards will be some device on us that will tell the thermostat what we like, the type of music we like. Hand gestures will allow us to turn on the TV, the stereo, the computer, and appliances. Smart offices with intelligent pads will take hand scribbled notes, sketches, as well as our boss' instructions, and transcribe them into beautiful sketches, documents, and publications.

In the distant future, we think beyond 2010, is a computer like that on "Star Trek," which interacts with the user-talks, understands things, mines massive data, and does it in real time. And way out, perhaps 2050, we should attain the Holy Grail of computer science, which is an artificial intelligence system that can rival or even surpass the human brain, and that really frightens a lot of people. The goal is nothing short of a machine, which has its own mind, which solves problems in an instant, and learns from its mistakes and does not age.

Today's computers, despite what your local salesman will tell you, are still very complicated. That has to change. To many people whose VCRs still blink 12:00, the personal computer of today is just mindboggling. And when you buy a computer and they hand you a package of software and it's got two linear feet of text with it, you certainly know it's mind-boggling. Well, we-would love to continue and tell you about fuzzy systems and genetic algorithms and neural nets, autonomous systems, but we need to hasten on. But we will point out, as we move forward, in the information age, there come new problems. As information technology becomes the capital commodity of the future, it must be protected. So as technology advances, there is an increased opportunity for vulnerability and complexity that is associated with this. So, in addition to the advances we have in information technology, we will now have some info criminals, or cyber crooks that we have to worry about. We already do that, but we just call them "hackers"? So the security and protection business will expand and grow at a rate that is equal or greater than that of the information technology that we just told you about.

Let us close by saying that when it comes to information technology, trying harder is not the answer; working smarter is the answer.

Safety in Automated Factory Environment

Prof Abdul Mubeen

Mechanical Engineering Department, Jamia Millia Islamia, New Delhi

Industrial safety relates to worker, workplace and environment of industry. It is the requirement of industry by way of legal obligation, social consciousness and ethics that the workers are protected from accidents and their health is not adversely affected by work methods or by coming in contact with hazardous material. The concept of industrial safety lagged behind large scale industrial expansion by 50 years and it was only in 1912 when in USA cooperative safety congress was organized that the idea of organized safety efforts in industries crystallized. Though hindered by a brief lull in second world war, the industries of all size and type have safety organizations which implement policies of the company in respect of workers working in workplace, providing compensation in case of injury or death, keeping environment clean and healthy, disposing and storing wastes in proper manner and taking all steps in collecting and disseminating information regarding safety of workers and policies of the company. We will avoid discussing overall and general safety thrusts in managerial and engineering practices of the companies. Such practices may have to vary from company to company but follow general rules laid down by law enforcing and compliance authorities created by the government. The advent of new concepts of free trade and globalization have also brought international standards of safety and health in focus of Indian industries. However, most practices seem to have been standardized with ideas of man-machine and man material interactions. Most causes have been attributed to fault or negligence of worker, supervisor or management or the stress of work and working condition felt by the worker.

The safety concepts need a great deal of boosting or rather modification with yet another advent of automation in industry - both manufacturing and service. The quality change in industry which is creeping in slowly is lesser interaction of man and machine and material. The automation has greatly spread in service industry, particularly in transport by road, on rails or in the air. Interesting to note is that such automation has brought vast volumes of information and fast working computers finally to be handled by men who would know that a small error in analyzing information or programming computer can jeopardize the health and safety of several people at a time.

Apparently realization of the fact that automation has increased the responsibility and also that the man has been put in competition with a machine or a computer for data handling him under the effect of high degeree of stress. Remember that stress may be the cause of accident.

IMPACT OF AUTOMATION

The development is a continum. The hand tools once used by man were naturally to be converted into mechanization followed by automation. Mechanization produced machines to replace hand tools and manual work, beginning from 1860. Hundred years after, automation began to help and replace mechanization. The early attempt brought stand alone automated system without mutual communications. Each system of course was supported by computer and numerical control. Later on stand alone systems were interconnected through local area networks(LANs) resulting in computer integrated manufacturing. The results of such system had obvious effects on workplaces and workers. The effects can be enumerated as :

1. The workers are required to perform less physical work.
2. Mental work is increased.
3. Mental jobs and labour intensive jobs are polarized.
4. Managers are subject to greater stress.
5. Traditional blue collars work is reduced.
6. Workers tend to lose loyalty toward employer.
7. Workers feel more and more powerless and helpless.

These changes further bring changes at accelerated rates which brings further stress upon the worker who gets involved in learning and relearning process without allowing any relief. The workers keep feeling that their job is about to be snatched away as more automated systems might come up to do what they are doing. These changes certainly place demands on worker which are function of social, psychological and physiological factors.

As a first step in describing effects of automation one has to realize that greater number of workers now pass their time watching visual display terminals (VDTs). Prolonged sittings with VDTs can cause health problems like eye strain, dryness, heaviness, discomfort, pain, blurring and double vision. The result may be vision impairment accompanied by accident causation. Opthalmologists in Japan have reported such defects as accomodation, convergence and lacrimation among the VDT users. Such defects reduce the ability of worker to focus on either near or far objects. It may also cause dry eyes.

Several remedial steps or precautions have been suggested to avoid VDT associated health problems. These measures include faster computer response, frequent breaks for work, keyboard placed in front of user and not on the side and adjustment of desk according to height of worker. The workers are also advised to soft touch the keyboard, avoid resting wrist on keyboard and avoid cradling of phone between neck and shoulder while looking at VDT. The screen brightness must be controlled, glare avoided and screen be kept dust free.

HUMAN ROBOT INTERACTION

Industrial robots are well known to have improved efficiency of process and quality of product. Robots are being used in industry for such applications as arc and spot welding, spray-painting, material handling and assembly. They also perform loading and unloading of machines. The robots form essential component of automated factory though people less factory is still in future. The robots still need controlling. They still require teaching through programming and thus invite very frequent human-robot interaction. The human and robot are required to coexists in the automated factory and therefore the human safety assumes different dimensions. The robots, being much more versatile than a machine, tend to behave intelligently in the limits of their much confined acquired knowledge. And if a robot acts on its own it becomes dangerous. In case of machines the man never loses his control and machine never shifts from its place. The most complex and most automated machine continuously requires supervision and data feeding without which it cannot function. But a robot has acquired knowledge, stored information and freedom to move in plane and move its parts in space. Thus it presents interacting obstacles to human worker who has to deal with robots inevitably.

The space in which the robot can move its parts is its work envelope and is dangerous area for any worker to enter. The hazards that have been identified with robot are:

1. Being struck by a moving robot while int work envelope.

2. Being trapped between a moving part of a robot and another machine, object or surface.

3. Being struck by a work peice, tool or other object dropped or ejected by a robot.

The perceived hazards become active only when a worker enters the envelope of a robot and such entry on several occasions become necessary. A worker has to enter the work envelope when a new function or motion is to be taught to robots. The teach mode of robot is one of many modes of its operation and it is unique mode in industrial equipment. In the teach mode an operator may come in very close vicinity of a robot which may be well within its work envelope. Such closeness is necessary to programme the motion of robot within very close tolerance parameters. Such a situation may turn into hazard if the robot goes out of control and moves in an unpredictable manner at high speed. A Japanese survey showed that greatest risk of accidents involving robots occurs during programming, teaching and maintenance. These are the occasions when a man will be within the work envelope of a robot. If worker does not have to enter the work envelope of a robot, the hazard would not exist and accident will not take place.

The strategies for minimizing the hazards during human robot interaction can be summarized as follows:

1. The robot site should be maintained glare free and well Jighted. The ligtlt intensity should be at least 50 - 100 ft candles.

2. The floors in and around the robot site should be kept clean, free of oil and obstacles so that operator does not slip or trip into work envelope.

3. The robot site should be kept free from hazards from other sources like blinding light from welding or vapours from paint booth.

4. All electrical and pneumatic components of robot must have fixed covers.

5. Keep work envelope clean of all non-essential objects and it should be ensured that all safeguards are in place before robot is started.

6. All tools that were used to maintain the robot should be counted and accounted before starting the robot.

ROLE OF INDUSTRIAL MEDICINE

Industrial machine has been introduced as a medical function especially concerned with work related safety and health problems. The workers in automated systems have added one more function to industrial medicine who now have human - robot interaction on the top of their list of health and safety problems. These professionals believe that maladaptation to changed environment in workplace is the major reason for health problems. According to Japan's Medical information system development centre mal-adaptation is manifested through such symptoms as

- Urge to quit work
- Problems with human relations
- Drop in work performance
- Social pathological phenomena such as drug use, crime, mood swings, loss of motivation and accidents.

Practitioners of Industrial medicine are trying to establish a more cordial relationship between human and various components of automated system. They are trying to establish methods whereby human can work more adequately with robots, machines and computers. Some of their recommendations include:

- Matching of human system and computer system.
- Positioning of machine systems as human supportive.
- Adopting human computer interaction to human use.
- Permit change of job and creating such opportunities.
- Allowing suitable rest period for users of automated equipment.
- Encouraging recreation.
- Promoting effective use of non-working hours.
- Increasing the contact with nature.
- Avoiding hazardous, dirty and harmful jobs.
- Shortening of working hours and sharing of jobs.

These recommendations might have been very useful in Japanese environment where both automation and distancing from nature are on the rise. But they also may suit Indian conditions where automated factories and robots are increasing in number. It is suitable time to draw upon the experiences of a more matured industrial order. One change of thought available with us is to design the automated system around needs of human and not to copy a system existing elsewhere, The important lessons we can draw from information on mal-adaptation is not to expect the workers to change according to an automated system rather the system should be designed keeping worker in the centre.

TECHNICAL ALIENATION

Many workers have shown resentment against high level of automated technology. This resentment has resulted in detachment from work and has been termed as technological alienation. Though the phenomenon manifests itself in several ways, following four have been identified as signficant by some investigators from U.S.A.

- Powerlessness is the feeding that workers have when they are not able to control the work environment. The feeling of powerlessness leads to the conclusion that technology is more important than the worker and that the worker are expendable.
- Meaninglessness is the feeling that the workers get when they find that their work is so much dependent upon the technology that they cannot relate themselves with the finished product or service.
- Normlessnessis the feeling by way of which the workers working in automated environment start feeling themselves to be detached from society, its norms and rules.
- Mindlessness is the feeling that workers get when they find that computers, robots and automatic machines can do so many things in so small time and that they can make decision much faster.

These feelings seem to cause several hazardous situations and bad workers, alcoholism, drug, theft, absenteeism, sick leave abuse, accidents and several personal problems. The turnover of the factory may be ultimately affected. Each problem is potential threat to safety and health. Absenteeism, sick leave, alcoholism may lead to induction of new and inexperienced workers raising risk of accidents and downfall of turnover. Reductions of quality and turnover may bring supervisors and managers under pressure such that they ignore several safety measures, thus faster jeopardizing safety.

MINIMIZING THE PROBLEMS OF AUTOMATION

For harmonious situation between man and automated system sociotechnical system theory was introduced in 1977 by Keio University of Japan. The components of this theory are described here.

- Variance Control involves controlling of unexpected event which is at variance with expected event. Variance control ensures that situation is avoided. For example, a robot going out of control presents a variance since it is not expected to run away.
- Boundary Location involves specific description of a job to be performed by a worker. For example, a robot operator must know that his job is only to operate a robot and not teach it or if teaching robot is also included in his job. Similarly he should know if maintenance of robot is also his job or he has to hand over the robot to maintenance staff at specified time. The safety procedure must also be included in job description.
- Organization of work group involves formation of a group of workers to do a job together with all precautions to be taken for safety and efficiency.
- Management Support is solicited by sociotechnical system theory byway of bearing with failure to meet production target for reason of safety. The management should not emphasize upon immediate steps to increase productivity or change of worker if the loss is due to consideration of implementing safety measures.
- Quality of Work Life insists upon working the technological system centre around worker or making them human - centred. It is important not to be controlled by the system. Thus, the morale of workers will be boosted and their interests safeguarded.

Additionally, the organization of automated factories must design and be ready to redesign in ways that promote productivity, quality, competitiveness, safety and health. The organization must be ready to acquire capability to redesign according to dictates of changing technologies and circumstances.

It is expected that through application of sociotechnical system theory the safety and health of workers in an automated factory can be ensured. This application should be undertaken by safety and health professionals and they must be ready to play roles of technicians, trainers, diplomats and lobbyist.

In their role of technicians they must be able to work with technical staff for variance control, boundary location, work group organization and design process and as trainer they are required to train workers in safe practices and appropriate accident prevention techniques. They must act as diplomats while working with supervisors and workers for promotion of adherence to safe practices. The safety and health professionals must lobby with the management for following the principles of safety, health and quality of life.

SAFETY MEASURES

In any automated system safety measures in physical terms must be implemented besides all philosophical, pshychological and training measures. The examples are:

1. Construction of safety fence around the system that defines the work envelope of the system.

2. Control the speed of movement of system components when working inside the work fence.

3. Install an emergency stop device coloured red and placed in visible and easily accessible location.

4. Install a control panel for the system outside the safety fence.

5. Establish an automatic shut down switch that is activated as soon as any system component goes beyond its predetermined operational range.

6. Institute training of operators and maintenance staff for their safe operations and practices. The workers must be trained to work in team. The maintenance staff must know that anyone component of an automated system can create disaster even if others are functioning well. Hence, up keep of all components is essential.

FUTURE CHALLENGES

The challenges in future are going to arise mainly due to the fact that a great deal of effort has gone into the development of automated system for achieving enhanced productivity and quality whereas very little has been done in the direction of matching these systems with human workers. A number of problems appear to be challenges in future.

1. Increasing international competition may cause tendency to neglect and ignore safety and health priorities in favour of short term productivity gains.

2. The level of mental stress is likely to increase as normous quantity of information is transmitted to workers who are poorly equipped to analyze and understand.

3. Despite the fact that workers may know that their action or inaction will have far reaching conseqences they are under pressure to take spilt second decision. Such automation and competition are likely increase level of anxiety of workers.

4. New occupational diseases relating to mental, visual and musculoskeletal problems are likely to arise. The remedies of such diseases are to be sought through combination of ergonomics, psychology, occupational medicine and design.

5. More safety and health risks in workplaces are likely to arise because of introduction of more robots there.

6. Greater allienation and frustration of workers may occur if introduction of automation in factories require lesser thinking, reasoning or judgement making on their part.

These challenges will pose much greater problems to health and safety professionals. They must prepare for training and continual retraining of workers, teaming safety and health professionals with management, workers, ergonomists, physiologists and occupational therapists. More research, better accident reporting and involvement of ergonomists in safety policies may help create conducive atmosphere in automated factories of future.

Manufacturing Competitiveness: Issues and Challenges

Prof S G Deshmukh

ABV-Indian Institute of Information Technology & Management, Gwalior

Abstract

Manufacturing sector in India has contributed significantly to the industrial development of the country. Its growth rate, of the order of about 8 percent in recent years has been impressive. The gradual transformation of the Indian economy through manufacturing with a service approach is also very interesting. Unlike in the developed countries, India's manufacturing growth has been based largely on its own domestic market with its own limitations and potential. Given the market dynamics today, the sector is poised for strong entry on the global stage. It is interesting to study the competitiveness of such a sector. Realizing this, the Government of India has established National Manufacturing Competitiveness Council (NMCC) to give thrust and direction to the sector.

The challenges before Indian manufacturing are immense. Some are external : the recent financial crisis around the world, restricted exports and raised national barriers, and the ability of firms to raise resources in the face of scarce credit crunch. The price competition will become intense and firms will be forced to offer more value for money. The internal challenges relate to tiding over the short term crisis financially. The environment also offers opportunity to focus on productivity through training and process improvements to build competitive strengths. As expected some of the sectors within the domain of manufacturing are relatively more competitive than the others. Auto sector is one such sector. Auto component sector offers interesting scope for enhancing the competitiveness of the sector. Based on an exploratory study, some insights are derived to understand issues and challenges before this sector.

Preamble

Manufacturing has often been a leading industry in most of the developed countries at some critical stage of their development, but maximum competitiveness enhancement in manufacturing in the last 3-4 decade seems to have happened in the East Asia, lead by Japan, and quickly followed by Korea, Taiwan, Hong Kong and Singapore. It seems that the countries in East Asia had better understanding of the role of manufacturing. Table 1 depicts growth statistics related to manufacturing in relation to GDP. While the US seems to be the leading exporter, China and Germany seems to be leaders from growth perspective. China has overtaken Japan to take No.1 rank among Asian countries. Higher growth rate achieved by China on top of relatively much higher export base as compared to India is indicative of stronger competitiveness for China.

Table 1: Statistics Related to Manufacturing vis-à-vis its growth in GDP

Country	Real GDP Growth Rates 2001	2003	2005	2007	% Share in GDP in 2007	% Share in Exports of goods/ services in 2007	% Share World population in 2007
USA	0.8	2.5	2.9	2.0	21.3	9.6	4.7
Canada	1.8	1.9	2.9	2.7	2.0	2.9	0.5
Germany	1.2	-0.2	0.8	2.5	4.3	9.2	1.3
France	1.9	1.1	1.9	2.2	3.2	4.0	1.0
UK	2.5	2.8	2.1	3.0	3.3	4.3	0.9
Japan	0.2	1.4	1.9	2.1	6.6	4.7	2.0
China	8.3	10.0	10.4	11.9	10.8	7.8	20.4
India	3.9	6.9	9.1	9.3	4.6	1.4	18.0
World	2.2	3.6	4.5	5.0			

Source: Enhancing Competitiveness of Indian Manufacturing Industry: Assistance in Policy Making (NMCC, 2009)

Significance of Manufacturing

The broad sector level break-up of Indian GDP as reported by CSO are a) Primary Sector, b) Secondary or Industrial Sector and c) Tertiary or Services Sector. The Primary Sector consists of agriculture, forestry and fishing while the Secondary Sector or Industrial Sector comprises of mining and quarrying, manufacturing, electricity, gas and water supply. The Tertiary or Services Sector includes construction, trade, hotels, restaurants, transportation, storage, communication, financing, insurance, business services, public administration, defense and other services. The share of primary sector in GDP (at factor cost) of India has decreased from 44% in 1970-71 to 18% in 2007-08. The share of the primary sector has been gradually decreasing from 1970-71. The share of the secondary or industrial sector in GDP of India has increased from 15% in 1970-71 to 19% in 2007-08., The share of secondary sector has been in the range of 15% to 21% in the period from 1970-71 to 2007-08. The tertiary sector or the service sector has witnessed the maximum growth with share in total GDP increasing from 40% in 1970-71 to 63% in 2007-08. Manufacturing with share of 79% is the leading industry in the secondary sector in 2007-08. The share of the industry manufacturing in the secondary sector has ranged from 74% too 82% from 1970-71 to 2007-08. The share of manufacturing in total GDP (at factor cost) of India has increased from 13% in 1970-71 to 15% in 2007-08. The share of manufacturing in total GDP of India has varied from 13% to 16% in period from 1970-71 to 2007-08 (Source: Enhancing Competitiveness of Indian Manufacturing Industry: Assistance in Policy Making (NMCC, 2009).

Manufacturing has been recognized as the main engine for economic growth and creation of wealth. Because of this emphasis was placed on growth of industry in most of our Five Year Plans. The significance of manufacturing can be gauged by the following:

a) Manufacturing is crucial to the Indian economy. The effect of improvement in manufacturing sector goes far beyond the parent sector. Manufacturing sells goods to other sectors and in turn buys materials and services from them for its growth and development. Manufacturing spurs demand for every thing from raw materials to intermediate components. It impinges on software to financial, health, accounting, transportation, and other services in the course.

b) The manufacturing sector has potential to offer employment opportunities directly or indirectly. Growth of manufacturing sector lends greater support to Agriculture through more intensive efforts on agro-based Industries. It also creates strong multiplier effects in the services sector in areas like trading, financial services, transport etc. Therefore, the overall employment effect of manufacturing would have to include the indirect generation of employment in the services sector. Besides, within the service sector those of the sub-sectors that are linked to the manufacturing directly need to be concentrated upon as they provide substantial job opportunities. It is, therefore, necessary that robust growth of the manufacturing sector is ensured for creating overall growth and employment possibilities in the economy.

c) Significant developments globally as well as within the country have impacted on Indian manufacturing sector. There is substantial reduction in trade barriers across the globe and in India, particularly in respect of manufactured goods. The information technology revolution has impacted on productivity and lowering of costs. The emergence of low cost manufacturing hubs-China and other South East Asian countries has offered promise to our manufacturing sector too. All these developments necessitates that the manufacturing sector in India has to necessarily adjust to these challenges.

d) Most of the economies that enhanced competitiveness leveraged manufacturing effectively and countries in East Asia provide good examples. Some countries from East Asia recorded the share of manufacturing in GDP from 25 per cent to 50 per cent. Countries such as China were more effective at leveraging manufacturing for their competitiveness and could gain global market shares of as high as 30-50per cent in select industry segments. It is good that stakeholders have identified the weaknesses in strategic management at the country level and the formal strategic initiatives such as formation of the National Manufacturing Competitiveness Council (NMCC) in 2005 reflects the long pending desire of stakeholders of manufacturing in India to improve competitiveness. With inputs from many leading associations and professionals on the advisory council, NMCC has brought out strategic perspective as starting point. A glimpse at key points highlighted in the strategy paper (NMCC, 2006)can be quite useful.

- India has to aim at achieving a long term GD P growth rate of 8 to 10 percent to substantially improve the living conditions of its people and to achieve this target required average growth rate for manufacturing of 12 percent.
- To achieve a growth rate of 8 per cent for the period 2007-2012, 12 per cent average growth rate in manufacturing is desired; the share of manufacturing in GD P is expected to reach 23 per cent by 2015.

- The solution to provide jobs to the millions joining the workforce can only be through a robust revival of manufacturing sector

Economic reforms since 1991 are aimed at making the Indian economy and Indian industry more efficient and competitive. The Indian economy continues to be progressively liberalized leading to its greater integration into the global economy. Liberalization and globalization have provided opportunity for the growth and expansion of the industry in general and the manufacturing sector in particular. At the same time the Indian industry is also faced with stiff competition from imports due to progressive tariff reduction. In the background, improving competitiveness alone will enable the Indian Industry in general and manufacturing in particular to take full advantage of globalization and survive.

India possesses a comparative advantage in many respects. With its experienced work force, large pool of scientists, engineers and managers, reasonable access to natural resources and a large domestic market India has the potential to emerge as a major manufacturing hub for the global market. This can materialize quickly only with improvement in the competitiveness of its Industry. Rising productivity is the key to maintaining and improving competitiveness of manufacturing. Innovation is the driver of productivity. Productivity gains in turn ensure economic growth as well as higher standard of living.

Rising productivity would help provide goods at lower costs, improve the purchasing power of the common man, and thus accelerate the domestic demand. Thus, competitiveness is central to robust growth of the manufacturing sector; In turn the Manufacturing sector is crucial for the overall growth of the economy as well as for providing jobs to the large work force entering the job market every year, particularly from the rural areas. The challenges faced by Indian manufacturers raise important questions for both industry and government.

The year-on-year growth in industrial production since 1993-94 (shown in Table 2) indicates the fact that the Indian industrial growth trajectory has never been smooth and there are intervening cyclical periods. However, this also reiterates the fact that the economy has undergone a major structural hange and the long run growth rate may have been moved up after last 3 consecutive years of over eight per cent growth. Since 2001-02 , the average growth has been quite impressive. In the last 3 years from 2005-06 to 2007-08, the secondary sector production grew at more than 8 per cent. The average growth of GDP for the same period is around 9 per cent or more. The tertiary sector has witnessed growth of more than 5% in all the years from 1993-94, the maximum growth rate being 11.2% in 2006-07.

Table 2: Year wise Growth rate Trends in various sectors of economy

(Source: *Enhancing Competitiveness of Indian Manufacturing Industry: Assistance in Policy Making* (NMCC, 2009))

Year	Primary Sector	Secondary Sector	Tertiary Sector	Total GDP	Manufactu-ring
1993-94	3.30%	7.50%	6.40%	5.70%	8.60%
1994-95	4.70%	10.40%	5.80%	6.40%	10.80%
1995-96	-0.70%	13.20%	9.60%	7.30%	15.50%
1996-97	9.90%	8.00%	6.90%	8.00%	9.50%
1997-98	-2.60%	2.00%	9.00%	4.30%	0.10%
1998-99	6.30%	3.60%	8.10%	6.70%	3.10%
1999-00	2.70%	3.50%	9.30%	6.40%	3.20%
2000-01	-0.20%	6.40%	5.70%	4.40%	7.70%
2001-02	6.30%	2.40%	6.90%	5.80%	2.50%
2002-03	-7.20%	6.80%	7.50%	3.80%	6.80%
2003-04	10.00%	6.00%	8.80%	8.50%	6.60%
2004-05	0.00%	8.50%	9.90%	7.50%	8.70%
2005-06	5.90%	8.00%	11.00%	9.40%	9.00%
2006-07	3.80%	10.60%	11.20%	9.60%	12.00%
2007-08	4.50%	8.10%	10.70%	9.00%	8.80%

Competitiveness

The issue of competitiveness has been receiving increasing attention lately because of its link with prosperity. The relationship between economic success of a country and its international competitiveness has become evident as reflected in World Competitiveness Report (WCR), a barometer of the relative competitive position of countries. The position and its trend can serve as an effective measure of success of strategic policies. Competitiveness has emerged as a useful indicator of the long term socio-economic health of a country. Competitiveness can be evaluated at various levels: company, sector/industry, country. At the country level, WCR has served as a comprehensive basis for comparing international competitiveness of key countries. At the industry level, Porter (1980, 1986, and 1990) provides valuable insights into factors shaping competitiveness of industries and nations. Porter (1980) defines competitive advantage as follows: "There are two basic types of competitive advantage: lower cost and product differentiation. Lower cost is the ability of a firm to design, produce and market a comparable product more efficiently than its competitor. At prices at or near competitors, lower cost translates into superior returns .... Differentiation is the ability to provide unique and superior value to the buyer in terms of product quality, special features, or after-sale service .... Differentiation allows a firm to command a premium price, which leads to superior profitability provided costs are comparable to those of competitors .... If labor is cheap enough, for example, even much higher efficiency can be nullified, unlike the case with differentiation advantages which normally must be matched to be exceeded. In addition, pure cost advantages are more vulnerable because new product designs or other forms of differentiation can eliminate a cost advantage in delivering the old ones" (Porter, 1990).

Table 2: Year wise Growth rate Trends in various sectors of economy
(Source: *Enhancing Competitiveness of Indian Manufacturing Industry: Assistance in Policy Making* (NMCC, 2009)

Year	Primary Sector	Secondary Sector	Tertiary Sector	Total GDP	Manufactu-ring
1993-94	3.30%	7.50%	6.40%	5.70%	8.60%
1994-95	4.70%	10.40%	5.80%	6.40%	10.80%
1995-96	-0.70%	13.20%	9.60%	7.30%	15.50%
1996-97	9.90%	8.00%	6.90%	8.00%	9.50%
1997-98	-2.60%	2.00%	9.00%	4.30%	0.10%
1998-99	6.30%	3.60%	8.10%	6.70%	3.10%
1999-00	2.70%	3.50%	9.30%	6.40%	3.20%
2000-01	-0.20%	6.40%	5.70%	4.40%	7.70%
2001-02	6.30%	2.40%	6.90%	5.80%	2.50%
2002-03	-7.20%	6.80%	7.50%	3.80%	6.80%
2003-04	10.00%	6.00%	8.80%	8.50%	6.60%
2004-05	0.00%	8.50%	9.90%	7.50%	8.70%
2005-06	5.90%	8.00%	11.00%	9.40%	9.00%
2006-07	3.80%	10.60%	11.20%	9.60%	12.00%
2007-08	4.50%	8.10%	10.70%	9.00%	8.80%

The multifaceted concept of competitiveness needs to be appreciated clearly at the appropriate level considering the views of important stakeholders. Momaya and Anuprita (2006) recognize the synergistic role of efforts at the industry level in enhancing competitiveness at all levels for the following reasons: a) Public policy designed to facilitate industrial restructuring often focuses at the industry level., b) International trade agreements are frequently specific to certain industries; examples include the Auto Pact between Canada and the United States and the Major Projects Agreement between Japan and the United States., c) There is a school of thought in competitiveness which argues that international competitiveness has meaning only at the industry level (WCR, 1989) .Competitiveness at the sector level is often considered the result of the strategies and actions of firms that operate in that sector. The terms sector and industry are considered equivalent and used interchangeably. The synergistic role of the non-business infrastructure is often overlooked by firms and policy makers. The non-business infrastructure includes educational and training institutions, R&D institutions, unions, governments, etc. Competitiveness of a sector is shaped by interactions between the non-business infrastructure and business firms. Some related definitions of the concept are given in Table 3.

Table 3 : Connotations Associated with Competitiveness

SN	Connotation	Source
1.	Superior manufacturing performance leads to competitiveness.	Leachman et al. (2005)
2.	Firm's competitiveness is dependent on its ability to provide goods and services more efficiently than others involved in the market place.	Ajitabh and Momaya (2004)
3.	Competitiveness comes through a process by which one entity strives to outperform another through the use of various resources and capabilities.	Hitt et al. (2001)
4.	Competitiveness is a concept comprising of the potential, the process and the performance.	GMR (2001)
5.	To be competitive, several factors must exist: the desire to win, commitment or perseverance and the availability of certain resources.	Khalil (2000)
6.	Competitiveness is defined in terms of 'helping business to win', 'price', product range and quality and 'distribution and marketing'.	Dou and Hardwick(1998)
7.	Competitiveness is the ability to persuade customers to choose their offering over alternatives and ability to improve cost process capabilities.	Chaharbaghi and Feurer (1994)
8.	Competitiveness arises or results from firm-specific initiatives like: better management, leveraging and stretching of resources.	Hamel and Prahlad (1993)
9.	Ability to design, produce and / or market products or services superior to those offered by competitors, considering the price and non-price qualities.	Cruz and Rugman(1992)
10.	Competitiveness is synonymous with productivity and is assumed to capture quality feature as well as efficiency feature.	Porter (1990)
11.	Competitiveness is the ability to raise income as rapidly as competitors and to make investments necessary to keep up with them in the future.	Scott (1989)
12.	Extent to which a business sector offers potential for growth and attractive return on investment	WCR(1994)

Based on this, the sector competitiveness can be perceived as: Extent to which a business sector satisfies the needs of customers from the appropriate combination of the following product/ service characteristics: price, quality, innovation, and satisfies the needs of its constituents; for example, workers in terms of involvement, benefit programmes, training, and safe workplace; offers attractive return on investment and also offers the potential for profitable growth. At the same time, it is accepted that company competitiveness is an important component of sector competitiveness. Company competitiveness is defined as "the ability to design, produce and/or market products superior to those offered by competitors, considering the price and non-price qualities" (WCR, 1991).

As noted by NMCC (2006), competitiveness of manufacturing sector is a very broad multi-dimensional concept that embraces numerous aspects such as price, quality, productivity, efficiency and macroeconomic environment. The OECD definition of competitiveness, which is most widely quoted, also considers employment and sustainability, while being exposed to international competition, as features pertaining to competitiveness.

Key Finding of 3rd Manufacturing Survey

Manufacturing survey is conducted every five years (1997, 2002 and 2007). The following are key findings of the 3rd Manufacturing survey (Chandra, 2009).

o Firms in different regions and of different sizes appear to be adopting differing strategies for competing in the market. Most consistent are the medium size firms that follow a medium volume, medium product variety strategy. Many of the large firms do not take advantage of the scale economies that is inherent in their operations. Most of the small firms do not compete on flexibility and innovation which is their natural strength but would rather become ancillaries to large customers.

o The scale of operations of most firms is below their global competitors. This is due to : expensive capital costs, restrictive labour laws and small size of the domestic market and inadequate systems to manage large work forces.

o Quality continues to remain as the highest priority for most firms. Innovation and R&D has the least priority. Similarly, they identify fast / on-time delivery as areas of concern where the gap between their strength and priorities is high.

o The five most important practices that the firms would focus on during the next two years are: Improving the quality of work life; Continuous Improvement of current manufacturing processes; Supervisor training; Management training; and Worker training.

o Skill building at all levels has been recognized as one of the most crucial driver for growth in the future. The presence of /I continuous improvement" as a priority reflects a recognition that firms are making towards improving processes on the shop floor.

o Supply Chain coordination emerges as a key weakness for most manufacturing firms.

o While firms do see benefits from investment in innovation, investments in R&D are very low. Most training for innovation happens when new technology or equipment is purchased. o Investment and usage of IT on shop floor is very low.

o Over the last three years, the three areas that have seen the maximum improvement are: overall quality as perceived by the customers, average customer defect rates, and delivery lead times. However, the variance across lead times is very high.

o Small firms that are customizing requirements of customers are doing well. This service approach to production may be the distinctive mark of Indian manufacturing.

o Regional imbalances exist in terms of capabilities of firms.

o Strategies of firms and their performance vary by size. Tiny and small firms spend a higher percentage of their sales in R&D as compared to large and medium sized firms. Medium size firms hold the maximum promise in terms of their ability to compete on the basis of higher productivity and operational parameters as compared to the sales value.

Though the concept of competitiveness is attractive at the sector level, due to inadequacy of database, it is felt that the issues be studied at the industry level. Competitiveness enhancement for Indian manufacturing will demand good understanding of changing global manufacturing landscape and real issues. Trends in global trade in manufacturing products and India's share hint at biggest trade opportunity for India in automotive components. Available trade data from WTO indicates that automotive products emerged as the largest sub segment in manufacturing with 9.5 percent share of global trade (Momaya and Anuprita, 2006).

With tremendous improvements in the operational efficiency, delivery and quality, India has tremendous opportunity to get a respectable share. It is estimated that India can theoretically address about 42 per cent of the global automotive component market of US $1650billion in 2015.However, pragmatic view says that India can achieve an export ofUS$20-25billion by 2015translating into share of 2-2.5 per cent (Kapuria, 2005).This vast gap between possibility and reality can be considered the biggest opportunity that can be addressed by rapid enhancement of competitiveness. Global benchmarking of leading countries indicates that India has the ability and potential to enhance competitiveness. The following perspectives that can be obtained:

- Asia is fast emerging as most competitive continent for manufacturing.
- Structure of the leaders has been changing slowly but steadily. For instance, countries such as Japan, that leveraged manufacturing massively for their competitiveness, slowly became less competitive due to increase in costs (e.g. labor costs). Still Japan has sustained competitiveness in manufacturing and remains the leader by competitiveness index.
- While India has made significant improvements in automobile industry, that are yet to be translated effectively in international competitiveness-related benchmarks. Rapid improvements in exports of full vehicles, components will have to be matched by investments in technology management and abroad for distribution channels or facilities.

Keeping the above in view, a case of auto components (based on Singh et al. (2007) is taken for further analysis.

Strategies for Competitiveness: Case of Auto Components

The Auto component sector is the core segment of Indian economy. Indian auto component industry, started just in the beginning of 1960s, has a relatively short history of development. Earlier auto component sector has based itself upon serving the indigenous vehicle assembly, which remained dormant for long period with fewer models and under regulatory protection. The Indian market scenario changed drastically after the industrial policy of 1991.The new policy regime spurred entry of a large numbers of new players into the component industry, almost all with technical or equity collaborations with a foreign company. In past few years, several Indian auto component firms have realized their need to grow and have expanded their customer base in developed countries (For example: Sundram Fasteners, Brake India, Gabriel etc.).This has necessitated a review of the nature of investments into volume capacities as well as quality management processes. Firms have adopted quality systems to improve their processes consistency and assure higher product reliability. The positive effects of such efforts are being observed in form of growth of Indian auto component sector in recent years.

Presently Indian auto component industry is very small by global standards and heavily depends on foreign sources of technologies. India's component industry is smaller than the annual turnover of number of global component manufacturers. Therefore barring a few, most auto component units can be categorized as small and medium enterprises (SMEs) and are consequently dependent on other firms and institutions for their growth or even survival. After liberalization of market many global automobile manufacturers such as Ford, General motors, Suzuki, Honda, Mercedes, Daewoo in four wheeler segment and Piaggio, Suzuki, Honda, Yamaha, Kawasaki in two wheeler segment have set their base for manufacturing or international purchase operations in India (Singh et al.,2004).

Global Competition, technological change and demanding customers are creating a more knowledge intensive, turbulent, complex and uncertain environment. In such a challenging, volatile and hyper competitive environment, any manufacturing firm, which is able to compete on all dimensions of competitive priorities such as fast delivery, high quality, low price, volume and product flexibility can be considered as a competitive firm. The foundation of organizational competitiveness has shifted from physical and tangible resources to knowledge. Ultimate focus of all connotations of competitiveness leads towards long-term performance of the organization in comparison to its competitors.

In sustaining their competitiveness, organizations face many pressures and constraints due to their limited resources of finance, skilled manpower and advance technology. Therefore strategy should match to organization resources, changing environment and in particular markets and customers. Therefore for surviving in this new competition, firms will have to develop suitable strategies for cost reduction, quality improvement, making new investments and development of competencies. Due to dynamic nature of market scenario, strategies will have to be dynamic with time. The main task of corporate strategy is not to describe the current state of art, but to identify and explore core competencies that must be added. Otherwise the current competencies can become obsolete and begin to function as core rigidities. A more natural and fruitful approach is therefore to think of knowledge and skills required by a company in order to maintain or improve its competitiveness. It is interesting to identify various pressures and constraints on Indian auto component sector, relationship of pressures and constraints with strategies and finally to analyze relationship of strategies with performance and competitiveness. According to the framework of Singh et al. (2007), shown in Fig 1, pressures and constraints on organizations will decide their strategies for investments, development of competencies and priorities for reducing cost and improving quality. Formulation of strategies and their effective implementation will decide their performance. Performance measurement can be subjective and objective. Performance of organizations on these measures will lead for its sustainable competitiveness. A survey based method was adopted to strengthen this framework. In all 75 respondents out of 500contacted from various parts of the country participated in this study.

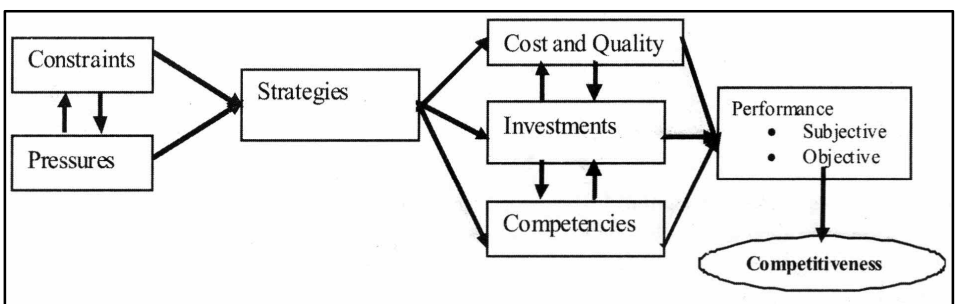


Figure 1: Framework for the study

Pressures

Globalization has changed the competitive environment for auto component sector drastically. To be successful, companies have to compete not only against domestic competitors but also against the best companies in the world. In order to compete effectively companies must embrace-new technologies and be capable of manufacturing innovative products of high quality and low cost and also provide a first class customer service. The new competition is in terms of reduced cost, improved quality, products with higher performance, a wider range of products and better service, and all delivered simultaneously. Various pressures being faced by Indian auto component sector (n=75) on a Likert scale of five (I-Very low, 5-Very high) are presented in Figure 2. It is being observed that to reduce cost (3.79) is highest pressure on Indian auto component sector. It is followed by pressures of improving quality (3.69)and reducing delivery lead-time (3.41).

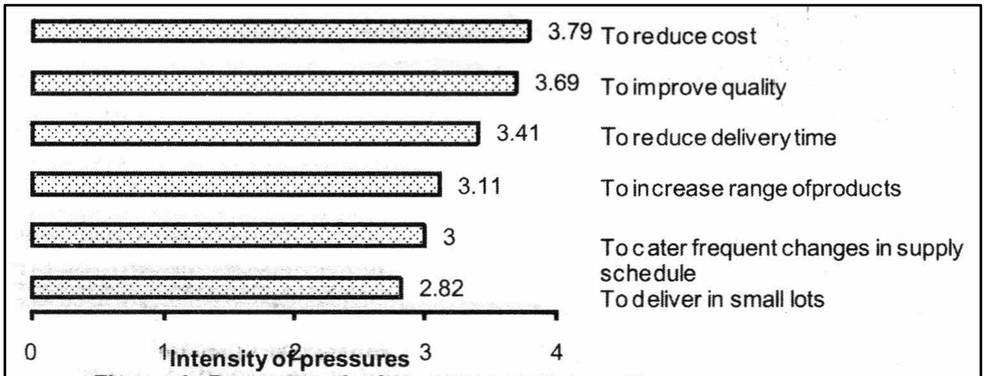


Figure 2. Pressures in Auto component sector

Constraints

SMEs have commonly been categorized to be component manufacturers for larger companies where they operate in the 'make to order' or rather the 'engineer to order' approach that imposes rigid constraints on meeting changes in requirements at short notice. SMEs often are oriented towards serving local niches or developing relatively narrow specializations. The main barriers to be competitive for SMEs are inadequate technologies as well as inadequate in-house human expertise and poor financial resources. Resource scarcity can impact on the ability of smaller firms to enter export markets and in implementing expensive software such as ERP system. Various constraints being faced by Indian Auto component sectors are shown in Figure 3. Most of the constraints are significantly below moderate level. For auto component sector, lack of growth-conducive environment (2.81), raising funds from market (2.77) and shortage of technical man power (2.76) are observed as most severe constraints. In creating growth conducive environment, government policies play important role. Government policies have played a facilitative role in countries like Japan, South Korea, Taiwan etc. In India, some initiatives such as raising of investment limit for small scale auto component sector and some others from 10 million to 50 million Rs, raising of loan limit and subsidy for technology up gradation (Economics Times, 2005), improvement in infrastructure, transparency and accountability of administrative systems are being taken but still lot of efforts are needed from government side for making Indian organizations, competitive in the global market.

Issues in Competitiveness of Indian auto component sector

An effective strategy must take into account the distinctive competencies of a firm that will give it a competitive advantage over its competitors. In present scenario of global competition, effective strategies for making investments, for developing competencies with time and strategies for reducing cost and improving quality are very important. These issues have been analyzed for auto component sector in following sections.

(a) Investments priorities

The factory of future image is associated with advanced technologies enabling production of a variety of high quality products at low costs, delivered to the customers without delay. To achieve these goals, technological innovations are necessary. Technological innovations may involve several orientations such as: design based, manufacturing based and administrative based orientations. These are intended to improve product quality and process efficiency through a better design, better control, improved logistics, quicker and more effective communication. Users of advanced e-' business technology perform better than non-user in the export market. According to a study done by Fletcher and Hardill (1995), stronger orientation of French firms towards human resource management (HRM) practices and investment in new technology was a key reason for their better sales growth as compared to their counterparts in UK. It is also commonly reported that quality and consistency of the manufacturing performance of SME scan be improved as a consequence of the use of the most appropriate information technology (IT) tools without any major changes in business practices, manufacturing operations or the production facilities. Information and communication technologies may be necessary.

Investment priorities for auto component sector are given in Table 4 based on a sample size of 75 (Singh et al. (2007)). For auto component sector automation of processes, market research and welfare of employees were major areas of priority for investment in past three years. In next three years automation of processes continues to be top priority of investment for auto component sector. In addition to this, market research and training of employees will be other areas of priority for investment. On the basis of statistical test (paired sample t test), it is observed that level of priority for most of the areas of investment have increased significantly with time. It is also observed that for auto component sector, investment in advertisement continues to be the lowest priority. From this study it is found that investment in research and development is still not the top ranking priority for auto component sector.

Table 4: Investments priorities for Auto component sectors

SN	Nature of Investment	During past three Years		In next three years	
		Mean	SD	Mean	SD
i.	Research and development	3.03	1.13	3.77	0.98
ii.	Automation of processes	3.33	1.11	3.94	0.81
iii.	Information technology	2.97	1.21	3.54	1.14
iv.	Training of employees	3.18	0.96	3.80	0.97
v.	Welfare of employees	3.19	0.89	3.66	0.84
vi.	Market research	3.30	1.15	3.88	1.08
vii.	Advertisement	2.30	0.91	3.13	1.17

(b) Priorities for developing competencies

According to Prahlad and Hamel (1990), core competencies of the organization are built on intangible assets that can not be easily imitated by the competitors and are the source of the company's ability to deliver unique value to its customers, and allow the company to be flexible in terms of markets and products. In past three years, Auto component sector had given maximum focus for developing competency in area of using customer to define quality standards. In addition to this, identification of market changes and optimization of work environment were other major areas of competencies development in past three years. In next three years, identification of market changes will become top priority in place of using customer to define quality standards. This change is being observed due to fast changing market for automobiles in India. In addition to this, use of information to optimize decisions and new products development will be the other areas of competencies development. Although most of the areas of competency development except identification of niches, have got significantly higher focus than moderate level in past three years but on the basis of paired sample t test, it is observed that level of focus for developing these areas of competency have increased significantly with time. Analysis also shows that present organizations differ from focused organization of the past. Reason is that to satisfy and retain their customers for their sustainable growth in present global competition, they cannot ignore any of these competencies.

Table 5: Areas of competency development

SN	Competencies	During past three Years		In next three years	
		Mean	SD	Mean	SD
i.	To identify niches	3.17	1.01	3.60	1.02
ii.	To develop new products	3.49	0.95	3.97	0.91
iii.	To optimize work environment	3.54	0.83	3.95	0.77
iv.	To use customer to define quality standards	3.61	0.98	3.95	0.93
v.	To introduce new technology	3.54	1.028	3.91	0.83
vi.	To use information to optimize decisions	3.54	0.92	4.01	0.91
vii.	To identify market changes	3.59	0.89	4.12	0.83

(c) Strategies for Cost and Quality

It has been observed that for European and US manufacturing executives, quality is the most important competitive priority. Lau (2002) has also found higher quality and lower cost as top ranking competitive factors among US electronics and computer industries. Intensity of strategies adopted by auto component sector (n=75) for cost and quality are given in Table 6. It is observed that for reducing cost, auto component sector is giving maximum focus on strategies of reducing rejection/rework followed by improvement of maintenance and process capability. For improving product quality, reduction of rejection/ rework continues to be top strategy. In addition to this improvement of process capability, product design and maintenance are other major strategies being followed. It is observed that intensity of some of the strategies adopted by auto component sector for cost and quality such as automajion of operation, improvements in product design and training of employees differ significantly

Table 6 : Strategies for cost and quality

SN	Strategies	To reduce cost		To improve quality	
		Mean	SD	Mean	SD
i.	Reduction of inventory	3.57	0.81	3.50	0.97
ii.	Reduction of rejection / rework	3.74	1.07	3.91	1.15
iii.	Automation of operation	3.47	0.99	3.74	0.90
iv.	Vendor development	3.52	0.97	3.59	0.94
v.	Improvement of process capability	3.68	0.92	3.90	0.89
vi.	Improvement of maintenance	3.73	0.90	3.88	0.71
vii.	Improvements in product design	3.65	0.97	3.88	0.80
viii.	Research and development	3.53	1.21	3.65	1.12
ix.	Training of employees	3.41	1.11	3.74	0.94

Performance and Competitiveness

Performance of an enterprise is often measured as a ratio of output to input. The outputs constitute the products of the enterprise and the inputs are the resources used by the enterprise. Performance of an organization relative to its industry standards may be viewed as its competitiveness. Therefore performance of organization with respect to industry standards will decide its competitiveness. For measuring performance both subjective and objective measures can be considered. Subjective performance of Indian auto component sector in comparison to national standards is given in Table 7. Performance of Indian auto component sector in comparison to national standards is significantly higher than moderate level for most of the performance measures except in terms of manufacturing cost, labor productivity and throughput (Rs/hr). Objective performance of auto component sector is given in Table 8. Objective performance on all measures such as market share, profitability, export is significantly higher than moderate level. For evaluating overall competitiveness (0.2 local+0.3 national+0.5 international) of an organization, weightage for different levels was decided on the basis of discussion with industry professionals. Results of competitiveness at various levels are given in Table 9. At local and national level, competitiveness is significantly higher than moderate level but at international level, competitiveness needs to be improved. At international market, Indian auto component sector needs lot of efforts to improve their performance simultaneously on various dimensions of competitiveness such as quality, cost, delivery and flexibility.

* Pressures and constraints do not seem to be significantly correlated with strategies adopted. Reason for this may be that Indian auto component sector has been formulating its strategies under these pressures of cost, quality and delivery for a longer time to survive in market. Therefore in spite of various constraints, they try to achieve these targets for their survival.

* Strategies for cost, quality, investment and competency development are significantly correlated with subjective performance but not with objective performance. Subjective performance is significantly correlated with competitiveness.

* Above findings indicate that subjective performance seems to be better indicator for measuring competitiveness. Reason for this may be that Respondents give subjective measures more openly and accurately as compared to objective measures such as profit and sales. In this study, objective performance is taken as average percentage change in past three years for various financial parameters. Some times for a newer organization average percentage change on these measures may be more than highly competitive established organization for a longer time.

It is observed that Indian automotive manufacturing companies are giving importance to quality, delivery, flexibility, and cost in descending order. This supports the competitive progression theory proposed by Roth (1996). Presently, Indian manufacturing companies are trying to achieve superior quality, then delivery, flexibility, and cost respectively. Roth (1996) empirically tested this theory in US, Japanese, and European samples and observed strong support to the competitive progression theory. Indian companies are too following a similar path i.e. quality to delivery to flexibility to cost. Therefore it can be said that Indian auto component companies although started late, but moving in similar direction as that of their counterparts in developed economy.

Table 7: Importance of Performance

SN	Measures	In comparison to the national standards	
		Mean	SD
i.	Manufacturing cost	3.17	0.75
ii.	Level of inventory	3.24	0.80
iii.	Delivery speed	3.65	0.58
iv.	Flexibility in production	3.23	0.89
v.	Percentage rejection	3.51	0.94
vi.	Labor productivity	3.16	0.79
vii.	Capacity utilization	3.25	0.98
viii.	Employee turnover rate	3.32	0.81
ix.	Throughput (Rs/hr)	2.98	0.87
x.	Employee satisfaction	3.48	0.94
xi.	Customer satisfaction	3.84	0.895
xii.	Supplier satisfaction	3.49	0.86

Table 8: Importance of objective performance

SN	Objective performance measures	Mean	SD
i.	Market share	3.54	0.66
ii.	Sales turn over	3.78	0.69
iii.	Profit after tax	3.46	0.74
iv.	Return on investment	3.37	0.62
v.	Export	3.58	0.77

Table. 9. Competitiveness at various levels

SN	Level	Mean	SD
i.	Local	3.48	1.01
ii.	National	3.49	0.87
iii.	International	2.93	1.28

Challenges

Some of the challenges faced by the manufacturing are as follows

a) Adoption of technology: If competitiveness is to be enhanced, it is imperative that technology (such as Advanced Manufacturing Technology or software such as ERP) needs to be properly adopted.

b) Training human resources at various levels: For implementing technology, training of manpower is a necessity. The training could include management of change and sensitization towards new paradigm of manufacturing

c) Synergistically combing manufacturing with services and thereby leveraging advantage in the global market: India is perceived as software capital of the world. This strength needs to be properly leveraged with hardware and other functions related to manufacturing so as to give a competitive edge.

d) Developing the overall supply chain perspective to strengthen the manufacturing function which can help to get competitive advantage : It seems that many firms have not yet integrated themselves along the basic philosophy of supply chain. This seamless transition is a must, if manufacturing is to be perceived as competitive.

From the study of auto sector, it is observed that level and priority of different factors of pressures, constraints, strategies and performance measures differ with each other. It is also observed that to face various situations after globalization, SMEs in this sector are adopting multi faceted strategy rather than depending upon single approach. On the basis of this study, some of the concluding observations are as follow.

* Cost, quality and delivery time are the main pressures on auto component sector.

* Lack of growth-conducive environment, raising funds from market and shortage of technical manpower as major constraints.

* Automation of processes, market research and welfare of employees are top ranking priorities of investments.

* Use of customer to define quality standards, identification of market changes and optimization of working environment are the main areas of competencies development.

* Reduction of rejection/rework, improvements in maintenance and process capability are main strategies adopted by Indian organizations for cost and quality.

* Strategies for investment, quality, cost and competency are significantly correlated with competitiveness of organization.

* Priority and focus on various areas of strategies changes significantly with time. This explains flexible nature of strategy development by this sector.

* Subjective performance with respect to industry standards seems to be better judge for measuring organization's competitiveness. This finding implies that organizations should benchmark themselves with industry standards.

Concluding Observations

In view of India's manufacturing sector's performance vis-a-vis its position in the overall economy, the following observations are significant:

a) Manufacturing sector offers tremendous opportunities on various fronts. It can act an engine for growth, offer employment directly or indirectly and can synergize our strong position in services.

b) Economic liberalized polices coupled with the global competitive scenario have acted to enhance the competitiveness of manufacturing sector. Manufacturing sector must respond to the challenges thrown by both domestic and the global scene. Role of NMCC is to appreciated in this context.

c) The domestic demand can act as a buffer against global pressures such as recent economic meltdown. Strategies to respond to these pressures may vary.

d) As proposed by Roth (1996),Indian manufacturing seems to be following a progression theoretic approach to achieve competitiveness(Dangayach and Deshmukh, 2001). This implies that after building a strong base in quality, other competitive priorities such as delivery, flexibility and cost are being tackled in a progressive manner, each building on the previous one and consolidating the position.

e) It seems that the strategies of Indian auto component sector firms are not influenced much by present pressures and constraints. It implies that they had been following competitive strategies for a longer time therefore they are quite aware and committed for changing market scenario for sustaining their position in spite of various constraints on them related with finance, technology and infrastructure. Findings also imply that their strategies for making investment, quality improvement, cost reduction and competency development are significantly correlated with subjective performance and competitiveness of the organization. Strategies for competencies development have highest correlation with performance. It implies that main task of corporate strategy is not to describe the current state of art but to identify and explore core competencies that must be added. Otherwise the current competencies can become obsolete and begin to function as core rigidities.

f) A more natural and fruitful approach is to think of knowledge and innovative skills required in order to maintain or improve its performance in comparison to industry standards.

g) There is a need to evolve a strong and robust quantitative set of measures to capture the competitiveness at various levels.

h) A synergistic framework needs to be developed at policy level involving various stakeholders such as NMCC, Industry associations, professional bodies such as Institution of Engineers, Academic institutes and industry to tackle the issue of enhancing competitiveness from all perspectives.

Acknowledgement

At the outset, the encouragement and time to time support of Prof GSYadava (Council member IEI) is gratefully acknowledged. Author would like to thank Dr Kiran Momaya (IIT Delhi) for his valuable suggestions and constructive comments and help in arranging various inputs required for this paper.

Author is also thankful to Dr Govind Dangayach (MNIT - Jaipur),Dr Suresh Garg (DTU-N Delhi) and

Dr R K Singh (DTU -N Delhi) for their valuable inputs and assistance.

References

1. Ajitabh and Momaya, K, (2004), "Competitiveness offinns: Review of theory, frameworks and models", Singapore Management Review, Vol. 26, No.1, First half, pp.45-61.

2. Chaharbaghi, K, and Feurer, R, (1994), "Defining competitiveness: A holistic approach", Management Decision, Vol. 32, No.2, pp. 49-58.

3. Chandra Pankaj,(2009), "Competitiveness of Indian Manufacturing: Findings of the Third National Manufacturing Survey, Nati?nal Manufacturing Competitiveness Council, Delhi

4. Cruz, D.J., and Rugman, A, (1992), "New compacts for Canadian competitiveness", Kodak, Canada.

5. Dangayach, GS., and Deshmukh, S.G, (2001), "Practice of manufacturing strategy: evidence from select Indian automobile companies", Iniernaiional Journal of Production Research, Vol. 39, No. 11, pp. 2353-2393.

6. Dou, Wand Hardwick, P. (1998), "The competitiveness of EU insurance industries", The Service Industries Journal, Vol. 18, No.1, pp. 39-54.

Engineering Research, Vol 13, No. 1&2, pp.121-127.

7. Fletcher, D., and Hardill, 1., (1995), "Value adding competitive strategies: a comparison of clothing SMEs in France and Great Britain", International Small Business Journal, Vol. 14 No. I, pp. 33-53.

8. Fleury, A, and Fleury, M.T., (2003), "Competitive strategies and core competencies: perspectives for the internationalization of indus try in Brazil", Integrated Manufacturing Systems, Vol. 14, No.1, pp.16-25.

9. Flynn, B.B., Sakakibara, 5., Schroeder, RG, Bates, KA, and Flynn,.J.B., (1990), "Empirical Research Methods in Operations Management, Vol. 9, pp. 250-284.

10. GCR (1996). "The Global Competitiveness Report 1996," prepared by the World Economic Forum, Switzerland.

11. GMR, (2001), "Capability based strategy: The role of knowledge, " Economics Times, General Management Review.

12. Hamel, G, and Prahalad, C.K, (1993), "Strategy as stretch and leverage", Harvard Business Review, Vol. 77, No.2, March-April, pp. 75-84.

13. Hitt, MA, Ireland, RD, and Hoskisson, RE., (2001), "Strategic management-Competitiveness and globalisation-Concepts and cases", Thompson Learning.

14. Indian Council for Research in International Economic Relations,(2008), Detenninants of competitiveness of Indian auto industry, National Manufacturing Competitiveness Council, Delhi

15. Kapuria (2005), "Potential for aglobal role", Survey of Indian Industries, The Hindu, pp 296-297

16. Khalil, T.M., (2000), "Management of technology: The key to competitiveness and wealth creation", Singapore: McGraw Hill.

17. Lau, R.S.M, (2002), "Competitive factors and their relative importance in the US electronics and computer industries", International Journal of Operations and Production Management, Vol. 22, No.1, pp. 125-135.

18. Leachman, C, Pegles, CC, and Shin, S.K., (2005), "Manufacturing performance: evaluation and determinants", International Journal of Operations and Production Management, Vol. 25, No.9, pp. 851- 874.

19. Momaya K. and Anuprita, (2006), "Glimpse of Global Competitiveness Scenario of Manufacturing: Opportunities for India in Auto Components Industry", DEI. Journal of Science &Engineering Research, Vol 13, No 1-2, pp 121-127

20. National Manufacturing Competitiveness Council,(2009), "Enhancing Competitiveness of Indian Manufacturing Industry: Assistance in Policy Making", National Manufacturing Competitiveness Council, Delhi

21. Oral, M., (1986) "An industrial Competitiveness model, "IIE Transaction, Vol. 18 No.2, pp.148-157.

22. Pace, R.W., and Stephan, E.G., (1996), "Paradigms of competitiveness," Competitiveness Review, Vol. 6, No.1, pp. 8-13.

23. Porter, M (1980). Competitive Strategy: Techniques for Analyzing Industries and Competitors, New York: The Free Press.

24. Porter, M (ed) (1986). Competition in Global Industries, New York: Harvard Business School Press.

25. Porter, M.E (1990), "The competitive advantage of nations", Nell) York: The Free Press.

26. Porter, M; Ghemawat, P and Rangan, S (1994). Developing Competitive Advantage m India, Confederation of Indian Industry, New Delhi, and Harvard Business School.

27. PraJa.lad,CK., and Hamel, G., (1990), "The core competence of the corporation ", Harvard Business Review, Vol. 68, No.3, pp. 79-91.

28. Roth, A. V. (1996). "Competitive progression theory: explanation and empirical evidence". In Manufacturing Strategy: Operations Strategy in a Global Context, (C Voss, Ed.), London: London Business School,309-314.

29. Scott, B.R., (1989), "Competitiveness: Selfhelp for worsening problem," Harvard Business Review School Press, Vol. 67, No.4, pp.115-121.

30. Singh R K, Garag, S, Deshmukh S G (2007), "Strategy development for competitiveness: A study on Indian auto component sector", International J of Productivity & Performance Management, Vol 56, No 4, pp 284-307

31. Singh R.K., Garg S.K. and Deshmukh S.G. (2004), "Competitiveness of small and medium enterprises: Case of an Indian auto component manufacturing organization", IIMB management Review, Vol. 16, No. 4, pp. 94-102.

32. WCR (1993). The World Competitiveness Report 1993, prepared by IMEDE and the World Economic Forum, Switzerland.

Engineering Solutions to Combat Climate Change

Prof R S Agarwal

Former Deputy Director (Faculty), IIT Delhi
and
Senior Advisor and Coordinator for HCFC Phase-out, UNDP-GOI Projects "Montreal Protocot", Ozone Cell, New Delhi

Protection of Climate System

The climate problem is one of a wide range of closely related global environmental problems that include desertification, the disappearance of biodiversity, deforestation and depletion of ozone layer. The rise in greenhouse gas emissions from fossil fuel combustion, agricultural and industrial activities has aroused global concern about the possible impacts of these emissions 'on climate. Greenhouse Gases, (GHGs) mostly carbon dioxide, some methane, nitrous oxide and to the some extent other three gases viz., hydrofluorocarbons (HFCs), perfluorocarbons : (PFCs) and hexasulfurfluoride (SF6) which are emitted to the atmosphere, enhancing an effect in which heat reflected from the earth's surface is kept from escaping into space, as in a greenhouse. Thus, there is concern that the earth's surface temperature may rise enough to cause global climate change.

In the last two decades, the United Nations has organized a series of negotiations in an effort to reach international agreements on reducing emissions of GHGs. In 1997 the first agreement on international, legally binding targets for emission reductions for industrialized countries was reached under the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto. It is known as Kyoto Protocol. This Protocol set out agreement for reducing emissions of GHGs over the period 2008-2012 (the first commitment period), compared with the level in 1990. The agreement in the Kyoto Protocol results in an average emission reduction of 5.2% in industrialized countries. According to the Kyoto Protocol, countries may achieve their reductions both domestically and in other countries with the flexible mechanism of Joint Implementation (JI), Clean Development Mechanism (COM) and International Emission Trading.

Since then the signatory countries are making all efforts to reduce their emissions as per the commitment targets. The COM is being widely used and many projects/ activities related to GHG reductions are being carried out in developing countries including in India. There are wide range of engineering solutions have been applied to combat the climate change. These can be grouped in following three categories.

Energy Efficiency:

• Use of electricity more efficiently through the deployment of advanced technologies: e.g., energy efficient appliances/ processes, intelligent building control systems, energy efficient lighting, energy efficient air-conditioning in buildings etc.

• Reduce use of electricity, gas and oil for space cooling, heating and water heating through building efficiency measures e.g., insulation, gas-fired heat pumps that provide highly efficient space heating and cooling, and building envelopes-Green buildings etc.

• Improve industrial resource recovery and use e.g., develop an integrated gasification combined cycle power technology, which can convert coal, biomass, and municipal wastes into power and products and industrial processes to save energy e.g., advanced catalysis and separation technologies etc.

• Increase transportation efficiency through new technologies e.g., fuel efficient road/rail/sea transportation, use of public transportation, hybrid electric vehicle etc.

Clean Energy:

• Change the energy mix to increase use of sources with higher generating efficiencies and lower emissions-increased use of natural gas, safer and more efficient nuclear power plants, renewable energy e.g., solar and wind power; use of biomass as fuel and for electricity generation, use of hydrogen to produce electricity through fuel cells etc.

• Efficient electricity transmission and distribution to reduce emissions e.g., distributed generation using superconducting transformers, cables, and wires.

• Switch transportation to energy sources with lower emissions e.g., trucks that run on biodiesel fuel; ethanol from cellulosic feed-stocks.

• Use of Clean Coal technology

Carbon Sequestration:

• Efficiently remove carbon dioxide from combustion emissions before they reach the atmosphere.

• Increase the rate at which oceans, forests, and soils naturally absorb atmospheric carbon dioxide.

• Develop technologies for long-term carbon storage in geological deposits, aquifers, or other reservoirs.

Protection of Ozone Layer and the Climate System

Another major environmental degradation is the Stratospheric Ozone Depletion. It is well known that depletion of the Stratospheric Ozone Layer emerged as one of the major global environmental concerns for the past four decades. The global community on 22nd March, 1985 established Vienna Convention for the Protection of the Ozone Layer. Thereafter, under the Convention, the Montreal Protocol on Substances that Deplete the Ozone Layer was agreed upon on 16th September 1987 to phase-out production and consumption of Ozone Depleting Substances (ODSs) as per the schedule for protection of the ozone layer.

The Montreal Protocol has a well established structured institutional set-up supported by the Assessment Panels, viz., Scientific Assessment Panel (SAP), Environmental Effects Assessment Panel (EEAP) and the Technology and Economic Assessment Panel (TEAP). The well reputed scientists and technologists to these panels are drawn from global Scientific and Technical community. The Parties to the Montreal Protocol take policy decisions on the basis of updated techno-economical information provided by these Assessment Panels on the status of Ozone Layer as well as technically proven, environmentally benign and economically viable alternatives to ODSs which are to be phase-out. The Montreal Protocol had a number of amendments and adjustments based on the scientific and technical advises for early recovery of the Ozone Layer.

1st January 2010 marked an important milestone in the history of the Montreal Protocol when production and consumption of most of the high Ozone Depleting Potential (ODP) substances like Chlorofluorocarbons (CFCs), Carbontetrachloride (CTC) and halons have been phased out globally including in India. This has not only protected the stratospheric ozone but it has also immensely benefitted the climate system. The ODSs happens to be the potent GHGs and these gases were not included in Kyoto basket of gases for emission controls. As per expert estimates, from 1st January 2010, the Montreal Protocol has reduced GHG emissions by 11 Giga tonnes CO_2 equivalent per year through its ODS phase-out activities which is amounts to 5-6 times reductions targeted by the Kyoto Protocol during first commitment period of 2008-2012.

Recognizing the significant benefits for protection of the ozone layer and climate systems by early phase-out of hydrocloroflurocarbons (HCFCs), the Meeting of the Parties to the Montreal Protocol held in September 2007 adopted a decision to accelerated the phase-out of HCFCs by ten years and defined a HCFC production and consumption reduction schedule. A unique feature of this decision was to achieve this phase-out through adoption of alternatives with minimum GHG impact. The acceleration of phase-out of HCFCs will reduce about 12-15 Giga tonnes of CO_2 equivalent emissions. HFCs have emerged as the main alternatives to CFCs and HCFCs for various applications because of their favourable properties and ease of use. However, HFCs have high-Global Warming Potential (GWP) but significantly lower than that of CFCs and other ODSs which they replaced. The other low-GWP alternatives are still emerging.

An extensive research and development work has been carried out globally including in India during the past three decades searching for alternative refrigerants as well as substitutes to ODSs. The research institutions including IIT Delhi and Indian industry has made a significant contribution in developing alternatives and technologies to ODSs and successfully phased out the major ODSs as per the Montreal Protocol schedule.

The historic progression of refrigerants can be categorised in the following four generations:

• First Generation Fluids (1830-1930): primarily familiar solvents and other volatile fluids including ethers, carbon dioxide, ammonia, sulphur dioxide, methyl formate, Hydrocarbons, water, CTC, and others; some ofthem are now regarded as "natural refrigerants.

• Second Generation Fluids (1931-1990): primarily CFCs, HCFCs, HFCs, ammonia, and water.

• Third Generation Fluids (1990-2010): primarily HFCs, HCFCs (HCFCs for transition use), ammonia, water, hydrocarbons, and carbon dioxide.

• Fourth Generation Fluids (2011on wards): primarily natural fluids like ammonia, Carbon-dioxide, Hydrocarbons and Water and other emerging low GWP alternatives initially, low-GWP HFCs, unsaturated 10 hydrofluorochemicals especially the hydrofluoro-olefins (HFOs).

The Montreal Protocol on Substances that Deplete the Ozone Layer has been recognized as the most successful international environment treaty in history. Another testimony to its remarkable accomplishments, the Montreal Protocol has received universal ratification; all countries in the world have now ratified this landmark agreement. In the twenty years of its operation, extraordinary international cooperation under this agreement, has led to phase-out of production and consumption of several ODSs which has not only helped to protect the ozone layer, but also immensely benefited the global climate system.

The job of protection of ozone layer is not yet over. There is a challenging task ahead to phase-out next category of chemicals, the HCFCs, in next two decades and applying low GWP alternatives to protect stratospheric ozone and the climate system. The 19th Meeting of the Parties of the Montreal Protocol in September 2007 had taken a decision to advance the phase-out of HCFCs from 2040 to 2030. The base line for production and consumption of HCFCs will be determined on the average of the years 2009 and 2010 production and consumption respectively. The freeze will be from 2013 and 10% reduction from the baseline in 2015 for stage-I reduction schedule of the accelerated phase-out schedule.

As regard to phase-out of HCFCs, the situation is similar as were for phasing out CFCs, CTC and halons almost two decades ago. India is the second largest producers and consumers of HCFCs in the world. The HCFC Phaseout Management Plans are being prepared by all the countries taking in to account the available and emerging low GWP alternatives to not only save the ozone layer but also to achieve climate benefits.

There are enormous opportunities for research and development in this field to evolve engineering solutions to phase-out remaining ODSs and then also replace high GWP HFCs to combat the climate change.

Industrial Laser based Manufacturing Technologies for Sustainability and Safety in Mobility

Dr G Padmanabham

International Advanced Research Centre for Powder Metallurgy & New Materials (ARCI), Hyderabad

PREAMBLE:

I feel greatly honoured to be delivering the prestigious Dr.S. P Luthra memorial lecture at the Twenty-eighth National Convention of Mechanical Engineers and National Seminar on Emerging Technologies in Product Development for Safe and Sustainable Mobility. I am grateful to the Institution of Engineers (India) - Coimbatore Local Centre and the PSGCollege of Technology, Coimbatore for giving me this opportunity. Further, the fact that I received my Ph.D from Indian Institute of Technology Delhi which immensely benefitted from Dr. S. P Luthra makes me feel more privileged to deliver this lecture in his memory. I chose to speak about application of industrial lasers for manufacturing, a topic in which I have been actively involved in the recent past and believe that it is really an emerging area with immense potential for application in the mobility industry, especially in the Indian context.

1.0 SUSTAINABLE MOBILITY - CONTRIBUTING FACTORS

While the definition and scope of sustainability is rather wide, as a manufacturing technologist one can consider the following aspects to apply new and emerging technologies,

- Control of harmful emissions
- Reclamation and recycling
- Improved life of components
- Cost-effective material usage and production methods

For example, light weighting of automotive bodies is the most effective way of reducing CO_2 emissions. It can also significantly improve performance in terms of noise and vibration. Several innovative designs, techniques and new materials are being tried world over, in this effort. Some such concepts are tailor welded blanks (TWB), hybrid body designs using lighter aluminium and composites in combination with steel etc.

Similarly, there are several components which are amenable for repair and re-use such as the diesel engine heads which are discarded due to very small local damages, worn out aircraft engine blades etc. Extension of life of components through engineering the surfaces with better tribological behaviour makes automotive more cost-effective. Surface engineering techniques can improve the tribological behaviour of several components extending their life significantly, even upto five times the original life. More efficient production techniques can minimise quantity of materials used and cost of production, indirectly contributing to the sustainability. Such innovations are possible in all the mobility sectors.

In this lecture I propose to cover some of the innovative laser based manufacturing technologies which have a significant impact on the mobility sector such as road transport, ship, aircraft and rail roads.

2.0 Lasers and Laser based manufacturing processes

When laser light is impinged on a surface some of the energy (depending on the reflectivity of a material to particular wavelength light) is absorbed and resulting in heating. Depending on the intensity of the beam and its interaction time with the material the degree of heating changes from simple heating to higher temperature to melting to vaporization. These phenomena coupled with the following advantages of laser as heat source make lasers a very effective manufacturing tool as shown in fig.1:

- Excellent beam control and easy conversion to automatic operation
- Non-contact, zero-force processing
- No tool wear related problems
- Low thermal input due to high energy density at the processing point
- High processing speed combined with reproducibility
- Can process hard, brittle or soft materials
- With the help of suitable CNC workstation, it can process intricate contours

- Variety of machining geometries can be done with changing tools
- Versatility il\terms of covering a variety of manufacturing processes
- Easy integration into conventional manufacturing process

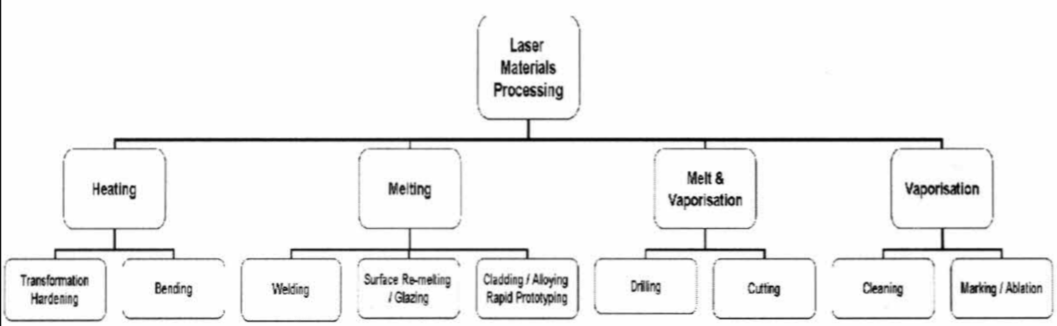


Fig.1 Manufacturing processes possible by laser

Laser based manufacturing processes include: cutting, welding, surface hardening, surface cladding, surface texturing, micro-drilling etc [1]. These processes are widely used in the automotive and related sectors and have a large potential for future applications as well. Laser based manufacturing is well developed in developed countries. In the year 2010, about US$ 2 billion worth industrial laser processing machines were sold [2]. In India, lasers are extensively used for cutting and marking. Applications of lasers for welding and cladding is available in a very few R&D laboratories and job shops. It is also understood that some automotive companies are using lasers for brazing operations.

Traditionally, CO_2 and Nd:YAG lasers have been popular in industrial manufacturing. Recently, diode lasers and fiber lasers are becoming more popular due to their high beam quality and power levels available. The laser power is generated either in continuous mode or pulsed mode and depending on the wave length can be delivered through fiber optic cable.

Principle features and selected applications of each of these processes in road transport, rail transport and aircraft sectors is briefly brought out in the following sections. The purpose of this is to sensitize the mechanical engineering community to this emerging technology and its potential in the mobility industry so as to attempt innovation in their respective domains.

3.0 LASERWELDING AND LASER-ARC HYBRID WELDING

Weldability is defined as "the capacity of a material to be joined under the imposed fabrication conditions into a specific, suitably designed structure and to perform satisfactorily in the intended service" [3] providing fitness for purpose with minimum distortion and a controlled or limited number of defects. Laser beam is a concentrated high intensity heat source, hence can be used for keyhole welding with precision and at high-speed. High weld aspect ratios (10:1) and minimal heat affected zones are other major advantages. At the same time there are certain limitations, such as formation of brittle welds in high hardenability materials; porous welds and undercuts due to vaporization of certain elements; and stringent joint fit-up requirements as the welding spot is usually less than 0.5 mm. But, for some applications, laser welding fits the bill very effectively. One such application is the TailorWelded Blankfabrication.

3.1 Tailor Welded Blanks (TWB) for weight reduction in automotive bodies Tailor welded blanks use two or more different blanks of steel to form one blank. The idea is to "tailor" the blank with different properties at different locations as per design requirements. This concept of locating multiple steel sheets precisely within the part where they are needed offered the engineering designer immense flexibility for component design and to reduce vehicle mass and reduce total cost [4] .

For example, a door inner in a car traditionally is made of single thickness blank and has a thickness sufficient to meet the stiffness requirement at the hinge. However, the same thickness is not needed on the latch side. The TWB concept adapts a two material blank which has a thicker sheet towards the hinge side and thinner sheet towards the latch side. Fig.2 shows a schematic of fabricating a TWB for door inner. A 2 mm thick sheet is welded to a 0.6 mm thin sheet and sheet metal blank fabricated.

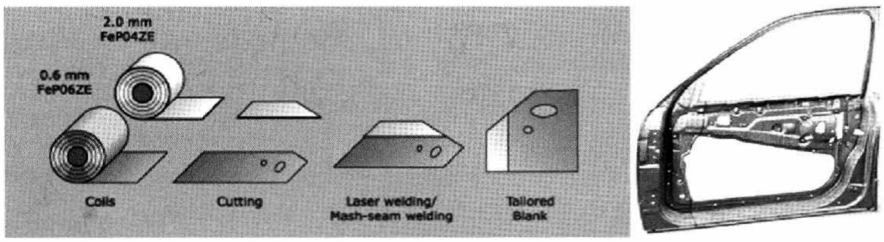


Fig.2 Schematic of tailored blank fabrication and pressed door inner from a TWB

The benefits of using TWBs include: weight reduction; fewer parts, consequently fewer dies and spot welds; design flexibility leading to improved structural integrity, safety and dimensional accuracy; reduced design and development time; lowered manufacturing costs due to reduced and optimal material use.

Tailor welded blanks are currently used for body side frames, door inner panels, motor compartment rails, centre pillar inner panels, and wheelhouse/shock tower panels. The TWB concept has been in application since 1990s in Europe, USA and Japan. But, in India efforts towards development of TWBs and their usage started only in the recent past.

The welding process for fabrication of TWBs is crucial as the blanks should exhibit formability similar to that of the base steels chosen. The welding process should be such that the defect free welds should be made with high repeatability and productivity. Even though several processes have been evaluated, laser beam welding and mash seam welding are preferred processes employed worldwide for the production of TWBs. A comparison of relative advantage of laser welding process for TWBs is shown in table-t, which is mainly possible due to high welding speeds resulting in narrow weld beads with high productivity. TWB has been a major application of laser welding as almost 25-30% of all steel body-in-white structure uses TWBs. However, accomplishing consistently good quality blanks requires development of suitable welding procedures. Several ccompanies around the world such as Thyssen Krupp A.G, Posco, including some of the automakers themselves such as Volkswagen etc., produce TWB forms in large scale.

Table-1: Comparison of laser welding with other welding processes vis-à-vis TWB fabrication

Requirement	Electron beam	Induction	Mash seam	Co2 laser	YAG laser
Rework weld	No	Needed	Cold rolling	No	No
Coated /Uncoated	Possible	Possible	In production	In production	In production
Curve welds	Possible	No	No	In production	Highly favorable
High/low Strength	Possible	Difficult	Possible	In production	Highly favorable
Changing Thickness	Possible	No	No	In production	Highly favorable
T-weld lines	Possible	No	No	In production	Highly favorable
Industrial Integration	Difficult	Good	Good	In production	Possible
Forming Behaviour	Very good	Difficult	Good	Good	Very good
Edge Preparation	Precise	Easy	Medium	High Precision	Precise

The effect of edge preparation on the defect levels in the laser welds of TWBs is shown in fig.3

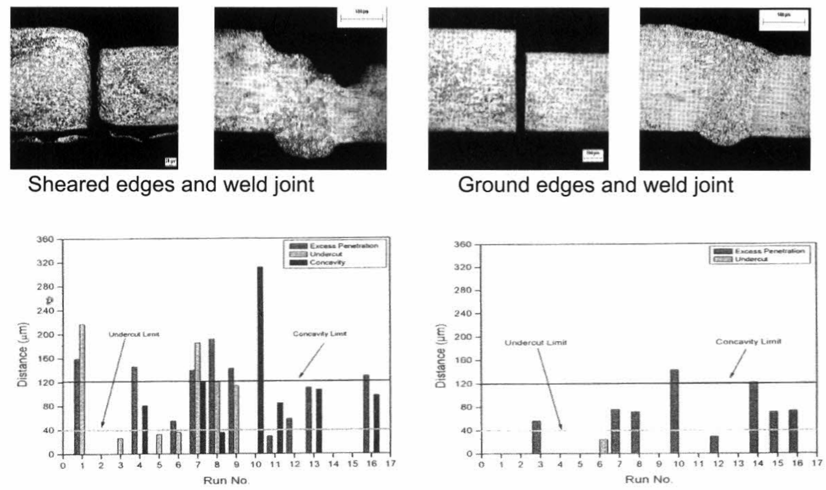


Fig. 3 Effect of edge preparation on defects in laser welded TWBs [5].

The materials that are widely applied for making TWBs include: C-Mn steel, Extra Deep Drawable steel (EDD steel), Interstitial free steel (IF steel); High strength Low alloy steels (HSLA); Bake Hardenable steel. In the recent past advanced high strength steels (AHSS) such as Dual Phase (DP) steels, Transformation Induced Plasticity Steels are also being considered for the TWB application. Hhowever, laser weldability of these alloys is being actively investigated [6-8].

3.2 laser welding of stiffeners on aircraft fuselage skin

Efforts towards weight reduction and high productivity aircraft fabrication is an important area of innovation. One such idea is replacement of riveting by welding. Joining by riveting is done at a speed of 0.2-0.4 m/min with full automation and additionally the rivets and sealants used add to weight. Presence of sealants can cause corrosion as well. In terms of productivity also the riveting technology has more or less saturated and alternate processes that can be applied on aerospace aluminium alloys needs to be investigated. Laser welding with advantages like high welding speed, minimal distortion, good joint efficiency etc is a potential candidate. The first application developed in that direction is the welding of stiffeners along the fuselage panels using two C02 lasers on either side of the stiffener. Fig.4 shows the large 16 m long fixture for accomplishing the task [9] .

Fig.4 Fixture for laser welding of stiffeners to fuselage skin [9]

Laser welding could be done at 6 m/min and eliminate rivet straps in aircraft skin resulting in structure weight reduction of 5%. There is further weight reduction possible by using higher strength aluminium alloys which probably could be weldable using lasers but otherwise not possible by conventional welding processes.

3.3 Laser-hybrid welding of ship hulls, sandwich panelled structures One of the major drawbacks of laser keyhole welding in autogenous mode is very tight joint fit-up (almost with zero gaps) required to achieve consistently good quality welds, as the laser spots are very fine. Especially, it is very difficult to prepare the edges of thick plates over long lengths. This scenario led to innovation of laser-arc hybrid process.

Laser beam is used in tandem with an MIG/TIG/Plasma arc. The laser contributes in terms of deep penetration and the welding arc (with or without filler) does the edge bridging [10]. Fig.5 shows arrangement of laser-MIG arc hybrid welding set up and cross section of typical laser-hybrid weld.

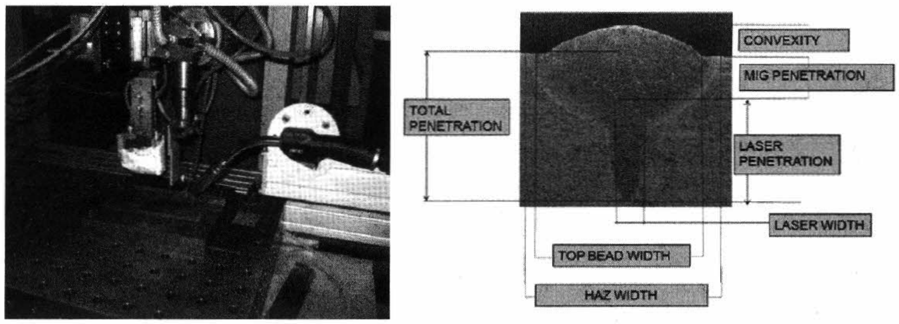


Fig.5 Laser-GMAW hybrid welding arrangement and weld cross section

For a given plate thickness, welding speeds with the laser-hybrid welding process are higher than autogenous or arc welding independently. Added advantages are minimisation of heat input, high productivity and possibility to add filler wire. Nd:YAG, CO_2 Disk, Fiber, Nd:YAG and CO_2 lasers can be used depending on the application. However, the process is complex in view of large number of parameters to be optimized viz., the laser welding parameters, arc welding parameters and common parameters like relative positioning of the two welding sources [11].

Laser-hybrid welding has been applied successfully in ship building, rail bodies and pipelines. In ship building [12], side wall plates and deck panels are joined by MIG or submerged arc welding process. But, heat input in these processes is so high that the panels undergo distortion and present a big challenge during assembly over long distances. A lot of straightening operations are involved to get the joint fit up to acceptable level. Subsequently, the stiffeners running along the plates are welded for the purpose of reinforcement. All these operations are time taking and the productivity needs improvement. Laser-MIG hybrid welding was developed to pre-fabricate the long panels made of 15 mm thick steel sheets (Fig.6). It gave the advantage of getting the penetration from single side at high speeds. It saved a lot of effort and expenditure in terms of rotating the large structure to weld from the other side. The increased depth of penetration and faster welding process was found to be very effective for this application. Amount of filler metal used also reduced Significantly as the required depth of penetration was obtained by laser and welding current need not be increased.

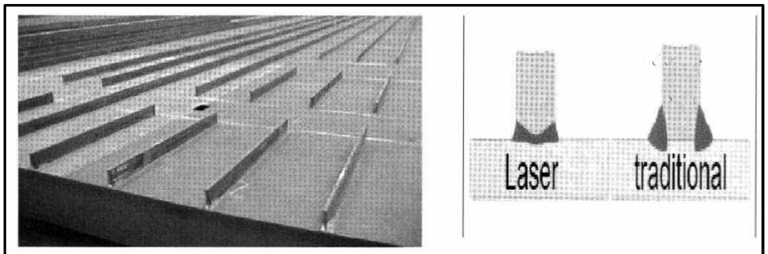


Fig.6 Pre-fabricated panels with single side welding of stiffeners

Laser hybrid welding has been used for aluminium alloy rail cars [13] with substantial quality and productivity improvements, for example, welding speed could be increased 3-4 times compared to MIG welding and smoothening operations could be eliminated as there was little excess metal.

4.0 SURFACE ENGINEERING BY LASERS

Modification of surfaces to transform metallurgical characteristics either by effecting transformations, coating with other materials by cladding, alloying by impregnating other elements and selective material removal are possible using laser. Depending on the application a particular process is selected. Some applications developed using these processes are as follows:

4.1 Laser hardening of crankshafts

As a laser beam is scanned on steel surface, the interaction zone attains a temperature above austenitization and when the beam passes the interaction zone gets quenched due to quick dissipation of the low amount of heat input through the bulk of the component being treated. Laser-surface hardening has advantages like highly localized treatment, low heat input and amenability to automation. Only the required zones can be hardened with precise control of the case properties. Diode lasers are popularly used for hardening. Recent studies showed greater promise in implementing the diode laser hardening technology for various applications in diverse industrial sectors [14-17].

Crankshaft an important engine component suffers wear over a period of time, affecting the engine performance. Wear resistance is improved by surface nitriding, flame hardening, induction hardening. Each of them has certain limitations such as inability to process complex geometries, distortion and non-uniform hardened case depth. Laser hardening process has been successfully applied to actual components like crankshaft and showed promise for introduction into production [18].

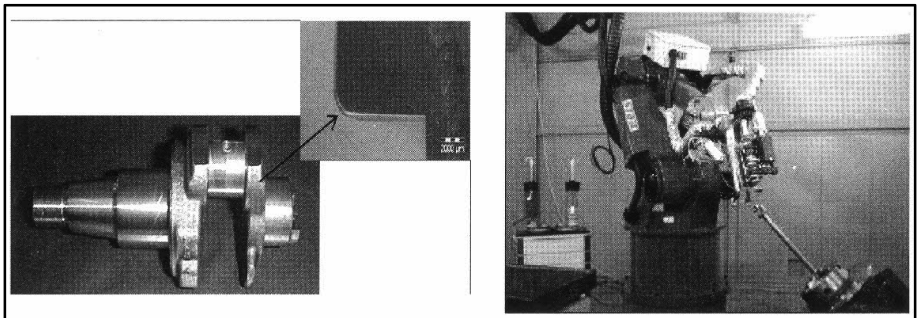


Fig.7Typical crankshaft and laser hardened corner of bearing seat and flange with uniform hardened case. A typical fiber coupled diode laser integrated with a 6-axis robot and turn-tilt table

Automotive braking system compressor crankshaft requiring surface hardening at five different locations is shown in fig.7. Conventionally, this is done by induction hardening in multiple steps using induction coils of different configurations matching the geometry. Further, in order to correct the distortion, machining was carried out. A single laser beam spot can be tailored to achieve the hardening at selected locations by scanning it in the identified locations using a robotic motion system or a CNC workstation. Figure 7 shows such laser processing set up. Hardness in the treated layer processing under optimized conditions increased to about 650-700 HV, throughout its depth of 375 microns as compared to that of untreated substrate (En180 steel) whose hardness was 260-280 HV. The martensitic microstructures obtained are also much finer than in other hardening processes. Laser power intensity, scanning speed on substrate, hardenability of the substrate material, substrate surface condition, component size and geometry are some of the important parameters to be optimised to get the desired hardening. In terms of effect of geometry, when there are edges, holeregions, corners etc there can be undue rise of temperature due to heat accumulation resulting in melting which is undesirable. Laser power is precisely controllable temporally and can be varied depending on the location it is scanning, for example ramping up or ramping down the power to control the surface temperature. Further, as there is no surface damage and distortion at the end of the process, laser hardening could be the final operation. As this example illustrates, the advantages of laser hardening include: localised treatment where it is necessary (avoiding heating of the whole component), versatility to handle different geometries with one system (unlike the need for new coil designs for each geometry in case of induction hardening), no post processing like machining for distortion correction (as surface damage and distortion are insignificant), environmental friendliness (as no quenching media are involved). Overall, the process can yield high productivity, minimal material wastage and performance improvement.

4.2 Laser surface texturing of cylinder liners

Laser surface texturing involves creation of features/microdimples (10-20 µm diameter and about 5-1 0 µm deep) by laser ablation using a high power density pulsating laser. These features are generated in a regular pattern applied on a given surface by scanning a laser beam on it. Q-switched Nd:YAG lasers and more recently picosecond and femtosecond lasers with adequate pulse energy are also being investigated.

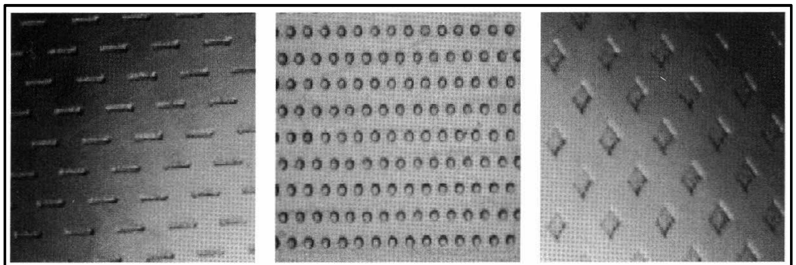


Fig.8 Surface texturing with laser ablated patterns

A large amount of research work on laser surface texturing was done at Technion - Israel Institute of Technology since 1996, mainly in laser surface texturing mechanical seals, piston rings and thrust bearings. The study on texturing of mechanical seal shows that the actual shape of the micro-dimple does not playa significant role and that the most significant parameter for optimum load capacity is the ratio of the dimple depth over diameter. Laser surface texturing increased the life of seal threefold [19-21]. A fundamental research work on laser surface texturing is carried out at Argonne National Laboratory in the USA. The effect of laser surface texturing on the transition from boundary to hydrodynamic lubrication regime was experimentally investigated by measuring friction and electrical contact resistance in a pin-on-disk unidirectional sliding conformal contact. Laser surface texturing was observed to expand the range of the hydrodynamic lubrication regime in terms of load and sliding speed. Also, laser surface texturing was observed to reduce the friction coefficient substantially under similar operating conditions when compared with untextured surfaces [21]. The use of laser texturing in the form of micro-grooves on cylinder liners of internal combustion .engines with lower fuel consumption and wear is now commercially available from the Gehring Company in Germany [22]. In an internal combustion engine, most of the combustion energy is lost as heat to the cooling system. Of the remaining available power, around 15% goes to mechanical losses due to friction in engine and drive train. In a diesel engine, up to 60 % of these mechanical losses result from friction between piston rings and cylinder walls. Consequently, it has been estimated that reducing this friction loss by even 10 %can lead to a decrease in fuel consumption of up to 3%. In the long term, this friction also causes wear to the rings and cylinder liners, reducing engine performance, increasing emissions and raising oil consumption. Laser surface texturing of automotive cylinder liner surface offers the opportunity to reduce friction and wear and enhances the overall tribological performance of lubricated sliding and rotating surfaces. Under hydrodynamic lubrication, and in the conformal contact configuration, microdimples on the contact surfaces can lower friction coefficients and may reduce wear. Under oil- or water-lubricated conditions, shallow dimples can serve as reservoirs for oil or water and thus increase the hydrodynamic lubrication efficiency of these surfaces. This low-friction technology has the potential for application in various engine components, such as the interface between the face seal and cylinder liner/piston ring, connecting rod eyes/pins etc. In India, R&D work in this area has been initiated at ARCI recently.

4.3 Laser glazing for enhanced life of rail road components

When a laser beam of sufficient intensity is scanned on the surface, a layer of material melts and as the heat source moves away, heat removal at a given spot takes place through the bulk material at a high rate (fig.9). The thermal gradients are created in such a manner that very high cooling rates (-500C/μs) are achieved. This is done by minimizing the heat input or increasing the scan speed. A very shallow layer (1-1 00 μm) undergoes the rapid heating and cooling cycles resulting in glassy microstructures (fig.1 0). Even if dendritic structures are generated, at a power density of 107 w/cm^2 it is possible to obtain dendrite spacing less than 0.1 μm.

The lack of crystalline order in such materials makes them substantially resistant to plastic flow, and hence very hard. They exhibit about a 30% or greater reduction in elastic modulus. If they do deform plastically, localized defects are not involved, and the more open structure tends to be self-healing. Consequently, repeated plastic flow is less likely to result in debris being deposited in a subsurface damage layer. For these reasons, the laser glazing process alone is sufficient to provide satisfactory reductions in friction and wear. Initial experiments conducted with a YAG laser on 1080 rail steel were found to produce a thin glazed surface layer, intimately bonded to a martensitic hardened layer (470-1072 HV) above the pearlitic substrate (300 HV). It was found to reduce the friction co-efficient of rail steel. Static block-on-ring friction experiments showed a reduction in friction by 25% relative to untreated surfaces at prototypic rail service loads. When friction at the Wheel/rail interactions is properly managed energy savings could be as high as 24%. Additionally, when the frictional forces between flange and gage face is high, there is a possibility of flange climb or low-rail rollover leading to derailment. The key aspect is control of the friction forces. The idea is to develop a durable, low-friction surface to the gage face of the rails to reduce parasitic frictional losses between the flange and rail gage. At the same time it is needed to maintain the toughness and relative inexpensiveness of rail steel. The goal should be to modify the particular surface of rail to become harder without affecting the bulk/substrate. Lasers with the possibility of achieving high energy densities and scan speeds at a precise location of choice can accomplish this by changing the surface microstructure as described above. Improved wear resistance of rail steels by laser surface hardening treatment is also being investigated [23]. A large amount of data on performance of laser treated rails has been reported by the US transportation department [24].

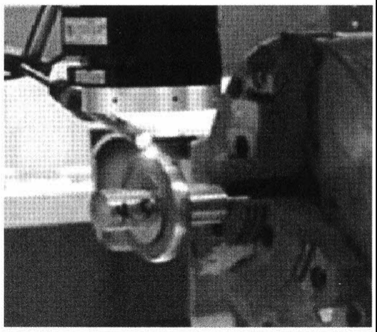


Fig.9: Laser Glazing Operation

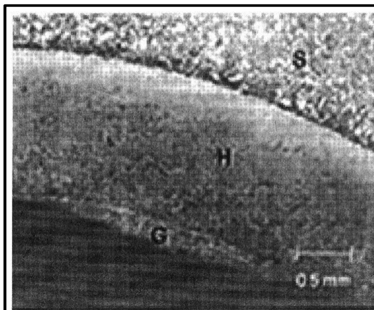


Fig.10: Laser-glazed 1080 steel with the glazed (G), hardened (H) and substrate (S) regions

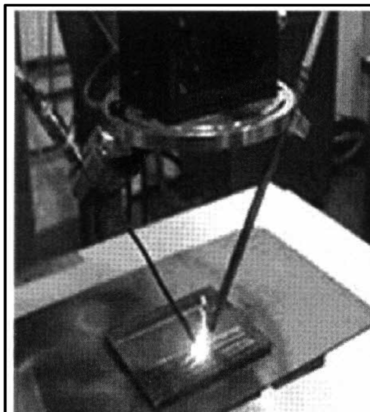


Fig.11 Typical laser deposition set up

5.0 Materials deposition for reclamation and reconstruction

The principle of Laser Metal Deposition (LMD) process is to deposit chosen materials on a surface or a profile. The material to be deposited is fed into the shallow melt created by the laser beam on the substrate surface in the form of powder or wire. This novel manufacturing process is capable of repairing worn out areas with minimal damage to the original component, creating functional prototypes and parts with very thin sections, functional gradient materials, and embedded sensors.

However, extensive experimentation is required to determine suitable process parameters (i.e., laser power, table velocity, and powder flow rate) for LMD processes and only near-net shape parts may be produced [25]. Subsequent processing is required if dimensional accuracy is critical.

5.1 Repairing turbines with metal beads [26]

Aircraft engine components such as turbine rotors are subjected to severe service conditions in terms of stresses, strains, high temperatures, damage due to external particles etc. Conventionally, the vanes are assembled on the shaft. However, in new concept, rotors are made of single part called as the "bladed disk" (blisk) made of titanium alloys as they are superior in strength, compactness and cost-efficiency. But, the drawback is single blade cannot be replaced when it is worn out or damaged. A new blisk typically costs 35,000 to 60,000 euros and replacement is very expensive. So, effective repair techniques are critical. Laser deposition of Ti alloys layer by layer precisely on worn edge of single blade is possible resulting in almost near net shape without distortion or heat damage to the actual disk. This has been successfully applied and it has been reported that it is six to seven times cheaper to repair the blisk using direct metal deposition. Slowly, this technique is getting accepted in aircraft engine parts repair. In car manufacture it is used for restoring forming tools. Laser beam buildup welding is one of the many generating methods now applied when one-off items or small series are produced or have to be individually repaired. The first step in the repair of a damaged component using this technique is to conduct a three-dimensional scan. A computer program then compares the part's dimensions with its original measurements and computes what is missing. A software system developed at the IWS guides the path of the laser as it welds on titanium-alloy powder and reconstructs the damaged area with layers of metallic beads. The entire process chain is a closed cycle and runs automatically from data collection followed by welding to finish machining.

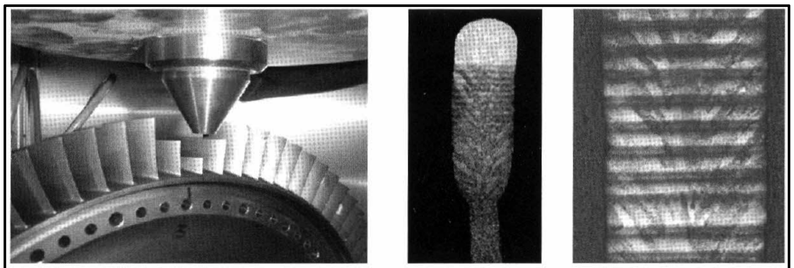


Fig.12 Bladed disk vane repaired by laser deposition layer by layer & macrosturcture

6.0 LASER BRAZEWELDING OFALUMINIUM AND STEEL

Laser weld brazing is a variant of laser brazing which is already used in automotive body fabrication. In laser brazing the laser beam is focused in the joint area and into the spot braze wire is fed. The braze wire melts under the influence of heating by the laser beam and the molten metal gets deposited in the crevice and wets the surfaces to be joined thus forming brazed joint. In braze welding one of the materials to be joined is melted to wet the surface of the other material which does not melt. No external filler material is used. Hybrid multi-material designs are being actively pursued by several automotive companies for weight reduction. For example, selective replacement of steel by lighter aluminium can significantly reduce weight. But, real application of this concept requires joining techniques for these two dissimilar materials. Laser weld brazing is one such process which can be used to only melt the aluminium side and wet the steel side thus avoiding melting of too much steel and minimising interrnetallic phases at the interface. Laser weld brazing of aluminium to steel is a very active area of research with emphasis on improving the wetting, reducing the formation of intermetallic layers at the interface and thus increasing the joint efficiency [27].

7.0 LASER CLEANING

Selective ablation of surface contaminants by subjecting them to laser light is the principle behind laser cleaning, which has been successfully used for surface cleaning of art works, microelectronic substrates and radioactively contaminated metals Laser surface cleaning has the following advantages over other surface cleaning technologies: Of course, high capital cost is a disadvantage. But, the advantages it offers in terms of automation etc. may outweigh this disadvantage.

Table-2 : Comparision of laser cleaning with other cleaning processes

Chemical Cleaning	CO_2 Pellet Blasting	Shot blasting
❖ Virtually no secondary waste produced	❖ Can remove deeply embedded contaminants	❖ Can be applied to delicate substrates
❖ No worker exposure to corrosive chemicals	❖ Can be applied to non-"line of sight" problems	❖ Can be applied to small areas selectively
❖ Little generation of toxic by-products	❖ Can be applied to small areas selectively	❖ Virtually no secondary waste produced
❖ Little explosion or fire potential	❖ Cleaning progress can be monitored continuously	❖ Can be applied to non-"line of sight" problems
	❖ Easily automated with computer control;	❖ Easily automated with computer control;

7.1 Laser cleaning of rails

Thin films of compacted leaves, lubricants and water on railroad rails reduce the traction between wheel and rail because of which acceleration and braking capacity of rail vehicles are reduced. This results in delays and increased wear of wheels and rails. Conventional abrasive particle cleaning has the disadvantage of increased wear of wheels and rails. Cleaning by brushes or high pressure water jets has limited cleaning performance. They also have the limitation of tool wear and need for cleaning agents. The laser-based cleaning systems permit non-contact and wear-free removal of rail residues at speeds of up to 60 km/h. In this system the radiation of a fiber-coupled pulsed Nd:YAG laser is converted by means of a transformation optical system into a line that maintains the original power density at a high aspect ratio. This has been accomplished by ILT Germany (under a contract from the British firm LASERTHOR). Initial tests were successful.

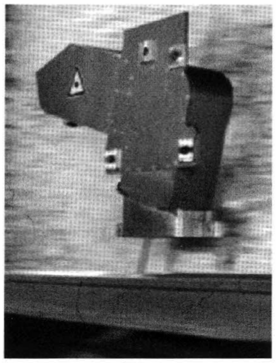


Fig.13 Laser cleaning of rails

A solid-state laser with an average power of 1000 watts in Q-switched mode can do efficient cleaning process. The laser beam can be delivered via fiber-optic on to chassis of the vehicle close to the surface of the rails. Trials carried out proved successful in implementation of laser ablation process to cope up with the railway environment with effective removing of leaf and other contamination from the railhead. Testing was done in 2002 with a unique test rig specifically designed and built for the purpose. Wide range of tests to find out how fast the laser could remove various substances from the railhead was carried out. Further studies in the advancement of the technology by fine-tuned design modifications and set up had been carried out in September 2002 which had shown vast improvement in speed of ablation (the removal of contaminants) as high as around 40mph. Recently, a system close to prototype stage has been tested using a Railtrack Multi-Purpose Vehicle (MPV) comprising of a laser mounted in a container, a railhead delivery system (RHDS) specifically designed to hold the optics box and deliver the beam to the railhead safely. With the advent of high power diode lasers, it has been planned to install the compact diode laser in the railhead-cleaning vehicle. Following the success of demonstration of the laser railhead cleaner, cleaning both running rails at a speed of 40 mph (in February 2004), Laserth or planned to sell the newly developed devices forthe global railway industry.

8.0 Summary

Laser based manufacturing processes due to specific advantages like low & precise heat input, high productivity, minimal post processing, amenability to automation and ability to weld in single-side access conditions coupled with availability of a variety of lasers with high beam quality have found numerous applications in mobility industry. Weight reduction, improved performance & safety, reduced material usage and improved' productivity were the drivers for incorporation of these manufacturing solutions in road, rail, ship and air transport systems. While world over several applications are in vogue, in India the applications are being developed and are on the rise. The potential to apply the laser based manufacturing processes is immense and . innovative solutions can bethought of using the unqiue capabilities of this technology.

9.0 Acknowledgments

Thanks are due to Director ARCI and colleagues at the Centre for Laser Processing of Materials at ARCI forthe inputs and assistance in putting this lecture together. Works of all groups mentioned in the text is also acknowledged.

References

1. LlA Handbook of laser materials processing, Edited by John FReady, Dave F Farson et aI., 2001

2. LPM Market size ILS Jan 2011

3. Standard Welding Terms and Definitions, ANSI/AWS A3.0-89, American Welding Society, 1989

4. Mombo-Caristan, J-C et aI., "Tailor Welded Blanks: A New Alternative to

Automobile Body Design", The Industrial Laser Handbook, Springer-Verlag, New

York, 1992, p89-1 02

5. G. Padmanabham, Unpublished literature

6. B. Shanmugarajan, J. K. Sarin Sundar and G. Padmanabham, "Laser Welding of Advanced High Strength Steels for Tailor Welded Blank (TWB) Applications", SAE2009-28-012

7. G. Padmanabham, Y Krishna Priya and B. Shanmugarajan, "Laser welding investigation on IF, HSLA and DP steels for Tailor Welded Blanks (TWB) application in automotive body", Proceedings of the ASM International Conference on "Materials and Manufacturing Technologies", March 8, 2011, Pune

8. K.v. Phani Prabhakar, Venkateswaran Perumal, M.Shome and G. Padmanabham, "Laser and Laser Hybrid Welding of Automotive Grade Steel Thin Sheets" International Symposium on Joining of Materials (SOJOM-2012), Organised by the Welding Research Institute and the Indian Welding Society, BHEL-Trichy,India, 19-22 January, 2012

9. I. Roetzer, Laser beam welding makes aircraft lighter, Fraunhofer Magazine 1 2005, pp. 36-37.

10. ASM Metals Handbook, vol.6A, Welding, 2012

11. G. Padmanabham, B. Shanmugarajan and KV Phani Prabhakar, "Laser – MIG Hybrid Welding of Thick Plates of Mild Steel in Single Pass, Indian Welding Journal, Vo.45, No.2 2012 p29-39

12. Meyer-Werft, Germany internet site

13. H.Yonetani, Laser-MIG hybrid welding to aluminium alloy car body shell for railway vehicles, Welding International Vo1.22,No.10, Oct 2008,701-704

14. 2. F Lusquinos, J C Conde, S Bonss, A Riveiro, F Quintero, R Comesana and J Pou, Applied Surface Science, 254 (2007), 948-954

15. 3. I R Pashby, S Barnes and B G Bryden, Journal of Materials Processing Technology 139 (2003) 585-588

16. 4. N S Bailey, W Tan and Y C Shin, Surface and Coatings and Technology, 203 (2009), 2003-2012 5. H Panstar and V Kunjappa, Surface and Coatings and Technology, 200 (2006), 2627 -2633

17. S Skvarenina and Y C Shin, Surface and Coatings Technology 201 (2006) 2256-2269

18. S. M. Shariff, Manish Tak,S. Shanmugam and G. Padmanabham, "Laser Surface Hardening of Crankshaft", SAE2009-28-0053

19. Etsion, I. and Burstein, L. "A Model for Mechanical Seals with Regular Microsurface Structure," Tribology Transactions, 39(3), 677-683 (1996)

20. Etsion, I., Halperin, G. "A laser surface textured hydrostatic mechanical seal" Tribology Transactions 45(3),430-434 (2002)

21. Feldman, Y, Kligerman, Y, Etsion, I. "A hydrostatic laser surface textured gas seal" Tribology letters 22(1),21-28(2006).

22. Gehring GmbH & Co. KG,URL httpJ/www.gehring.de

23. S. M. Shariff"T. K. Pal,S. V.Joshi and G. Padmanabham, "Sliding wear behavior of laser surface modified pearlitic rail steel", Surface Engineering April, 2009 Vol. 26 Issue: 3 Pages: 199-208

24. In-track demonstration of laser treated rail to reduce friction and wear, Report no. DOT/FRNORD-07 /17 of Office of Research and Development of Federal Railroad Administration, May 2007

25. "Control of Laser Cladding Processes for Rapid Prototyping - A Review," M. R. Boddu, R. G. Landers, and F.W. Liou, 2001 Twelfth Annual Solid Freeform Fabrication Symposium, Austin, Texas,August 6-8, pp. 460-467

26. Steffen Newton. EtalJournal of Thermal Spray Technology, Sept 2007

27. Laukant, H.; Wallmann, C.; Muller, M.; Korte, M.; Stirn, B.; Haldenwanger, H.G.; Glatzel, U. Fluxless laser beam joining of aluminium with zinc coated steel Science and Technology of Welding and Joining, Vol.10, no.2, April 2005, p219-226.

Super Critical Technology - Mitigation of Environmental Impact

Dr S Sekar

Executive Director, Bharat Heavy Electricals Limited, Hyderabad

Super critical conditions as we all know is the state of substance where there is no clear distinction between liquid and gaseous state. In the context of power plants with steam generators, operating beyond the critical pressure of 221 bar (critical point being 221 bar and 374 deg C for water) would mean super critical conditions of operation. Increasing pressure and temperature offer higher efficiencies in Rankine cycle, which is applied in BTGs (Boiler - turbine -generator) in power plants.

Super critical operation improves efficiency orin other words heat rate, which is the heat input(kJ) per energy (kWh) generated. An improvement in heat rate of about 5% is possible with super critical operation, depending on the pressure and temperature. Overall, efficiency increase to about 42 % is possible with this type of plants as compared to subcritical boiler efficiencies of about 37%. Hence, corresponding reduction in coal consumption is possible, thus the progress towards environmentally less impacting technology.

Other than environmentally friendly impacts, super critical technology also offers many advantages like shorter start up times, better efficiencies at part loads due to variable pressure operation, better control on temperature and faster control enabling load changes.

Reduced fuel consumption implies reduction in carbon foot print. Hence large super critical plants are candidates for COM (Clean development mechanisms) that contribute to reduction in green- house gases like CO_2 commensurate with the reduction in fuel.

Considering all these advantages the 12th plan of our country envisages almost 70 % of thermal power generation using super critical technology. Further almost 100% of 13th plan will be from super critical technology.

Hence all power engineers involved right from R&D to operations and maintenance would benefit from this National Seminar on this subject which is of great relevance.

One of the significant factors in today's power plant requirements is the land availability to put up these plants. Further the requirements of control on particulate as well as gaseous emissions from a large, cluster of plants are also driving introduction of new technologies in these fields. This will be the subject I will cover in my address and I am sure many other areas of interest in super critical technology will be covered by other experts in this two day seminar.

Electrostatic Precipitators for large power plants, size and foot print issues:

From the particulate control aspect, Electrostatic precipitators are most commonly used in power plants, but they occupy a significant portion of the power plant. For example a 660 MW ESP will need to have about 80 fields arranged in four streams, while a 800 MW unit would have typically 120 fields arranged in six streams. The area occupied will range from 4000 to 8000 m2. Sometimes this becomes the factor for distance between two units in a plant! Hence, optimising the pollution control equipment in super critical plants in becoming significant.

The present analysis tools in flow analysis and structural designs come in handy while optimising ESPs. Providing better controls including wireless technologies and remote monitoring can enhance the availability of the plant. This can result in lesser number of S streams chosen for E P and this can substantially reduce the power area requirement as well as cost of ESP. ESP technology is sufficiently mature in terms of electrode designs, high voltage power supplies etc. One of the areas offering further optimisation is the height of the electrode system. Going for larger than 15 or 16.5 m tall electrode system to 18 m tall systems can further reduce the ESP foot print and optimize the cost.

While significant opportunities exist for product optimisation as above, system optimisation also has a significant impact in ESP sizes. Experience elsewhere in the world say that ESP sizes can be reduced very significantly when flue gas temperatures are reduced. For example, if flue gas temperature is reduced from 150 deg C to 100deg C, then the performance increases to such an extent that ESP size could have been down by half the original size, when dealing with low sulphur, high resistivity fly ash as it often the case in Indian plants. This is because of the lower fly ash resistivity at lower temperatures and also lower gas flow rate due to lower temperature and also better high voltage withstand conditions due to low temperature.

Another area to optimise would be the design for excess air and air heater leakages. With today's technology for combustion optimisation and also online control for air heater seal settings, it should be possible to correctly size the precipitators for more optimum flow conditions, as well as more favourable ash resistivity conditions.

Use of imported coal:

Properties of coal, especially ash content and sulphur impact ESP size significantly. It is obvious from the fact that many ESPs elsewhere in the world are less than half the size in India due to the sulphur content and ash content.

Hence while designing plants, source of coal and consequently the ash content, sulphur and moisture content, as well as sodium or potassium content in coal would have to be considered while sizing ESPs.

Significant size reduction can be achieved if coal sourcing with required properties is controlled, so that plant investment can be optimised.

Use of Fabric filters:

A significant echnology that has been used elsewhere in the world, namely Fabric filters is yet to be exploited in Indian power plants. It is worth noting that when ESP sizes are large, Fabric filters are the choice in many countries. The size of the fabric filters are as low as one third of that occupied by ESPs. Considerations like increase pressure drop, bag life, temperature fluctuations, firing of high sulphur oil etc would have to be carefully evaluated while considering Fabric filters for power plant application. Certain retrofit experience is available in Indian power plants and the learning from the same would be useful in coming to optimum configuration of such FF options for Indian plants.

Issues with Hybrid filters:

A variation of the above two known technologies for particulate control is the Hybrid systems, having a combination of ESP and FF. Often both are housed in the same casing. This technology was originally introduced with a view to retrofit existing ESPs to enhance collection performance. The pressure drop in the fabric filter can be influenced by electric charge and hence smaller FF can be used in retrofrt cases. However, not many installations are available elsewhere in the world. Many plants are coming up with this technology in India, whose performance would have to be watched.

In this technology with both ESP and FF in the same casing, isolation of Fabric filter for online maintenance is not possible. This gives rise to difficulties in attending to FF. Further flow distribution issues are also important. It is also not evident as to why ESP is required at all, while elsewhere in the world, FF alone meets the needs. Further independent FF gives provision for chamber isolation and hence online maintenance which is very desirable feature for FF. Further while ESP handles temperature fluctuations with ease-so is not the case with FF in the same casing. This will often necessitate use of high temperature fabric filter materials, which are expensive.

Gaseous emissions:

Emissions of sax and NOx are of importance from large power plants, especially when ambient levels are already high. Environmental impact assessment performed while proposing the plants may also necessitate use of control technologies for gaseous emissions. Indian coal predominantly is having low sulphur and hence sulphur emissions are often handled through properly size stack height. However, when more plants are coming up in one location and also when the plants are to be located in places with already high level of such gases, control of the same would become essential.

NOx controls are often more cost effectively handled by using over fire air and other combustion technologies.

Sulphur control on the other hand would require use of CFBC technologies with limestone added in the furnace or use of Desulphurisation equipment downstream in the flue gas path.

As regards SOx control, FGD (flue gas de-sulphurisation plants would be required in order to meet emission levels for the location, considering the coal used.

The emission restriction for SOx elsewhere in the world, for e.g., are Europe- 200 mg/Nm3, Japan- 180 mg/Nm3, China- 400 mg/Nm3 etc. Typically use of coal with 0.5 % sulphur wiil result in emission of about 1800-2000 mg/Nm3 of sulphur dioxide. Thus- SOx collection efficiencies of the order of 90 % would be required for such a coal, while it increase further for higher sulphur coals. Commercially, saleable gypsum can be got as a by-product when limestone - gypsum process is chosen for FGD scrubber.

While sea water scrubbing is one of the options, environmental considerations would have to be taken into account while using sea water for scrubbing in FGD plants.

Typical 500 MW plant requires a space of about 4000-5000 m2 and the power consumption would be a few MWs and hence this is a significant portion of the investment and running costs. However as more and more plants are coming up, sulphur controls can become a necessity.

Need for Integrated Engineering and simulation of plants:

These challenges in addition to the many that will be discussed in this seminar throws up a lot of opportunities for designers, engineers and scientists in the fields of material science, combustion physics, flow design, plant optimisation and diagnosis and prognosis packages and many more.

Predominantly, agility in engineering for varying input coal properties and other load conditions including the connected grid will be in great demand to meet these new challenges. Customized design for each plant is a need. Further, flexibility during engineering for changing environment of coal supply etc will call for agile engineering practices.

Significantly, use of 3D tools for design and optimisation, 3D plant layout and optimisation would become essential requirements in providing optimum solution to powerplants. An integrated platform for collaborative design like PLM (plant life cycle management) platform would be essential to meet the needs of optimum design of ~such large plants. Interface issues with other equipment and quick changes to enable modified interface with equipment designed/would be designed elsewhere at a different point of time (bought outs etc) would be success factors for survival in the years to come.

Further from the user point of view, many opportunities exist for plant optimization and enabling decisions for future. These require integrated simulators specific to the plant. The simulators are only as good as they are conceived, based on the accumulated knowledge and experience of the various products and the way they interact as a system. Sometimes dynamic simulation will also be essential when plant conditions and load conditions change. No need to emphasize that, putting together a set of products would not yield desired results. In depth knowledge of the product dynamics and systems dynamics are essential to meet these changing needs of customers.

I am sure the seminar will provide ample opportunities for power engineers to align themselves to the need of the hour and contribute effectively in their respective fields. I wish the seminar a grand success.

Respice, Prospice Mechanical Engineering: Look Behind, Look Ahead

Dr Souvik Bhattacharya, *FNAE*

Professor of Mechanical Engineering & Deputy Director, Indian Institute of Technology Kharagpur

Mechanical engineering has been a fabulous forerunner of other disciplines and a resolute companion as well of a few others in engineering. Dramatic changes have become the norm lately in terms of how technology has percolated in our daily lives and any attempt to make a forecast on how the future would shape our life, education and the civilization in general becomes a formidable task. However, some projections are possible as we review the various trends in engineering education and practice. Mechanical engineering should draw from its rich history of accomplishments and learning to enthuse the next generation.

The strategic theme of mechanical engineering would be to develop technologies to meet new grand challenges in environment remediation, energy, healthcare, water resources, smart transportation, food security, safety, and housing. In terms of our nation building in India, specific areas of interest could be flood resilience, solar energy harnessing, food security and technology intervention in nutrition enhancement, future cities and other societal grand problems. Consequently, the discipline will create globally sustainable solutions that improve life of people and will nurture global collaboration to achieve those goals. While thermo-fluids, applied mechanics, design and manufacturing science will remain the foundation blocks of the domain in terms of depth, knowledge and skills in niche breadth areas will be essential to adopt multi-disciplined and systems engineering approaches across multi-scale systems. Simulation of complex and large systems will enable engineers to design optimally along with its manufacturing. Big data analytics will become central to various analyses and will play a dominant role in decision making support. Virtual prototypes and running simulations across a networked group of individuals will become commonplace. Driven by the major trends of big data, cloud computing, mobility and socialization, and crowd-sourcing, traditional enterprises are becoming digital enterprises employing agile networks. Technologies invented for one application will spread its wings to revolutionize other areas; a good example could be additive manufacturing and bio-printing of human organs. MEs will play a role in such domains with specific expertise of microfluidics.

The future mechanical engineering education will exhibit a pervasive practice-based curriculum with broader, multidisciplinary and flexible approach that is systems-focused with greater emphasis on synthesis and versatility and that integrates content, including humanities and social sciences, and communication skills; it is envisaged to emphasize globalization, quality of life issues, and solving society's grand challenges. Such a curriculum is expected to foster the business of engineering, leadership, entrepreneurship, creativity and innovation. The magic has to be brought back to the classroom through techniques such as flipped teaching, novel pedagogy and pervasive practice based engineering experience for students which are able to tap into students' zeal, imagination, inquisitiveness, engagement and dreams. We will need a curriculum with a design spine strongly encouraging design-build-test evaluate exercises at every level, integrating convergence across the silos that we are following today, introduce systems engineering approaches across multi-scale systems. We must build that disciplinary depth and trans-disciplinary breadth of research and education connecting science, engineering, technology, social science and humanities; the approach is to change from reductionism (simplistic basic construct) to complexity, analysis to synthesis. Students must recognize, invent, test and deploy solutions to address the formidable challenges of global sustainability, introduce fully immersive 3D multi-user virtual environments for remote learning. A common bespoke innovation lab with subsystem level design/fabrication support is to be embedded in the curriculum design.

The profession while promoting lifelong learning will spread public awareness and advocacy to proactively influence policy making related to science and technology. The technology perspective in larger social issues will have to be brought in by mechanical engineers. To get there, engineers must be trained to enable comprehensive discernment of human condition in today's world. Our engineering leaders must have a clear pragmatic approach to deal with complexities of life and to wrestle with ethical dilemmas. The approach that is envisaged is engagement with the humanities leading to an understanding of the nuances of human relationships through exposure to human history, civilization and literature. Such an approach serves the purpose of industry as well as the cause of greater societal good; e.g. manufacturers and service providers must understand the needs of the customers better than the customers themselves and such engagements as part of the curricula will reinforce that training.

A few examples from India, Asia, and USA of how recent approaches to such novel curriculum will be presented to explain the drivers of change and how to implement these disruptive ideas to bring in the paradigm shift.

Maturity of Advanced Coal Combustion Technologies and the Indian Priorities

Mr M S Unnikrishnan

Managing Director & CEO, Thermax Limited

The impending ratification of COP -21, though intended to support the continuity of human life on the earth, is certainly going to exert undue pressure on the need to develop and deploy technologies that will replace the existing fossil dependent combustion technologies. India with a near total dependence on coal for its short-to-medium term power generation requirements will need to very quickly shift over to clean combustion technologies.

Coal as a source of energy is predominantly deployed by the developed world only for Power generation. The technology development in those countries - primarily in the US and to a limited scope in Europe – was focused more on cycle efficiency combined with capacity enhancement. Thus, what started at 50-60 MW individual steam generators went all the way up to 1300 MW in capacity. Alongside, the steam pressure climbed up from 21 ATA in the early stages and crossed the critical barrier in 1950's and super-critical became a normal standard from the sixties. Steam temperatures which was constrained by metallurgy, breached the carbon steel barrier into the alloy steel regime by 1930's and have reached almost 620 degree Celsius making advanced ultra-super-critical a reality.

Electricity ·which remained a total state subject till the advent of Indian Electricity act of 2003, was constrained by regulations and depended totally on indigenous technological development. While the first super-critical boiler of the world was commissioned by Babcock & Wilcox in the US in 1953, India waited for another 60 years for the deployment of this technology (the first super-critical power plant of India was commissioned in 2012 at Sipat).

This absence of participation in the technology advancement journey was compensated to a certain extent by the Industrial sector owing to the peculiar energy resource constraints of the country (China is the only other country which had a similar situation). While the entire western world deployed electricity, oil & gas for their Industrial energy requirement (of heating, cooling and power), Indian industrial development was on the back of captive power and co-generation that was primed predominantly by coal and a good proportion of the heating and cooling requirement also met with coal and biomass as the input fuel. This unique situation has afforded the Indian steam generator industry an opportunity to bring in and further develop advanced coal combustion technologies right from the early nineties.

Peculiarity of Indian Coal

India has a wide variety of coal, most of which is inferior in overall quality when compared to the rest of the world.

	India	Indonesia	South Africa	USA
Calorific Value	3000 – 4750	4000 – 6500	6000	5000 – 7000
Ash Content	25 – 45%	6 – 12%	12 – 14%	8 – 15%
Moisture	8 – 12%	18 – 38%	8 – 10%	2 – 3%
FBN	0.5 – 1.15%	0.7 – 1.15%	1 – 2.5%	1.5%
Sulphur	0.3 – 0.8%	0.3 – 1.2%	1%	0.2 – 4%

Calorific Value: Indian coal on an average is 30 to 35 percent lower in its heating value in comparison to the rest of the world. This would translate into enhanced sizing of the entire coal transportation and handling system by a similar percentage, apart from over-sizing of the furnace and other heat transfer zones too.

Ash Content: Arguably Indian coal has the highest ash content among the commercially exploited sources in the world. There are technical limitations for most of the prevalent coal combustion technologies to handle ash content of this magnitude. In fact, this has prompted the Central Electricity Authority (CEA) to stipulate a ceiling of 35 percent ash content in coal for feeding into steam generators deployed in power plants. It is likely that as we go deeper and deeper for extracting the coal from mines, the ash content in coal will further enhance, making it even more difficult to combust. In order to overcome this difficulty, the power industry is left with no choice, but, to resort to deployment of large scale coal washeries to reclaim higher quality of coal with lower ash content. Consequently, the washeries produce mountains of middling and rejects that cannot be used in the conventional power plants deploying pulverized coal combustion technology.

Apart from a higher content of ash inherently present in Indian coal, the quality of ash and its content pose an added challenge while designing a power plant deploying Indian coal. Silica content in Indian ash is as high as 55 - 65percent. And the iron content varies between 4-6 percent. Erosion characteristics, owing to these abrasive contents in the ash poses one more challenge while designing Indian power plants.

Fuel Bound Nitrogen: One of the major advantages of Indian coal is a comparatively lower presence of Fuel bound Nitrogen. The biggest challenge while limiting the NOx emission from a power plant is the FBN percentage, since almost 75 percentage of all the NOx created within the steam generator emanates from the fuel and the rest from the nitrogen carried into the furnace through the combustion air. Thus a lower FBN will certainly help in reducing the size of de-NOx plant deploying SCR technology. But this advantage will get partially negated by the higher ash content of the coal, which will have an adverse impact on the effectiveness of the impregnated catalyst in either form of the SCR design i.e. honey-comb as well as plate type.

Sulphur: Indian coal, with the exception of the one mined in the north-east, has relatively lower Sulphur content when compared with the rest of the world. This affords a positive advantage in bringing down the sax emission while designing a power plant deploying Indian coal. Apart from reducing the overall size of the Flue Gas Desulphurization unit, the lower Sulphur content also brigs down the operating cost for meeting the emission norms, with a lower consumption of chemicals and power.

Coal Combustion Technologies

The coal combustion technologies that are proven and in practice differs substantially between power plants and industrial captive and cogeneration plants in India.

Power plants: Indian power industry has successfully migrated from moving grates into Pulverized Fuel (PF) in its early days itself. This technology is today almost perfected by the Indian manufacturers as well as India based joint ventures of global leaders around the peculiarities of the domestic coal in all aspects.

Thanks to the seamless working of the academia, research institutions and the industry, considerable amount technological advancements were accomplished in the past few decades in this technology through indigenous research and development. PF technology in coal preparation, pulverizing, combustion, heat and mass transfer through radiation, conduction, convection, nucleate boiling, super-heating, re-heating, all allied hydraulics, material sciences, control and automation are totally a part of India's knowledge stream. In fact, today, the academic and research institutions of the country are producing sufficient (may be more than necessary) talent in combustion and power plant engineering and we will be able to provide this capability to the rest of the developing world too.

What we need to develop further is the next level of advanced ultra-critical thermal power plants that will work at 700+ degree C temperature and enhance the cycle efficiency beyond 50 percent. The main challenge we need to overcome for this is more to do with material science and metallurgy rather than combustion technology. We may also need to co-develop it along with global research institutions to accelerate the pace of this development, rather than totally depend on domestic capabilities alone. Since the developed world may not have a strong inclination towards coal based power generation any more and we, in India, will have to certainly depend upon coal for a considerable period of time for our economic development, it will be in our national interest to elicit global association! partnerships to hasten the advanced ultra-critical technology development and deployment.

Industrial Power Generation: Captive and co-generation in India, though started off with different varieties of moving grate technologies, had to migrate to fluidized bed technology as the ash content in the domestic coal crossed the 30 percentage barrier, way back in the eighties. Starting with a Bubbling bed, the industry quickly advanced into Atmospheric Fluidized Bed Combustion (AFBC) technology at very quick pace. By late eighties the country created total indigenous capability and capacity to design, manufacture, construct, operate and maintain AFBC technology, with a well-oiled domestic supply chain too.

Industrialization of India took a vertical path, post the liberalization and opening up of the economy in the nineties. As the scale of manufacturing multiplied, industrial captive power generation capacity got elevated to 40 - 60 MW in steel, cement, non-ferrous metallurgy and heavy chemical segments. Apart from this, advent of global completion compelled the Indian industry to opt for cheaper versions of solid fuels like Low grade Indian coal, pet coke, Lignite, and washery rejects. This duel challenge of fuel complexity and elevated capacity could not be addressed by the AFBC technology. This paved the way for a selected, innovative and technically savvy Indian manufactures to upgrade to the Circulating Fluidized Bed Combustion (CFBC) technology. All of them struggled in the initial days with this highly advanced technology but has perfected it by the early days of the new millennium. On the back of an unprecedented economic growth and industrial development of the country in the past decade, CFBC technology has matured in the country and has today entered also the core Power Industry in the sub-critical range with single plants of up to 250 MW.

India IS priority for advanced combustion technology

C F Be Technology: CFBC technology with its innate ability to combust coal with even a 60 percent ash content is far more suited for dealing with the already inferior and further deteriorating Indian coal. Since the CFBC furnaces are designed to operate at temperatures ranging between 850-950 degree C, generation of NOx will be lower too when compared with PF furnaces that operates at much higher temperatures. Apart from these two distinct advantages, CFBC technology also has the ability to capture predominant part of the Sulphur within the furnace itself through the usage of crushed lime as the fluidizing media.

Poland was the first country in the world to deploy the CFBC technology in the super-critical range with a 400 MW power plant. Korea Power Corporation is currently building a 4×600 MW CFBC based supercritical thermal power plant. China will be ready with their CFBC super-critical plants in the near future.

India is ideally the most needy and deserving market for super-critical thermal power plants with CFBC technology. The ongoing joint development program supported by the government for the development of ultra- super critical technology should certainly incorporate CFBC as one of or even the primary option for our country.

Clean Coal Technology: Emission reduction commitment in line with the Paris agreement will necessitate development of clean coal technologies to restrict the per capita CO_2 emissions. There are two distinctive possibilities for India, that needs closer evaluation for further development.

1. Oxy-fuel Combustion and Carbon Sequestration: Carbon capture and sequestration combined with oxy-fuel combustion is theoretically the best solution available to contain or even negate the ill effects of coal based thermal power generation. But, despite the support given by the wealthiest of global economies and engagement of the most brilliant technical intellects of the world, no tangible and commercially viable solutions are created nor in sight at this juncture. Even if a technically viable and universally acceptable solution is developed in the near to medium term, it is going to be an unviable solution for a financially constrained economy like India. Unless a major and disruptive technology development happens in this arena, India should keep away from this imaginative solution.

2. Coal Gasification and Combined Cycle: Gasification of coal and further conversion of it for petrochemicals was developed as a viable technology and part deployed by the Oil and Gas sector, quite some time back. But the globally manipulated oil and gas pricing has kept the further development and commercialization of this technology at bay. The current glut in crude prices and the expectation of it remaining range bound between $ 40 - 65 per barrel will further dampen its deployment in the near future.

With sufficiently large enough coal reserves, that will remain the mainstay and backbone of our economic development in the medium term, India will have to develop coal gasification technology at a faster pace. This technology route will offer a two dimensional advantage for the country by way of enhancing the power generation efficiency to over 60 percentage (as against the dream of a maximum of 50 percentage with ultra-super critical) as well as bringing down the entire emission worries (both technical and financial) to a manageable level.

Conclusion

India has already created a robust platform in advanced coal combustion technologies. This was sufficient to support the size and pace of development of our economy in the past. As the countries embarking upon the path of becoming the manufacturing and technology giant of the ongoing century, we need to change the strategy, path of technology and its pace of development. This will need policy and financial support from the government along with active participation from the academia, research institutions and the industry.

Modeling of a Manufacturing System: An I.T. Perspective

Dr Rajat Bhagwat

Professor, Department of Mechanical Engineering
M.B.M. Engineering College,
Faculty of Engg. & Arch., J.N.V. University, Jodhpur.

Introduction

Evolving manufacturing environment is characterized by the new challenges faced by the manufacturing systems. These include the pressures of manufacturing in increasing variety of consistent quality products at competitive costs with an emphasis on significantly improving the delivery performance. A truly time-based competition inspired by the vast potential of flexibility in manufacturing is shaping up. In this environment the focus is on manufacturing system effectiveness rather than the subsystem efficiencies.

For most enterprises the long term goal is to stay in business and grow. This is particularly true of manufacturing enterprises. The business environment is changing and is quite different to the business needs of the mass production period. The era of mass customization is emerging leading to a need to manufacture a changing product and volume mix effectively. The increased and fast changing product variety has dramatically increased the complexity, which requires more effective design, planning, scheduling and control of production systems. An important goal for any manufacturing enterprise, who endeavours to successfully compete in this environment is one related to reducing the lead times to become more responsive. This means that a time based competition demanding a focus on containing the time delays is emerging.

Now in present gecade, apart from cost, quality and other performance measures, the additional focus is on time-based performance measure. These time-based performance measures play key role in reducing the lead time (in any form such as in setup time, waiting time, make-span etc.) in manufacturing system. Wadhwa and Browne (1990) have indicated that flexibility offers opportunities to change the control on flow of entities (material, resources and information etc.) in a desirable direction. This can offer lead-time reduction benefits.

An important and central aspect of this trend is the changing of role of information system applications. Information is the means of interfacing and integrating the entities of manufacturing systems, the mode of synchronizing the various entities and the method of coordinating them in order to achieve the objectives [Weber & Moodie (1989)].

Browne et. al. (1984) presented a scheme used to categorize the role of computers in manufacturing. The nature of computer interface to the production systems. This interface may be indirect in which computers role being that of an information and decision support system. In this computer system manipulates information that have been extracted from the manufacturing process and fed into the computer. Secondly interface between the manufacturing process and computer may be direct, with the computers directly monitoring and actively controlling sections ofthe manufacturing process.

At the enterprise level, computer role is to have a coordinated approach and integration of strategies, technology, resources and control decision to work in synchronized manner to achieve the objective. All the functional elements of the manufacturing system plays a pivotal role in defining the manufacturing enterprises and integration of all the functional element is very important. Apart from all this a collaborative timely decision making is the way to achieve congruence between the enterprise objectives.

Patankar & Adiga (1995) observe that in a system, the integration is a timely availability of information required by each activity. Jorysz & Varnadat (1990) describe information as lifeblood of the CIM systems, the binding glue which ties together the various system function and component, and as such a careful attention must be paid to its modelling.

The control of all systems is highly contingent upon availability of information· about the system's local and global status. In fact, there exists a symbiotic and intimate relationship between the control system and the information management system (Veeramani et. al. 1993), The control decision action is a function of the input information. On the other hand control decision event changes in the system status. These changes generate new information that needs to be updated (see figure 1).

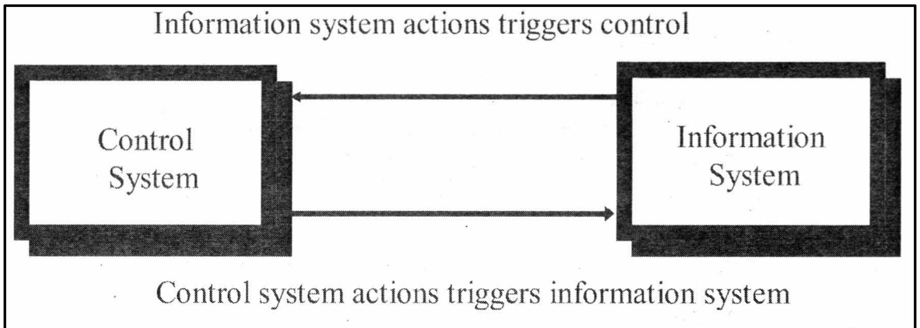


Figure 1 Inter-relationship between control decision system and information system

The GRAI methodology (Doumeingts et. al., 1995) presents this focus in its macro reference model quite explicitly, This model as shown in Figure 2 assumes that the structure of any system is comprised of three sub-systems: the decision, information and the physical system.

• The decision system represents a hierarchical structure with each level determined by a horizon and a time interval during which a decision is valid.

• The information system, provides the decision system with relevant information and provides a link between decision and operating system. This permeates through the entire structure.

• The physical system comprises of the machines, materials, operators and techniques divided into work centers. This is the operational level and the operating system is based on the working procedure related to the use of the physical system.

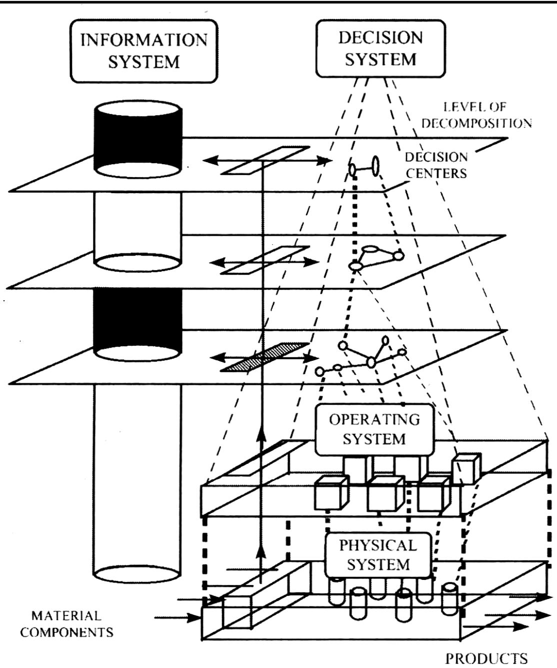


Figure 2 : Illustrates the GRAI macro reference model (Figure from Doumeingts et al. 1995).

The GRAI method views that decisions start and terminate events within a system, which in turn change the information status. These events determine the performance and operating characteristics of the system. As systems are dynamic, the control decisions will only be appropriate for a given time horizon. The GRAI model motivates us to view the control decision, information and physical systems and their associated activities and events explicitly while modeling a system. The GRAI model further outlines the role of timely control decision making, particularly at operating levels, as these decisions at operational levels may be valid for a very short interval. Further, the number of control decisions are more at this level. The control system itself can be decomposed into two entities: the Informational System (IS) and the Decisional System (DS) (figure 3).

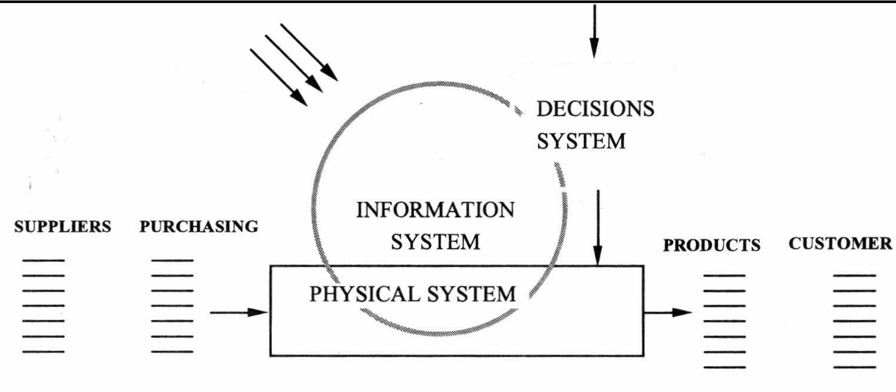


Figure 3 : The decision and information systems

The physical system describes the transformation of PRODUCTS by RESOURCES. An activity describes this transformation. A product can be material object or non material in the case of services. This transformation starts from the purchased product to the final product sell to the customer. The product flow follows this transformation. It is also possible to consider the transformation performed by the physical system from the customer (supplier of a demand) to the customer (supply of the product).

The decision system elaborates the set of decisions which allow to control the physical system, from a set of information. At this stage of the decomposition, it can be recognised that the difference between Decision and information activities is conceptual because a decision activity is composed of information activity (because decision activities transform information) plus additional concepts as :

• Objectives: Goal to reach by the decision activity,

• Decision Variables (D.V.): Variables on which the managers can act in order to reach the objectives.

• Constraints: domain which limits the effect of the decision variables,

• Criteria: Variables which allow to determine on which decision variable we should act between several.

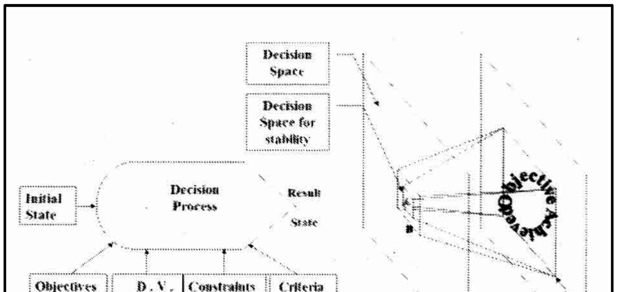


Figure: Showing the decision space for achieving target

These four concepts compose the "Decision Frame / Decision Space". The decisional system is very complex and it is necessary to decompose it in order to facilitate its modelling.

Two decomposition axis are defined:

A vertical axes linked to the nature of decisions: The first criteria is a temporal one linked with the classical decomposition by level of decision: strategic, tactical, operational (Figure 4).

- Strategic : the decisions which allow to define the goals to achieve on a long term horizon,
- tactical : the decisions which allow to set up the resources and the products on a middle term to reach the strategic objectives,

- operational: decisions which allow to execute the product transformation activities by the resources on an horizon short term in order to reach tactical objectives, the decisional levels, each level controlling a part more or less aggregated of the physical system.

We assign to each level a temporal characteristic: the couple Horizon/Period:

• Horizon: The interval of time over which the decision extends (i.e. remains valid).

• Period: The interval of time after which we reconsider the set of decisions. In such a structure, the horizon is a sliding horizon.

The couples Horizon / Period are linked. Inside a considered period of time, decisions can be made on event.

• An horizontal axes linked to the nature of decisions: The second criteria of decomposition is the functional activities decomposition criteria. For the enterprise, six functions are taken in account : to manage commercial, to manage design, to manage development, to manage production, to manage assembling, and to manage delivery (figure 4) or can be defined as per requirement. It can exist other functions according to the type of enterprise. It is possible to develop reference models to bring new answer to this question.

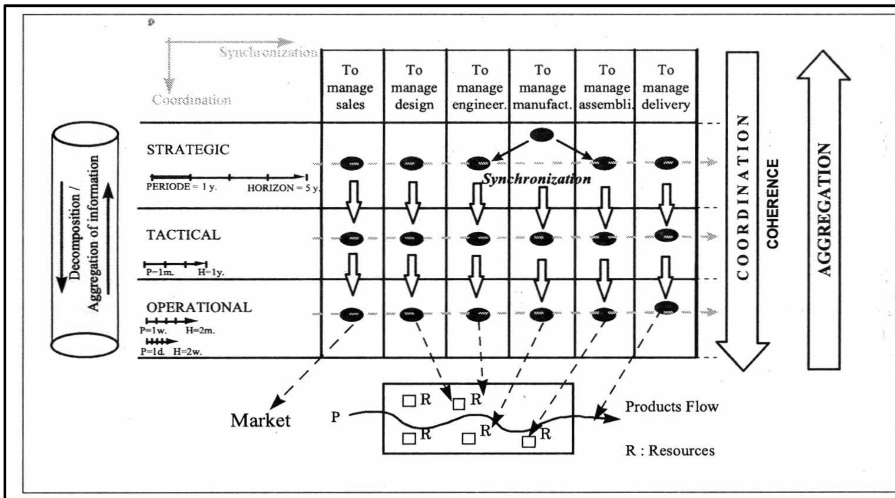


Figure 4 : The Global GRAI Model for the enterprise

The interest of this model is to facilitate the integration between decisional levels and between functions. The matrix structure allows to co-ordinate the functional view (vertical) and the process view (horizontal) by decisional level. Moreover, there is a strong relationship between the physical system decomposition and the decisional levels, each level controlling a part more or less aggregated of the physical system.

A decision centre is conceptually defined as the cross between a function and a decision level. The synchronisation of activities is performed horizontally, by decision level, the coordination being ensured through the decision levels.

Each function of the enterprise can be decomposed more accurately taking in account the basic principles of the GRAI Model to manage the synchronisation of activities. At each decisional level, the performance objective imposes to synchronise in time the product and resource availability to perform the activity with a maximum of performance. For instance, considering the function "To manage production", a grid can build to control this function with synchronizing at the different decision level "The product management" activities, and "The' resource

management" activities. This synchronisation is obtained by the planning of the activities.

The product management activities are linked with the purpose of the function, which is : to transform raw materials and components into final products according objectives, constraints, and criteria (optimisation of some features). The resources management activities are linked with the means which transform the material flow.

The recursive structure of the GRAI Model gives to a decisional centre the same structure as previously: A physical system (controlled system), a decisional system and an information system (Figure 2). The physical part is the model of the Physical system at the level of decision considered. It is evident that the view of the Manufacturing System by the managers of the factory is broader than the view of the responsible of the cell, but the view of the last one is more precise, the first one is more aggregated. This model of a decision centre describes internal activities but also its relationships with other decision centres (Figure 5). Then, in order to reach objectives of decision centres (DC), each activity of this DC has its own goal, and this structure of activities is obviously organised according to the finality of the decision centre. This organization of activities depends also of the image of the physical system at the DC level.

The decision maker receives a decision frame I decision space explaining what he has to achieve (objectives), which he can act to reach these objectives (decision variables) and until which value (constraints) and how (criteria). According to these information of follow up coming from the physical system and of technical data required, he defines a decision frame for the lower level. With comparing the results of the activities, he can modify the decision frame he transmits or ask for adjustments. The role of the decision maker is to compare with the expected result of the lower level, to adjust, if necessary, and to ask for adjustment the upper level if this level cannot reach the objectives given.

The information part receives aggregated information from the lower level, use this aggregated information and send aggregated information to the upper level.

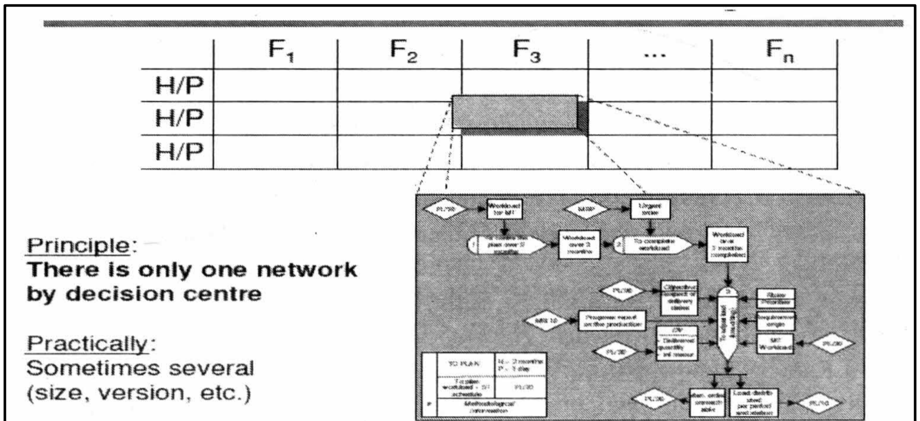


Figure 5: Decision Centre and its internal activities

The application of a methodological module of GRAI Methodology must be well structured and must abide strictly by good procedures. This generic structured approach is certainly one of the key points of the GRAI Methodology because it is a one of the most constant point with the transition from the conceptual to the operational models.

Conclusion

1. The GRAI method can represent and analyze the operation of all or part of a production activity or of any system. The strength of the GRAI method lies in its ability to provide modelling practitioners can effectively model the decision-making system and information system of the company, i.e. organizational processes that generate decisions.

2. The GRAI models give a generic description of a manufacturing system while focusing on the details of the control part of this system. The control of a manufacturing system will be presented first from a global point of view and afterwards at the level of the decision center.

3. The GRAI method is developed more for the user oriented design than for the technically oriented design. The design of the GRAI method is an on - going process and development will allow an improvement of the technically oriented design phase. Besides, because of the amount of work necessary to model all of the necessary views used during the analysis and the design phase, the use of a computer tool support is absolutely necessary. All the supports allowing the design to be concentrated on added value activities must be provided. A computer tool support will allow one to facilitate the modelling of the views, the coherence checking between the architecture and methodology models, the detection of inconsistencies, the use of reference models during the design phase and the production of documents.

4. The process of modeling of the enterprise is a methodological gait well structured aiming the representation of an enterprise while developing models or languages of modeling and with contribution of all actors of the enterprise to arrive to a well identified finality. This approach is developed according to three essential stages: functional model, informational model and decisional model of the organization system of the enterprise.

(NOTE: This review is collection of material of published authors' view)

References:

1. A. Errasti, (2008) - Engineer to order supply chain improvement based on the GRAI meta-model. Entreprise interoperability III. London. pp. 524-531.

2. Andrew P. Sage, W. B. (2009) - Handbook of system engineering and management. USA.

3. Beeckman, D. (1989) - "CIM-OSA: Computer Integrated Manufacturing - Open System Architecture", International Journal of Computer Integrated Manufacturing, Vol. 2, (2), pp.94-105.

4. Browne, J., Dubois, D., Rathmill, K., Sethi, P. & Steke, K. E. (1984) - "Classification of Flexible Manufacturing Systems", The FMS Magazine, April-1984, pp. 114-117.

5.. Chan F. T. S., Bhagwat R. & Wadhwa S, (2009) - "Study on suppliers' flexibility in supply chains: is real-time control necessary?", International Journal of Production Research, Vol. 47(4), pp. 965-987.

6. Doumeingts, G., Vallespier, B., & Chen, D. (1995) - "Methodologies for Designing CIM Systems: A Survey", Computers in Industries, Vol. 25, pp. 263 - 280.

7. ESPRIT (1992) - Project PISA (Plateform for Information Sharing by CIME Applications) Deliverable 1101, Information Modeling Framework.

8. Felix T.S. Chan, Bhagwat R., & Wadhwa S., (2007) - "Flexibility performance: Taguchi's method study of physical system and operating control parameters of FMS", International Journal of Robotics and Computer Integrated Manufacturing, Vol. 23(1) pp.25-37.

9. H. R. Jorysz, and F. B. Vernadat, (1990) - "CIM-OSA Part l: Total Enterprise Modeling and Function View," International Journal of Computer Integrated Manufacturing, vol. 3(3)pp.144-156.

10. Harhen, J. & Browne, J. (1984) - "Production Activity Control; A Key Node in CIM", Strategies for Design and Economic Analysis of computer supported Production Management Systems, Edited by H. Huber, Amsterdam: North Holland.

11. Higgins P, Browne J. (1990) - "The monitor in production activity control systems.", Production Planning and Control, Vol. 1(1), pp.17-26.

12. Higgins, P. & Browne, J. (1990) - "The Monitor in Production Activity Control Systems", Production Planning & Control, Vol. 1(1), pp. 17 - 26.

13. Patankar K., and Adiga S., (1995) - "Enterprise Integration Modeling: A Review of Theory and Practice," Computer Integrated Manufacturing Systems, vol. 8(1), pp. 21-34.

14. Veeramani D., Bhargava B., and Barash M. M. - (1993) - "Information System Architecture for Heterarchical Control of Large FMSs," Computer Integrated Manufacturing Systems, vol. 6(2),pp. 76-92.

15. Wadhwa, S. & Browne, J. (1990) - "Modeling FMS with Decision Petri Nets.", International Journal of Flexible Manufacturing Systems, No.1, pp. 253 - 280.

16. Weber D. M., and. Moodie C. L. (1989) - "An Intelligent Information System for an Automated, Integrated Manufacturing System." Journal of Manufacturing Systems, Vol. 8(2), pp. 99-113.

17. Wortmann,H, (1995) - "Editorial", Computers in Industry, Vol. 25(3),pp. 231.

New Vistas of Mechanical Engineering for Industry 4.0

Prof (Dr) P B Sharma, *PhD (Binningham), FIE, FAeroS, FWAPS, FISTE*

Vice Chancellor, Amity University Gurugram
Founder Vice Chancellor, DTU and RGTU &
Immediate Past President, AIU

Expressing his immense happiness in delivering the Dr S P Luthra Memorial Lecture, Professor PB Sharma, recalls his close affinity with Prof Luthra at IIT Delhi, Delhi College of Engineering and at The Institution of Engineers (India), Delhi State Centre and traces engineering attributes of the legendary Prof Luthra as being nobility, humility and unconditional passion for quality technical education for the advancement of the humanity.

Prof Luthra, with his humble beginning at Lahore in undivided India, worked at Delhi Polytechnic (that later became DeE and now DTU) from 1940s, where he grew to the level of Vice-Principal and there after shifted to IIT Delhi in 1960 carrying with him the initial genes of quality conscious teachers of engineering and technology. He later rose to the prestigious position of the Director, IIT Delhi. But for Professor Luthra, the love for engineering education and his relentless quest for institution building had no place for personal ego or professional esteem. He was, always closely connected to the people and was a down to earth type of a noble citizen of the Indian Republic.

In this Dr S P Luthra Memorial Lecture on "New Vistas of Mechanical Engineering for Industry 4.0", Prof Sharma opines that Mechanical Engineering being the backbone of modern scientific technology driven growth and development of the agro-industrial society since the time immemorial, has always remained on the forefront of engineering and technology revolution, ever since the advent of wheel and wings of fire (Combustion based drivers of industrial revolution}. It has traversed a lot from macro to micro and to nanomechanical engineering and shall be playing a major role in pica or molecular engineering of tomorrow. From its role in design and manufacturing of large and complex mechanism and systems it has contributed immensely to the manufacturing of ultra large integrated circuits and micro controller devices that prompted the accelerated growth of modern advanced and integrated electronics and fast response switching devices making it possible for the mankind to transact business at almost the speed of thought.

In recent times it has come a long way to propel the accelerated growth and development of innovation driven new industry revolution, code named as Industry 4.0. Here the automated systems, connected and networked with global systems of Robotics and Automation and IoT based new and immerging technologies are causing change waves of unprecedented development, giving rise to an upsurge of human ingenuity and creativity. But, at the same time, causing an un-imagined disruption of both the manufacturing as well as the service sectors. Mechanical Engineering is also facilitating a quantum jump to higher levels of opportunities to address the noble objectives of Zero Defect Engineering, Net Zero Waste Manufacturing and at the same time making mankind capable of achieving the millennium goals of sustainability, green manufacturing, combating climate change and energy security on the strength of green energy technologies.

In his memorial lecture on "Mechanical Engineering for Industry 4.0", Prof Sharma vividly describes the role played by mechanical engineering through the ages and excites the imagination of the audience about the new vistas of mechanical engineering of tomorrow that shall drive the Industry 4.0 of today, Industry 5.0 of tomorrow and eventually Industry 10.0, in the not so distant future.

Now that the power of innovation and intense scientific explorations have led us to new horizons of new and smart materials, nanostructured materials and composites, bio degradable plastics and polymers, bio-inspired manufacturing beyond 3D printing of today all these developments shall enable us to embark up on "molecular manufacturing" of tomorrow, thus in turn minimizing both the waste as well as the energy consumption in manufacturing. It could then give us an opportunity to witness, at the end of life cycle of design of products, their disintegration back to the basic molecules of materials that were assembled through molecular manufacturing into forms and intelligent designs, fine-tuned to perform as engineered products and devices. In such an industrial era, molecular manufacturing shall enable us to see the disintegration of molecules of carbon to carbon, hydrogen to hydrogen, Sulphur to Sulphur etc. leaving no waste whatsoever to dispose off.

Likewise, the new energy systems shall thrive on the ever expanding deployment of the renewable, like solar in a big way. But the real challenge for us, the Mechanical engineers of the new age, is to design and develop solar cells of 98 percent efficiency, against 18 percent, as of now! Likewise, on the mobility fronts, the electric cars and vehicles powered by high energy storage batteries, charged by solar power are going to make petrol and diesel vehicles redundant, A major disruption of the automobile assembly line is just round the corner. Mechanical engineers have to cope up with new design engineering emerging out of compulsions of sustainability, reliability and agility and that too in the age of innovation infinite.

With massive automation and IoT of everything, the industries shall see a sea change in their work force that shall comprise of humans, robotic co-workers and intelligent machines together working as a winning team of the knowledge workers of tomorrow. A new meaning and purpose of Quality, Safety and Reliability at all levels of manufacturing and associated Supply Chain Management will have to be recognized in line with the fast and connected internet of everything in the world of industry and services. The decision making in such a networked environment shall demand use of the highest levels of augmented artificial intelligence of the team of humans and robotic co-workers.

On the scientfic fronts, already steam at room temperature from sea water using single layer graphene is throwing a challenge to the power industry, making coal and oil based power plants redundant in the near future. Scientific advancements such as these shall also be solving the problems of desalinate of sea water, giving the hope for water security to billions of people around the world. Compressed water, compressed air and explosive power of nano-particles of explosive materials shall fuel the imagination of mechanical engineers of tomorrow to design and develop cost effective innovated new systems and devices for industrial advancement to drive Industry 5.0 that shall assure high levels of sustainability and productivity.

But then the best would still remain as yet to come. The scientific innovations and technology advancements shall, in times to come, unfold new vistas of engineering where "wireless transmission of electricity" and translation of "energy into matter" shall open immense opportunities to roll out a whole lot of new mechanical engineering systems and devices. These are a few widows from where we could peep into the engineering of tomorrow. All these shall create the bliss of Industry 10.0, where a car without a battery shall run on road and an aeroplane shall fly in air without an engine! Mechanical engineering by then would have been transformed into infinity engineering, covering a vast canvas of human utility engineering.

Here a word of caution, that mechanical engineering education and research should, necessarily now onwards, lean heavily on the interdisciplinary character of mechanical engineering and should assimilate, as far as possible, major scientific advancements, in a seamless environment of integration of science and engineering, so that the scientific discoveries are translated into new and innovated products and systems, creating new markets and solving the pressing problems of the society here at home and around the globe. Mechanical Engineering has been and shall remain, ever so relevant and at the core of engineering activity in all times to come and shall continue to impact the advancement of human society to its destined glory.

I am sure the soul of the eminent engineer of his time, Dr SP Luthra in his heavenly abode shall be smiling on the mechanical engineers of the knowledge and innovation age to make the impossible possible and bring billions of smiles on the people of the planet Mother Earth.

Study of Performance, Combustion and Emissions of Biodiesels and Diesel Additive (2-EHN) Blends in DI-Diesel Engine and Calibrations of NOx-SOOT-BTHE Trade-off Characteristics through Taguchi-Fuzzy based Multi-objective Optimization Technique

Dr Swapan Bhaumik

Vice President, IEI & Former Head, Dept of Mech Engg, NIT Agartala

Introduction

The variation of world energy graph has logically attributed to the retribution of painless world energy trade and professions. Presently, 7 billion people model the entire world energy structure and have an undeviating impact on the foundation of energy demand. The effects of the world economy, security and environmental design are the impact of energy. Energy is the first principles to the modern world, and as the population increases from 7 billion to 9 billion by 2040, a challenged to overcome energy crisis to build superior lives achievable. The Country like China, India and the Middle East has projected for the rise of energy requirement beyond one-third from 2035 to 2045 by 60% of the growth. Pollution vandalization and passing fossils fuel reservoir forced many scientist, researchers, and engineers to undertake the investigation on the substitution to fossil fuel. Effects of increased environmental pollution from motors and increased fossils fuel price enforced biodiesel platform as a substitute to fossils fuel. Worldwide biodiesel production has risen practically sevenfold since 2005. Besides the world biofuel production of 127.7 billslliters in 2014, bioethanol considered to be 74% and biodiesel considered to be 23%.

Currently, the ongoing inquiry and found inspection effects about the substitution of the diesel fuel with the fusion of biodiesel and ethyl alcohol like diesel supplements in diesel engine was found victorious due to the closer fuel properties to diesel fuel and biodiesel content. Diesel additive plays a vital role in the world of motors combustion. The utilization of the diesel additive, intake fuel temperature and inlet air temperature are the contemporary recommendation to excel viscosity, tribology and completion in fuel vaporization. Blending alcohol with the commercial diesel 4S an authentic technique for decoding lubricity and vaporization complication. Nevertheless, the immiscible character of diesel and alcohol could be intricate because of splash blending, thermal cracking, and dissociation by another process. This complication can overcome by the emulsifiers or co-solvent.

Biodiesel as an alternative fuel.

Vegetable oils are an organic oil (triglycerides) extracted directly from the plant product, animal product, and waste product. Vegetable oil for the diesel engine is not a new thought. Scientist Dr Diesel in 1911 ran his diesel engine on pure vegetable oil extracted from peanut. However, the vegetable oil has employed in the compression ignition engine until 1920s. Throughout the 1920s, the manufacturer of the diesel engine redesigns their diesel engine to run on the lower viscosity (petro diesel) instead of vegetable oil, which attribute to some disadvantage of vegetable oils properties. With the expanding of time before the world war-II in South Africa, the first ever utilization of trans esterified vegetable oil (biodiesel) was effortlessly powering heavy duty motor Vehicles.

Generally, since biodiesel came in to picture, its application extended for combustion in the diesel engine after meeting the specification of ASTM-D6751 standard. Experimental engine test with methyl and ethyl ester have manifested that methyl ester released higher power and torque when related to ethyl ester. Methyl ester (biodiesel) obtained from net-vegetable oil is brown or amber-yellow colour, viscosity similar to diesel fuel, non-flammable, non-explosive, biodegradable, non-toxic and reduce emissions when burning in the diesel engine. Under many circumstances, biodiesel has an advantage as well as disadvantage given below.

The Advantage of biodiesel is its availability, portability, renewability, underneath sulfur, excessive combustion efficiency and aromatic content, excessive biodegradability and unreasonable cetane number. Besides all the advantages of biodiesel, domestic origination is the central advantage of biodiesel, which would diminish local energy demand, biodegradability, skyhigh flash point, and lubricity.

The main drawbacks of biodiesel are predominantly its excessive viscosity and density, beneath energy content, high pour point and cloud point, lower power and engine speed, engine affinity, fuel injector coking, greater engine scratch, excessive NOx emissions, and Significantly high cost. Another demerit is the technical complications due to the biodiesel and diesel blends leading to fuel chilling in winter, minimised energy density, fuel degradation under lengthy periods of storage, and layers deposits inside the tank, hoses and blocks the fuels filters. Nevertheless, this blocked fuel filter can be maintained and replaced.

Concerning to this climax, this present experimental investigation significantly manifests the ability of methyl ester in compression ignition engine. Biodiesel utilisation in the diesel engine is the successful technique of exchanging petro diesel in the long run. Since biodiesel is environmentally friendly, it has outstanding prospective to utilise as a substitute in diesel engine

Significant Confidential of 2-ethyl-hexyl-nitrate.

Ignition quality in a compression ignition engine gambols all the important parameter predicting how the quality performances and emissions delivered by a diesel engine. Thus the improvement of combustion quality can be obtain by the various approach. The present experimental work adopts 2-Ethyl-hexyl-nitrate (2-EHN) as cetane improver to achieve quality combustion.

Chemically, 2-Ethyl-hexyl-nitrate (2-EHN) is an organic compound called ester of nitric acid shown in Fig. 1(Test tube-D), where, test tube-A, B, C, and D are filtered neem biodiesel, filtered cotton biodiesel, diesel and 2-Ethylhexyl nitrate. 2-EHN is 99% purity which is built by a chemical reaction of HNO_3 (nitric acid) with $C_8H_{18}O$ (2-Ethylhexanol) as detailed below.

$$HNO_3 + C_8H_{18}O = C_8H_{17}NO_3 + H_2O\downarrow$$

The industry work group of 2-ethyl-hexyl-nitrate (2-EHN) was organised in the year 2002 in Europe by the manufacturers of the technical committee of petroleum additive (ATC), members affiliated by the council of European chemical industry (CEFIC). It incorporates of various members of ATC companies including all the European and North American producers of 2-EHN, along with the auxiliary input from the oil manufacturing companies, European Federation for health, environment, and security in concentrating and dispensation.

2-Ethyl hexyl nitrate, when blended with petro diesel fuel is predominantly to increase cetane number, to accelerate the diesel fuel auto-ignition properties, shorten the duration of combustion and improve combustion characteristics.

1. Miscibility test and blend preparation.

In this experimental investigation filtered neem seed methyl ester (NSME) and filtered cotton seed methyl ester (CSME) were fused with pure diesel and most significantly with 2-ethyf-hexylnitrate (2-EHN) as an emulsifier in volume fraction (3:2: 1) VN% basis. The significant footprint of this miscibility test was base on the questions of the blending ability of pure diesel and 2-EHN with a much higher concentration of biodiesel. This comprehensive miscibility test in a volume fraction (3:2: 1) basis was equivalently states as (U:V:W) in test tube- A, and (X:Y:Z) in test tube-B. where, 'U', 'V' and 'W' are 2-EHN, Diesel and Neem biodiesel, simultaneously X, Y, and Z are 2-EHN, Diesel and cotton biodiesel respectively.

These two blends were compared with 100% NSME and 100% CSME and finally with 100% Diesel as a whole. After obtaining the complete requirements, the properties of the required fuel of the net-diesel, net- methyl esters and additive blends were obtained by IS: 1448 (Protocol) within the ASTM standards limits.

Experimental setup and methodology.

The experimental setup is a single cylinder, four strokes and water cooled DI-Diesel engine (Make- Kirloskar, IS-No. IS: 11170-1985) as shown in Fig. 1.

The diesel engine connected to an eddy current type dynamometer (Make- Kirloskar) is for loading. It is connected with the necessary sensing device for measuring combustion pressure inside the cylinder and also for measuring Crank Angle. These two sensing devices connected to a computer is for obtaining P-8 diagram. Other interfaces are also made for fuel flow, air flow, and load measurement and also sensing the temperature at different loading conditions. The experimental set up has stand-alone panel box consisting of air box, two fuel tanks, manometer, vertical buerate attached to control panel, transmitters, process indicator and engine indicator. Rota meters was provided for measuring water flow and also for cooling the engine. The experimental setup enables the study of VCR engine performance for all the developed power, pressure, efficiency, specific fuel consumption, AIF ratio, and heat balance. Engine Performance Analysis software provided was for measuring all the performance and combustion evaluation.

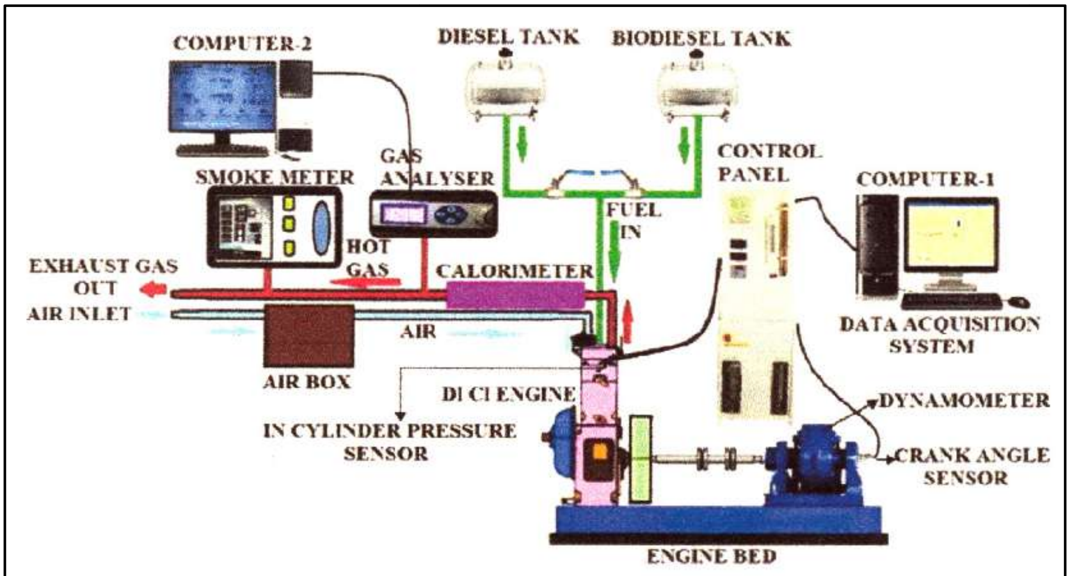


Fig. 1. Experimental Setup completes Circuit Diagram.

Experimental Methodology

Initially, the experimentation of this present works was run by the pure Diesel, filtered Neem biodiesel, filtered cotton biodiesel, 2-EHN, and its blends at different compositions. The experiment was run on VCR engine at various loading conditions with a constant speed of 1500 rpm (± 2%). The variable load test was conducted at the injection timing of 23° BTDC, and at the fixed injection pressures of 200 bars.

Initially, the engine was warm-up with Net-diesel (0100) for 30 minutes for stabling the diesel engine. After that, the data was taken for the reference and also for the comparison of performance and emissions characteristics with various chosen blends. All the instruments interfaced to the control panel was for revealing the desired data. Once the base data obtained from the base fuel, the blended fuels were injected once at a time for experimentation. The blended fuels were also allowed to settle down for the proper and homogenous mixture. Technically all the instruments were interfaced to a computer DAQ system as well as synchronized with a crank angle encoder to software. The experimental data were so obtained was by the DAQ system. The standalone control panel fitted and connected with sensing devices helps to regulate the entire machine. The eddy current dynamometer was connected to a voltage controller for adjusting the loads (from 0% to 100%). In additions, for acquiring an accurate reading for every blend, the fuel flow line was thoroughly cleaned with acetone. Further, the experimentation was continued base on the same technique and process. The NOx emissions sampled was obtained with the 5-gas analyzer (Make: AVL India, Model: 444).

Uncertainty analysis.

Error analysis is a part of experimentation. It safeguard the repeatability of the experiment and also acknowledge the gentility of the instruments of the manufacturer. Uncertainty analysis or error identifications of any specific apparatus of an experimental engine explicitly manifest the requirement and repeatability of the experimental work paradigm. Vitally, the Uncertainty analysis of performance and emissions parameters are found out by the root mean square method given by Eq.(1).

$$\Delta U = \sqrt{\left(\frac{\partial u}{\partial x_1}\Delta x_1\right)^2 + \left(\frac{\partial u}{\partial x_2}\Delta x_2\right)^2 + \ldots + \left(\frac{\partial u}{\partial x_n}\Delta x_n\right)^2} \qquad (1)$$

Where, ΔU the total uncertainty of the projected number Q is accountable on the various variables Q = f (X1, X2, ..., Xn) possessing ΔX1, ΔX2,... , ΔXn as well defined errors.

Results and Discussion.

Different blended fuels prepared are experimentally investigated in the DI-Diesel engine at a constant speed of 1500 rpm. The effect of the tested fuels has been determined by the engine performance parameter, combustion characteristics and emissions characteristics as enormously described below.

Combustion characteristics.

In-cylinder pressure.

In-cylinder pressure of a diesel engine has directly attributed to the fraction of fuel burned during the initial combustion stages (premixed combustion). At 0.8kw load, D100 attained the maximum pressure (46.50 bar) registered around 370° crank angle (TDC) than others tested fuels. Simultaneously the ignition delay of all the tested fuels in this same load was prolonged from 360° to 364° crank angle which indicates late combustion.

Pure cotton seed methyl ester (100% CSME) at 1.4kw load shows maximum in-cylinder pressure (49.91 bar) registered at 3700 crank angle (TDC). The increased in in-cylinder pressure is directly attributed to oxygen content in biodiesel molecules resulting in maximum pressure. Diesel additive (2-EHN) concentration in the tested fuels shows maximum pressure at higher loads. 5% EHN1 attained consistent in-cylinder pressure rise (maximum) from 2 kw to 3.2 kw are 54.25 bar, 56.87 bar and 57.72 bar respectively. Whereas, 5% EHN2 follow the same trends as 5% EHN1 from 2.6 kw to 3.2 kw loads are 56.25 bar and 57.03 bar. Most significantly, the maximum in-cylinder pressure of 5%EHN1 than others fuels is the effective result of 2-EHN addition in the blends which forced the pressure near the TDC. This maximum pressure rise is attributed to low auto-ignition temperature, shorter ignition delay.

NOx emission

Figure 8 shows the effect of diesel, Net-biodiesels, and 2-EHN additive on the NOx emissions concerning various engine brake power. Exhaust NOx emissions increases with the increase in engine brake power. Exhaust emissions contain eight oxides of nitrogen which are composed of 5% N02 by volume, 5% N_2O+N_2O_3+N_2O_5 by volume and 90% NO by volume. The combustion temperature inside the cylinder, duration of high temperature and in-cylinder oxygen concentration are the vital factors for NOx generation.

Soot emission

Soot emissions is the major complication of the diesel engine. Even though, Diesel fuel being the top contender for compression ignition engine, its particulates consist of carbonaceous materials directly indicated as Soot and some organic or inorganic compounds were also discovered.

In brake power, Whereas, 5% EHN1 crack the overall prominent BTHE, lowest SOOT emissions with the penalty of NOx emissions as shown in point Fat higher load (2.6kw). The increased or decreased of NOx, SOOT and BTHE are being undeviatingly ascribed to combustion efficiency of the test fuels.

When differentiated with 100% diesel, 100% NSME and 100% CSME, 2-EHN concentration in the blends enhance combustion model revealing the increasing trend of BTHE, reducing trends of UHC and SOOT emissions and quantum of NOx emissions penalty.

Optimum Input Parameters Selection by Taguchi-Fuzzy based Approach.

The current experimental investigation data's are being governed by L_{25} orthogonal arrangement of the Taguchi artistry by utilizing 25 permutations of five engine brake power and five tested fuel which are noted as A and B in the Table 6. The center of attention of the present investigation was not on the design of collection and inspection of experimental data's, but on the signals to noise ratio (SIN) to grasp the experimental data are in Taguchi orthogonal ordering. The integrated governable set of parameters by an orthogonal arrangement in Taguchi technique can yield undeviating complication effect. The number of experiment and the accuracy of the experimental analysis results can be optimized by implementing the Taguchi technique. Thus, the Taguchi technique minimizes the duration and caliber the lone character of the experimental analysis. "Larger-the-better" and "Smaller-the-better" are numerically investigated based on the outcomes of the factor to achieve the signals to noise ratios (SIN). So, the operation factors by model arrangement for sole characteristics like BTHE, UHC, NOx and SOOT can be attained. The characteristics of the value of signals to noise ratios (SIN) of "Larger-the-better" have implemented. Thus, BTHE is the focus in these sorts of analysis. As for conveying in Eq. (3)

$$\frac{S}{N} = -10\log\frac{\sum_{i=1}^{n} y_i^2}{n} \quad (3)$$

Besides that, "Smaller-the-better" is implemented for the characteristics like UHC, NOx and SOOT as shown in Eq. (4)

$$\frac{S}{N} = -10\log\frac{\sum_{i=1}^{n} y_i^{\frac{1}{2}}}{n} \quad (4)$$

Where, n = number of measurement taken.

Y = numbered ith characteristic.

Conclusion

The ultimate focus of the contemporary experimental investigation was to exploit filtered methyl ester of neem seed oil, cottonseed oil and its blend with diesel along with the diesel additive (2-EHN) concentration and analyze the combustion, performance and emissions characteristics of a diesel engine at non-identical loads and blend. Concurrently, the succeeding focus on this experimental investigation was multi-objective optimization to minimize the experimental endeavor, to blueprint the experiments and simultaneously to optimize the performance and emissions parameters of a particular DI-Diesel engine. The consecutive effects drawn from the experimental investigations are attested below.

1. The outcome of the filtered methyl ester of neem seed oil and filtered cotton seed oil with and without diesel and also with the minor diesel additive (2-EHN) concentration manifest the future substitute to diesel fuel.

2. Improvement of Brake thermal efficiency (BTHE) has been distinguished for non-identical blends point of view when compared to 0100 at different loading conditions.

3. Tri-ingredients blends of NSME, Diesel, and 2-EHN showed reduced UHC and SOOT at various load condition when compared to 0100.

4. The overall verified conclusion notify that the particular method is suitable for optimizing the performance and emissions parameters of a diesel engine.

This present experimental investigation narrates a multi-objective optimization approach to ascertain the optimum engine constrain when fueled with filtered methyl ester (neem and cotton oil) - 2-EHN (additive) - Diesel fuel blends for the performance and emissions characteristics improvement exhibit that the 5%EHN1 at higher loads will deliver optimum outcomes.

About Mechanical Engineering Division Board

The Mechanical Engineering Division of The Institution of Engineers (India) was established in the year 1954. This Division consists of quite a large number of corporate members from Government, Public, Private sectors, Academia and R&D Organizations.

Vast array of technical activities are being organized under the aegis of Mechanical Engineering Division all over the year including International Conferences, All India Seminars, All India Workshops, Conferences, Lectures, Symposiums, Panel Discussions etc, at various State/Local Centres of the Institution. Apart from these, National Convention of Mechanical Engineers, an Apex activity of this Division is also organized each year on a particular theme approved by the Council of the Institution. In the National Convention, several technical sessions are arranged on the basis of different sub-themes along with two Memorial Lectures in the memory of '**Dr S C Bhattacharyya**' and '**Dr S P Luthra**', the eminent Mechanical Engineers of the country, which are delivered by eminent experts in this field.

Due to multi-level activities related to this engineering discipline, this division covers different thrust and emerging areas such as:

- Micro Machining;
- Nano Technology & Smart Materials;
- Condition Monitoring;
- Eco-friendly Materials;
- Alternative Energy Systems;
- Rural Industrialization;
- Composites Fabrication;
- HVAC & R;
- Green Manufacturing;
- Additive Manufacturing/3D Printing;
- Bio Mechanical Engineering;
- Super/Ultra Supercritical Boiler for Energy Efficiency;
- Metal Matrices and Composites;
- Biomedical Engineering for Mankind;
- Advance Heavy Water Reactors;
- Under Water Robotics;
- Solar Energy;
- Logistics and Supply Chain;
- Heat Transfer Enhancement;
- Application of Micro and Nano Fluidics;
- Performance Analysis and Testing of Prime Movers;
- Non Conventional Energy Resources for Power Plant Design;
- FEA and FMEA in Mechanical Design;
- Reverse Engineering;
- Computational Fluid Dynamics;
- Application and Performance Analysis of Refractories in Process and Thermal Power Plants.

In order to promote the research and developmental work in the field of Mechanical Engineering, the Institution publishes **Journal of The Institution of Engineers (India): Series C** in collaboration with M/S Springer which is an internationally peer reviewed Scopus indexed journal. The journal is published six times in a year and serves the national and international engineering community through dissemination of scientific knowledge on practical engineering and design methodologies pertaining to Mechanical, Aerospace, Production and Marine engineering.

The Institution of Engineers (India)
8 Gokhale Road, Kolkata 700020
Phone : +91 (033) 2223-8311/14/15/16, 2223-8333/34
Fax : +91 (033) 2223-8345
e-mail : technical@ieindia.org; iei.technical@gmail.com
Website : http://www.ieindia.org