IEI Centenary Publication

Dr S C Bhattacharyya 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 C Bhattacharyya Memorial Lecture

Dr S C Bhattacharyya, born on August 20, 1894, passed M Sc in Mathematics from University of Calcutta in 1919 and obtained the degree in both mechanical and electrical engineering in 1921 from the Bengal Technical Institute. Almost simultaneously, he passed the final examination in mechanical engineering from the City and Guilds, London. Subsequently, he went to Germany and obtained the degree in mechanical engineering from Berlin Technical University in 1926, and Dr Ing from the same University in 1928. He stood first in his degree examination in mechanical engineering at National Council of Education, Bengal, as well as at the Berlin Technical University.

India was then reverberating with the spirit of nationalism and Dr Bhattacharya, after his return from Germany, had no hesitation in responding to the call of the nation and joining the National Council of Education, Bengal as a teacher in mechanical engineering ignoring tempting offers from other reputed engineering colleges. His entire career was thereafter devoted and dedicated to the service of NCE, Bengal and Jadavpur University and in planning and implementing his ideas in the development of human resources in mechanical engineering till his retirement as Professor and Head of the Department of Mechanical Engineering in 1959. He acted as Vice-Chancellor of Jadavpur University for a short period. After his retirement, he was made Professor Emeritus of Jadavpur University.

Dr Bhattacharyya excelled in whatever subject he touched, be it thermodynamics or applied mechanics, theory of mechanics or strength of materials, machine design or machine tools.

He was not only a pioneer in introducing and advancing mechanical engineering education in the country but also a pioneer Indian author of such engineering textbooks as 'Engineering Thermodynamics', 'Machine Design', 'Machine Tools', etc. Besides being a teacher par excellence during his entire service career, he was associated with various indigenous industries as technical consultant. He left behind an academic legacy virtually beyond comprehension.

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 C Bhattacharyya Memorial Lecture

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

The Vidyasagar Setu

Shri Susanta Ranjan Choudhury

Chief Executive-Projects & Construction Division GEC ALSTHOM India Ltd

Homage

Dr Satish Chandra Bhattacharyya was my Professor. A Professor who dedicated his entire life for technical education in the country. He joined the National Council of Education, Bengal, during the British colonial days to build a cadre of technically competent personnel who would be capable of building the new free India. A generation of students who were fortunate enough and had the unique opportunity to study under him today occupy many important positions in the country. A teacher who appeared to be very hard from outside but was soft at heart. Those who came to know him very closely knew his affection for his students. But he never expressed it. He believed in the word Guru-Sishya relationship of India. A teacher who taught a generation of engineers the basic strength of material engineering will be remembered by his students and also future generations for his outstanding contributions in this field.

I dedicate this lecture to my beloved teacher Dr Satish Chandra Bhattacharyya. I have chosen specifically the subject 'The Second Hooghly Bridge' which is now known as 'Vidyasagar Setu' because of its unique construction in nature. This bridge was conceived during his life time and I have been fortunate to be associated with this Bridge. At the outset, I would like to acknowledge my sincere gratitude to my one time colleague, Shri C K Ganguly, who was the Project Manager for this Bridge and who helped me in preparing this paper.

INTRODUCTION

October 10, 1992, had been a red letter day in the history of bridge building industry of this country when Shri Narasimha Rao, Prime Minister of India formally inaugurated the Vidyasagar Setu over the River Hooghly in Calcutta - the first cable stayed bridge of India.

Vidyasagar Setu, with its 457 m main span is the longest bridge of its type in Asia and in the world and is surpassed only by the 465 m Annacis or Alex Fraser Bridge in Vancouver completed in 1987. It narrowly beats the Bangkok and Dartford Bridge (England), both with 450 m main spans.

Due to considerable time overrun this project at one stage became something of a national joke. Now that the bridge has been completed let us look into the events chronologically and try to assess and understand the project along with its background for fair assessment.

The tender for the design and construction of this high level, long span bridge was invited by the Calcutta Port Trust in 1970 based on the tender documents prepared by Rendel, Palmer and Tritton (RPl), U K.

The contract for the main bridge was awared to Bhagirathi Bridge Construction Co Ltd (BBCC) - a consortium formed by Gammon India Ltd who were responsible for the substructure and B B J Construction Co Ltd, who were responsible for the construction of the superstructure.

The original design engineering was supplied by Freeman, Fox and Partners, U K.

Even before the take off, the project ran into its first trouble when Milford Haven Bridge in the U K, and the Yarra Bridge in Australia, both designed by FFP, collapsed and the clients, HRBC appointed Leonhardt Und Andre (LUA), Germany, as a check consultant in line with the recommendation of the Merrison Committee.

The design philosophy of the two consultants differed widely and this difference continued to widen with the passage of time. Ultimately, in 1979, the clients decided to reverse the role of the consultants; thereby making LUA responsible for the design and FFP responsible as check consultants. In 1982, LUA nominated Schlaich and Partners (S+P) as their representative for the design of the bridge. With this, Episode One was concluded and the project entered into its second phase.

The construction of the sub-structure was started in February 1979 by GIL and it was completed in November 1987. BBJ, however, could start planning the fabrication only in 1982, after getting the design and drawing from LUA.

The project suffered its second setback because B B J had become organizationally weak as most of their experienced bridge engineers had left the company by them. This could only be resolved when BBJ became a part of the holding company, Bharat Bhari Udyog Nigam Ltd (BBUNL) in early 1987. BBUNL's constituents include Jessop & Co Ltd, who fabricated the pylon elements (5200 t). Braithwaite and Burn Standard Co Ltd. who fabricated the deck steelwork [4000 t (approx) each].

Meanwhile, the organization of BBJ was strengthened by reinduction of experienced bridge engineers who had left the organization earlier and engineers from the rest of constituent company of BBUNL. BBJ now had the required infrastructure to face the challenging task and also had its access to resources of the other companies of the group. The confidence was built and the onward march started.

Initially, the fabrication was a bit slow as the design called for drilling holes to very close tolerances and the fabricators had to import sophisticated drilling machines and the like. The structured job did not call for any such accuracies. The bridge structures were really highly precision machined structure.

In Calcutta side, the main erection started in late November 1985 and almost a year later at the other end at Howrah. To speed up the erection on Howrah side, a floating crane was hired from Vizag Port Trust to erect the pylon elements of pier 3 in parallel with the erection of the Howrah side span. In January 1989, the erection of Calcutta and Howrah pylon had reached practically the same stage when the third and most unfortunate shock rocked the project once again.

On January 20, 1989, the Howrah pylon erection crane met with an accident due to human error. Although no life was lost, but it delayed the project by a year. The damaged crane consisting of 250 t structure was brought down with a scheme developed by BBJ and a new crane was re-erected to complete the pylon erection. To make up for the lost time, a feeding system from the river was arranged so that during the erection of the main span, when the deck slab concreting would have to follow the erection closely, there would be no interruption to the feeding of the steel work to the erection head.

Also the pre-erection assembly system of middle girder and cross girder were so changed that time cycle of erection of deck panel was reduced considerably. Looking at the course of the events, one can definitely conclude that the history of Vidyasagar Setu had been vary much eventful and many elements that had contributed to time over run of this project had been beyond the controllable zone of the builder.

FEATURES

Capacity of the Bridge

The anticipated volume of traffic is about 85 000 vechicles per day with a peak hour intensity of 8500 vehicles per hour.

Navigation Clearance

This high level bridge crosses the river allowing a navigation clearance of about 35.00 × 152.00 m so that ocean going vessels of considerable size could reach the wharves further up the river.

Principal Dimensions

The main bridge connecting the Calcutta and Howrah approaches is a three-span double plane cable stayed bridge of 822.96 m length. The central main span is 457.2 m long and is the longest of its type in Asia. The two side spans are each 188.20 m long.

The 35.00 m wide deck structure carries a carriage way of 12.30 m for three traffic lanes and one pedestrain lane of 2.50 m width in each direction. The up and down lanes are separated by a 1.70 m wide medain strip. The deck structure is completely suspended from two steel frame pylons by parallel wire cables with narrow spacing of only 12.30 m. All horizontal forces in the longitudinal direction are transferred to pier 1, while the lateral loads are shared by all the four piers.

All four bridge supports are formed by twin well foundations and connecting pier walls on top of them.

The Approaches

Based on the recommendation of the RPT, it was decided to construct this high level bridge at Princep Ghat which would connect the city of Calcutta with various highway at the Howrah end. The anticipated flow of vehicles being considerable, it was decided to segregate the traffic at the approaches itself through a system of interchanges so that there was a gradual mingling of the inflowing traffic into the traffic system of the cities.

The Calcutta side approach consists of an entrance viaduct of 527.00 m length (approx) and 7.50 km long interchanges. The length of the interchange in the Howrah side at about 7.80 km and the length of the viaduct is about 875.00 m.

Superstructure

The deck consists of two longitudinal high tensile steel riverted plate girders at 29.1 m centre (in the same vertical plane as the cables), a middle girder for better live load distribution wit welded mild steel cross girders at 4.1 m centres.

A concrete slab 230 m thick spanning over the cross girders and covering the entire width of the bridge is rigidly connected by block shear connectors so as to act compositely with the steel gird. The main girders are 1 m wide by 2 m deep and generally 12.3 m long so that they can be easily transported and erected. The site connection are riverted except at bottom flange splices of longitudinal main girders where because of thicknesses involved turned fitted bolts were used. The top flange of the main and middle girders were of high tensile weldable quality so that the shear connectors could be welded. In all other locations where welding is required only mild steel weldable quality was used.

The 122 m high pylons are rigid frames in lateral direction with a portal below the deck and at pylon head level. Its two legs are inclined so that the pylon heads lie exactly in the vertical cable plane where as a deck level they pass outside the longitudinal main girders. In the longitudinal direction they act as a simple cantilever stiffened and also loaded by the cables. All pylon units except the base section are riverted box girders of high tensile steel. The main dimensions of the pylon leg are 4 m × 4 m at bottom tapering to 4 m × 3 m at the top. The box girder walls are formed by double steel plates upto 25 mm thickness. During erection the pylons have to be rigidly anchored to the piers by approximately 4 m long Dywidag bars tensioned to the required levels. They are left in this state during the final stage also. Because of extremely high wind loads (maximum design wind speed at pylon top is 67 m/s. The pylon legs had to be temporarily guyed by cables to the deck when the hight of pylon exceeded (approx) 67 m. These temporary cables were removed when the final cables have been installed.

Cables and Corrosion Protection Cables

The bridge deck is supported by 152 stay cables with diameters varying from 140 mm to 200 mm. The cables constitutes parallel wire bundles of 7 mm wires covered by a HOPE sheathing.

The cables are anchored into the deck and pylon by 'HI-AM sockets'. In the HI-AM anchorage the parallel wires in the bundle are flared out slightly and held against a steel plate by means of bottom heads at their ends. The conical space inside the anchor is filled with a mixture of hard steel balls, epoxy based resin and zinc.

To achieve the optimum corrosion protection the wires that makeup the cables are first treated with anticorrosive oil at the shop. On receipt of the cables at site, the same are unreeled from the cable drum and sufficient time is allowed for regaining of the cable shape to normal (provided any distortion of shape is observed) and then a two component anticorrosive grout is injected through the HDPE tube for better performance. The grouting of main cables by a mixture of polyurethene - polybutadine was chosen based on the following:

(i) Excellent permeation so as to fill up sufficiently between voids of wire stands.

(ii) Sufficiently weather resistant

(iii) Flexibility of the material

(iv) Satisfactory performance during trial grouting at site.

Corrosion production of Fabricated Structure

Owing to the proximity of the bridge to the bay, it is exposed to saline atmosphere which, in turn, had necessitated extensive corrosion protection of the fabricated structure. The fabricated girders were shot blasted/sand blasted to Swedish standard SA 2 and half (21/2). Then two coats of red lead primer paint totalling to a thickness of 90 microns (approx) were applied. On drying up of the primer paint one coat of aluminium paint was applied at the shop and then despatched to site. After erection, repair and touch up paintings were done. The second and final coat of aluminium paint was then applied the total thickness being around 110 and 120 micron.

Elastomer Collars

The aerodynamic effects of wind on the bridge deck and pylon were studied in wind tunnel tests. The tests were conducted using models of the bridge and pylons at the Indian Institute of Science, Bangalore. No significant oscillations of the deck were observed. However, to arrest elastomer collars have been provided around the cables at both the deck and pylon head around the cables in the bearing slab locations. The elastomer collars are divided into four segments and gap between the collar and bearing slab is sealed with tar epoxy compound.

Crash Barrier

A special barrier, with three hollow steel rails and vertical posts was developed for the medium and outer crash barriers, improving both the safety and the aesthetics of bridge at the deck level. The crash barriers have been made sufficiently strong to arrest the unlikely event of an errant vehicle penetrating the barriers.

Maurer Sohne Expansion Joint

The bridge is having a continuous composite deck from pier 1 to pier 4. For expansion and contraction of the deck due to change in temperature, the total movement was allowed in pier 4. To take care of this phenomenon the bridge is provided with an expansion joint at the junction of main and approach bridge at pier 4. The expansion joint is manufactured and supplied by Maurer Sohne of Munich, Germany.

The mean dimension of this expansion joint is designed to be 1360 mm at 38°C with alowable movements of +440 mm. the movement per 1°C is 9.6 mm. The main bridge end of the expansion joint is bolted to the end X-girder while the approach bridge end is anchored to the deck slab by anchor hooks and studs.

Drainage

The roadway drainage gullies are connected into drain pipes which run through the cross girders in the Calcutta side span discharging at pier 1. In the rest of the bridge the gullies drain directly into the river.

ERECTION

Side Span

The steel grid of the 182.88 m long side span was erected first on temporary trestles 24 to 30 m height and 24.6 m (approx) at centres. The Calcutta side span was entirely on ground and hence the steel the grid was erected by a 50 t ring crane (RC) moving on the ground along the centre line of the bridge on a rail. The erection crane required for the erection of the deck steel grid was erected after erection of four panels of steel work to suit the reach of a ring crane. The end main girder weighted 62 t and was erected by the ring crane after increasing the kentledge. All side splice connection were by rivet except main girder bottom flanges which were through turned and fitted bolts because of long girds involved.

The Howrah side span was mainly over the river and the erection had to be done by deck erection crane (DEC). After erection of first two panels the DEC was erected on steel deck grid. The ring crane was stationed by the side of pier 4 and was sued to lift steel work from ground into bogies running on feeding track laid on the deck. The bogies were hauled by diesel loco to the erection point from where the DEC was used to lift and place the girders in position.

ERECTION OF PYLONS

Calcutta Side

At Calcutta, side the first six pylon elements were erected by 75 T Tata 955 ALC crane and ring crane. The pylon leg was anchored to the pier by Dywidag bars. The 45 t capacity Pylon erection crane (PEC) was then erected on element 3 by RC and raised to element 4, From element 7 onwards the erection of pylon elements was done by the PEC. After erection of two elements and completing the rivetting in the splices, the PEC was raised by self riding winches provided on the PEC main beams by a reaving system connected to cross heads placed on top of the pylon element.

Initially, the pylon legs were erected upto element 13 as free cantilevers, after which the leaded to be anchored. The bottom portals were erected at element 5 to provide lateral stability and temporary cables fitted at panels 14 and 17 for stablising in the longitudinal direction. For this reason the deck steel work panel was erected upto panel 17 and supported at the bottom portals. To prevent uplifts of the deck, temporary cables were provided in the main span from panel 17 to pier 2. For the side span it was planned that the deck concreting which was due to commence would be adequate against uplift. In absence of side span deck concreting, the steelwork of the side span was held tight to the temporary trestles by adequate kentelege.

Howrah Side

The erection of the Howrah side span, which was started almost a year after the Calcutta side span commenced and hence to make up for this gap a floating crane was hired from Vizag Port Trust. With the help of the floating crane pylon elements were simultaneously erected upto element 6 and the PEC erected in the same sequence as on Calcutta side.

As mentioned earlier, there was a serious accident in PEC due to human error PEC collapsed. The broken PEC had to be brought down in the damaged condition and all damaged parts were dismantled and new parts were erected. The pylon element 11 which was damaged slightly was also repaired. This job was done successfully but unfortunately considerable time was lost. Additional safety devices were provided to prevent occurance of such accidents.

The pylon legs at Calcutta and Howrah were erected fully and then the pylon head sections, where the cables converged, were erected by the PEC at level 8. The top portals were then erected. During the erection of the pylon the deck slab on the side span was completed.

MAIN SPAN ERECTION

The cables 14 and 17 were first erected so that the temporary cables at 14 and 17 could be removed. Permanent cables 15 and 16 were then installed and the PEC was removed after lowering to the deck. As the concreting of deck slab was to follow after erection of 4 panels of steelwork the feeding of steelwork had to be such that it does not interfere with deck concreting. A river feeding scheme was adopted where all the steelwork for both Calcutta and Howrah main' spans could be loaded on barges by RC standing on a temporary jetty and the barge brought to within reach of DEC by tug. The sequence of erection of a panel was similar to the side span except that the permanent cables had to be fixed. Panel 18 was first erected and the cable 18 installed and tensioned to fit the required packs. The pack thickness was calculated according to the inaccuracies in fabrications and variations to the weights considered in the design. The length of the cable was adjusted for the final dead load geometry. The back cable (in side span) corresponding cable 18 was not installed at this stage. The side span being heavier, installation of cable 13 could have pulled the pylon towards the back, which was not desirable. After completion of panel 18, the DEC was moved forward and panel 19 was erected. During the rivetting of panel 19, cables 13 were installed and stressed and from cables 19 were erected and tensioned after panel 19 including erection of temporary bracings. Deck concreting was commenced in main span after panel 21 steelwork was erected. The erection of next panel 22 could be started only after 48 h of curing. The sequence was repeated till erection of panel 30. At this stage it was nccessary to fix the deck at piers 1 and 4 as there could be uplift at these piers. Four holding down cables in each cable plane were provided at piers 1 and 4 and were tensioned to 555 t each to produce a vertical compression on the bearings. A wigaring (load measuring device) is fixed at each cable so that the load on the cables can be measured. The HD cables were fitted to the brackets on the main girder and pulled against the pier 1 at the bottom. HD cables had to be stressed on two or three stages so that each cable had the minimum specified tention.

MAIN CABLES

The Hooghly Bridge had a unique feature feature in which all cables were stressed at the pylon. It had the advantage where the jacks need to be shifted within the heads. Cables were manufactured at Usha Martin Industries, Ranchi, and transported on special low bed trailors reeled in drums. They were unreeled at site by an unreeling stand. After unreeling, the cables were grouted to all the gaps between the wires and HDPE tubes by polyurethene filler. Main hoist (32 t capacity), fixed to the pylon heads and a 5 t winch placed on the top portal were used to pull the cables in the initial stages. Cable sockets were provided with threads suitable for screwing the adopter strands used for pulling/stressing the cable. To ensure that the cable was in the correct inclination at deck and pylon, saddles were fixed. The strand adopter assembly was lifted by the 5 t winch with multiple falls and strand bundle was lifted by 2 t Tirak winch. The bottom socket was placed in position, as soon as it reached the deck anchor, while the lifting was stopped. The lifting was resumed until the cable saddles reached just under the line of the previously erected cables. Meanwhile, the pilot strands were fed into the jack. The jack and main hoist working were used in tandem to move the saddle to the final cable access position. The saddle was set in the pylon head and the socket was pulled into the pylon by continuous jacking until the bearer bar and shims were fixed. A pair of back or front cables were tensioned simultaneously. The geometry of the pylon axis towards/away from the river was closely monitored by surveys after the cable erection during early hours of the day (between 0400 to 0600 h).

DECK CONCRETE

The concrete mixture for deck was prepared in two batching plants of 40 m^3 (approx) capacity located on each bank, Calcutta and Howrah side, adjacent to the approaches. The concrete was transported by two transit mixers to the panel, which was to be concreted. Required dosage of admixture (superplasticizer) was added to the concrete inside the transit mixtures at the pouring point. The concrete was placed by a concrete pump of 28 m^3 capacity and placer boom. The concrete was placed first in the footpath area and then continued along the width of the panel till the panel was completed. The concrete was vibrated with two screed vibrators travelling on rails which were set at the correct slope. Askim float was used to achieve a rough finished surface.

Steel shutter plates were used for formwork, supported on shutter beams connected to cross girders. Holes for the connections of shutter beams had been decided during the design stage and cross girders fabricated accordingly. In the standard panels, shuttering was lowered by jacks on to a temporary gantry and the gantry moved forward to the next panel where the shuttering was refixed.

JOINING OF BRIDGE AT CENTRE

After erection of steelwork (panel 34) it was found that the 'deflection' at its tip was much higher than the calculated values. It was felt that the concrete slab should be cast as much as possible to reduce the deflection at the centre before joining the deck.

At the Calcutta end, after erection of panel 34, deck panel 31 was concreted. DEC was moved back and dismantled. Deck panels 32 and 33 were then concreted. Meanwhile, the gap between steel grid panels 34 and 36 was measured over a range of temperatures to determine the length of longitudinal girders in panel 35, to allow for deviations during construction. Splice 34/35 was designed to be transferred through contact at splice. Before erecting panel 35, the Howrah deck had to be pushed back towards pier 4 and allow for movement due to temperature of the Howrah half before connecting at centre. In the final condition the Bridge is 'fixed' at Calcutta end and all movement takes place at Howrah. The Howrah deck was shifted by jacking at the location of the temporary horizontal bearings at pier 4. Panel 35 was then erected after the girders were modified to the length determined at site after survey. Deck panel 38 was concreted, DEC moved back and dismantled and panel 37 concreted to reach the condition as in Calcutta side.

The Calcutta deck and Howrah deck were found to be in the same vertical plane so that no adjustment was needed to bring the bridge in transverse alignment. There was a difference in level of about 100 mm between the two halves. The Howrah half was pushed back towards the centre line in the early morning on August 25, 1992, by jacking at pier 4, such that the gap between the girders 34 and 35 was nominal 12 mm. Trucks loaded with 10t kentledge were brought as close as possible to the front which reduced the difference in level at centre to approx 50 mm. Cable 36 was then released by removing 50 mm (approx) shims which brought the level difference ro 5 mm which could be adjusted by jacks placed at girders 34/35.

The splice plates were then fixed to girder 34 and positions of holes in splice plate at girder 35 were transferred from the holes in main girder 35. Splice plates were then removed to drill the holes marked. Howrah half was pushed back towards pier 4 so that there was no risk of the two halves meeting during the day when the temperature was likely to rise.

On August 26, 1992, early morning, the Howrah deck was moved towards the centre line and the splice plates with holes drilled were connected to girder 34/35. Slight jacking was required to make the holes to match. After fixing bolts and drifts in splice 34/35 connection the temporary restraints at P4 were released. After rivetting the splice 34/35 and fixing all cables, the deck concreting was completed.

CONCLUSION

This is the story of the Second Hooghly Bridge-Vidyasagar Setu.

Right from the manufacturing stage upto the erection and completion stage was totally a new job for our country. This was a technological challenge which called for new manufacturing technology, total new technology for erection but inspite of the initial problems the challenge was met adequately by the young engineers who built this bridge around a few experienced engineers. Even those experienced engineers had only the knowledge of conventional bridge that have been built in the country so far. It will be rather unfortunate if we do not construct in the near future such type of bridge in the country as the skill and knowledge acquired through this job will be totally wasted. It takes an enormous amount of time to gather such knowledge and acquire such skills. I am an optimist and I am sure in the near future at least some more bridges will come up where our engineers and technologists will be able to apply the knowledge and skills that they have gained through this job. The engineers and workmen worked round the clock, 7 days a week, 365 days in a year during the last three years of the job to complete the bridge against adverse media publicity and public reaction. I think when this bridge is used to the fullest extent when the Howrah side connections are complete with the main highways then the impact of the new bridge will be fully realized. I have not tried to deal with the cost aspect here mainly because there has been so much of change from the initial concept that there is hardly any relevance between estimated cost and the initial cost but if one is to build such a bridge anywhere else in the world today it will cost much more than it has cost to build this Second Hooghly Bridge and the gain has been enormous as the country can now look forward to build this type of bridges without help from abroad so far as manufacturing and construction are concerned. This bridge has been designed by LUA and during the later part Slice & Partner, Stuttgart, did the detailed project monitoring, inspection work and the design was checked by Freeman Fox and Partner, UK. Even in future days we might have to take some help for designing such bridges but not for anything else. The story will not be complete if I do not say a few words about the workmen who worked in this bridge for their admirable courage and skill. One can only believe if one has watched how the pylon elements have been erected one after the other when the risk involved was tremendous but our workmen and young engineers faced this with indomitable courage which is second to none. I am convinced, given the opportunity, our engineers and workmen can take any challange.

Before I conclude, I would like to pay my gratitude to the Institution of Engineers (India) for giving me this opportunity for which I shall remain always grateful.

Natural Resources, Technology and Environment

Dr S Dutra, *Fellow*

Formerly Professor of Mechanical Engineering, Jadavpur University, Calcutta

INTRODUCTION

This earth of ours, which started its journey into eternal space some 5 billion years ago, with its biosphere, hydrosphere and lithosphere provides the basic life support systems -land, water, flora, fauna and the atmosphere. The Biosphere or the envelope surrounding the earth provides the life-sustaining air. The Lithosphere or the earth's crust consisting of an outer layer of soil of varying thickness lying upon a mass of hard rock extending to a depth of about 100 km provides the minerals. The Hydrosphere is the watery portion of the earth's crust comprising the oceans, seas and all other waters.

Thus the biosphere, lithosphere and hydrosphere together provide the basic natural resources -air, water, agricultural soils, mineral deposits including hydrocarbons, forest lands, grasslands, plant and animal species and energy. It is the exploitation of these natural resources through progressive development of science, engineering & technology that has brought about the vast change in civilization and society from the stone age to the present high technology era. In fact, the mad race for industrializatiou and economic development has resulted in over exploitation of natural resources thus leading to a situation where the two worlds of man - the biosphere, lithosphere and hydrosphere of his inheriteuce and the technosphere of his creation arc out of balance, indeed on a collision course bringing to the fore issues like -

(i) Depiction of natural resources that are non-renewable,

(ii) Recycling and reuse of waste products released by industrial and other activities,

(iii) Conservation of resources and energy,

(iv) Development within the regenerative and carrying capacity of the eco-system to determine the maximum rate of resource consumption and waste discharge,

(v) Environmental impact assessment,

(vi) Development of renewable sources of energy,

(vii) Biotechnology for substitution of non-renewable with renewable resoruce base, and the like.

TECHNOLOGY FALL-OUT AND ENVIRONMENT

Technology, during the course of its continuous development and advancement through the ages, has transformed and revolutionised human life and society. It is HOW truly recognised as the most important agent of social change and progress, and exerts an all pervading influence on socio-economic growth of all countries.

It is the same technology which in the process of its development and utilization has brought in unforeseen problems and undesirable effects to which the whole world is now waking up. It has now been realized that most of our present environmental difficulties is the outcome of man's ecological misbebaviour. Failure to recognize the physical limits imposed by ecological system on economic growth in the pursuit of material benefit has led to the present environmental crisis.

Progress has so far been identified with the conquest of the external world and exploitation of its natural resources. In the process, it bas been forgotten that eco-systems have limited regenerative capacities and all developmental activities must take place within the carrying capacity of the system. Over exploitation of natural resources directly undermines the potential for development and indirectly affects the future development through the discharge of residuals.

Environmental Issues: a Multi-Dimensional Problem

Environmental issues may be generated in a variety of ways, namely,

i) Excessive quantitative use or exploitation of physical resources like coal, petroleum, water, rare minerals, water, land and soil, forests, etc. causing an environmental degradation or 'depletion problem' ,

ii) Release of waste products resulting from industrial and other activities causing pollution and affecting adversely the regenerative capacity of natural environmental resources-air, water, land, floral and fauna thus creating ecological imbalance,

iii) Poverty, under development and consequent inadequate care of environment;

iv) Accidental events like oil spills, hazardous releases (as at Bhopal and Chernobil) affecting environmental quality.

Environmental Impact of Technology-Driven Change

The Primary routes of techno-economic development have been through

(i) Energy generation,

(ii) Industrial activity, and

(iii) Agriculture and food production.

Unfortunately, the technology development so far associated with all the three areas has resulted in ecological imbalance and environmental degradation.

The two major environmental problems of our times are air and water pollution, the former being caused primarily by combustion of fossil fuels in thermal power stations and automobiles and, to a lesser extent, by biomass fuels, and the latter by a wide range of industrial and agricultural activities, deforestation, urban development, modern fisheries, etc. While emission of 'green house gases' — carbon dioxide, methane, nitrous oxide, hallocarbous, etc. is increasing at an alarming rate through energy conversion as well as through industrial and agricultural activities, the forests and soil that provide natural sinks for CO_2 — the most important green house gas-are being increasingly threatened by air pollution, land clearing and degradation and other harmful man-made processes.

During the current century, industrial activity, especially relating to chemical and allied products, has grown more than hundred-fold. More than 70000 new chemicals like the most talked about CFCs have been created, which find their way into the environment. As a result, effluents and emissions of a number of polluting agents and toxic metals including lead and cadmium have reached levels several times that emitted from natural sources. For instance, in the manufacture of nitrogenous fertilizers — urea, ammonium sulphate and ammonium phosphate-e-commonly made in India, wastes containing arsenic are generated. The waste generated from the tanneries, mostly unregulated being in small scale units, lead to all forms of pollution — air, water and land. The liquid effluents, when discharged untreated into water bodies, adversely affect its physical, chemical and biological characteristics making them unfit for human consumption, threaten aquatic life and contaminate ground water with possible carcinogenic form of chromium.

Again, in our quest for meeting rapidly growing food demand, the modern system (If agriculture or 'industrialized agriculture' has promoted an ever-increasing use of oil based chemicals in the form of fertilizers and pesticides. Excessive use of chemical fertilizers, however, affects soil fertility and causes degradation of the quality of surface and ground water with possibility of eutrophication caused by nitrogen running off lands. Excessive use of pesticides has resulted in destruction of predators and nontarget species and enhanced resistance in target pests besides contaminating water and soil. In the process of ushering in modern technology-oriented agricultural system, the art of traditional methods of farming based on biological or organic manures and microbes in the ground has been almost forgotten. Renewable resources has been replaced by non-renewable resources.

In short, the effects of technological intervention into the human environment have created problems that arc becoming increasingly worldwide and there is general acceptance of the fact that environmental pollution is an inescapable consequence of industrial development.

The global concern for rapidly deteriorating environmental quality and the need for taking a critical look at the development programmes have been amply reflected in the United Nations Conference of Environment and Development (UNCED) held at Stockholm in 1972 and in Rie-de-Ja nciro in June 1992 under the banner 'The BIrth Summit '. To quote the classic words of our late Prime Minister Smt Indira Gandhi at the Stockholm Conference, ' higher standards of living must be achieved without alienating people from their heritage and without despoiling nature of its beauty, freshness and purity so essential to our lives'.

ENERGY AND ENVIRONMENT

Energy is the most important and vital input to all sectors of economic activity and as such a discussion on the issue in greater detail appears to be in order. Of all forms of commercial and non-commercial energy, electrical energy occupies the priority position since it can be transmitted instantencously, is pollution-free at the consumer's end and can be easily controlled and regulated. However, the major portion of the ever increasing demand for electrical energy throughout the world is being satisfied through the burning of coal which is an environmentally hazardous source.

As would be apparent from a study of Table 1 representing growth of installed capacities in utilities in India that at present 73% of our electrical energy generation is primarily thermal or coal- based. Combustion of coal releases gases such as CO_2, CO, SO_2 and NOx over and above fly-ash and particulates which are harmful to human life as well as to flora and fauna with teratogenic (pertaining to malformations or abnormal growths), carcinogenic (cancer producing) and/or mutagenic (change in chemical constitution of chromosomes) effects. But by far the strongest case against indiscriminate use of coal and other fossil fuels for our energy requirements is the growing threat of thermal and chemical pollution and environmental imbalance induced by:

i) 'Greenhouse' effect and global warming resulting from rise in atmospheric CO2 by 20% since the beginning of the current century (WEC, Canada, 1989);

Table 1 Growth of Installed Capacities

Plan/ period	Total capacity addition, MW	Installed capacity at the end of the Plan period, MW				
		Hydro	Thermal	Gas †	Nuclear	Total
Fourth Plan 1969-74	3 707	6965 (42)	9 059 (54)	166	640 (4)	16 664
Fifth Plan 1974-79	10 016	10 833 (41)	15 207 (57)	168	640 (2)	26 680
Sixth Plan 1980-85	15 905	14 460 (34)	27 030 (63)	542	1 095 (3)	42 585
Seventh Plan 1985-90	21 390	18 287 (29)	44 123 (69)	2 352	1 565 (2)	63 975
Eighth Plan 1990-95	38 369	25 721 (25)	74 353 (73)	10 096	2 270 (2)	102 344*
Ninth Plan 1995-2000	64 965	51 679 (31)	106 480 (64)	10 696	9 150 (5)	167 309*

† Thermal Capacity includes Gas capacity also
* As per Report of the Working Group on Power
Note: Figures in brackets indicate the percentage of total capacity.

ii) Depletion of stratospheric protective ozone layer and possible creation of 'Ozone Hole' because of man made CFCs (chloroflurocarbons) and release of NOx in the stratosphere by supersonic and hypersonic jet planes thereby exposing plant and animal life to UV radiation with disastrous effect,

iii) Acid rain caused by man-made SO_2 emissions which over Europe and North America arc estimated to be 10 times greater than natural production (WEC, Canada, 1989);

iv) CO and other air borne toxics, and

v) Hydrocarbons primarily from automobiles.

Temperature and climate and indeed life on earth arc entirely due to a steady-state equilibrium that is reached between the incoming solar radiation absorbed in the earth's atmosphere and by ground and water, and the infrared light radiation from the earth's surface back into space.

The thermal equilibrium is disturbed if either the thermo-optical properties at the earth's surface arc modified, for example, by transforming large forest areas into fields, or by modifying the water-CO_2 zone, etc content of the atmosphere, or by releasing heat energy into the atmosphere. This happens when fossil fuels are burnt, or fissile materials are used in nuclear reactors. Current energy consumption affects the equilibrium concentration of CO_2 (0.03% by volume, or 2.4×10^{12} in the atmosphere because the reaction products resulting from the combustion of fossil fuels arc CO_2, H_2O, etc. R T Watson and others[9] in their study on greenhouse gases and aerosals during 1980-1989 found that all the CO_2 emitted to the atmosphere could not be accounted for in the known storage sinks of the global carbon cycle. According to their estimate, out of a total CO_2 emission of 7 Gtc/year, only 5.4 Gtc/year (uptake by oceans 2.0, accumulation in atmosphere 3.4) could be accounted for in the natural sinks thus leaving an imbalance of 1.6 Gtc/year. The thermal equilibrium has already been disturbed and a major increase of fossil fuel burning rate in the future would undoubtedly increase the disturbance further.

Greenhouse Gases and Global Warming

Current coal use worldwise is about 3.35×10^{10} tonnes (t) corresponding to about 9×10^9 t of CO_2 emission into the atmosphere. Total CO_2 emission from fossil fuel use is currently estimated to be about 22×10^9 t and is expected to reach a staggering figure of 150×10^9 t by the year 2100 for the high coal use scenario as projected at the 15th World Energy Congress held at Madrid, Spain, in September 1992, out of which coal use alone would be responsible for about 53×10^9 t. Over and above fossil fuels, the other contributors to enhancement of CO_2 in the atmosphere are biomass burning and deforestation reducing earth's carbon sink. The contribution of the latter is estimated to be 0.6 - 2.6 Gtc/year in 1990 by the Inter-Governmental Panel on Climate Change (IPCC).

The 1988-1989 estimate for India gives carbon emissions from coal, petroleum, natural gas and transportation or 85, 35, 5 and 15 Mt respectively or a total of 140×10^6 t, that is, $140 \times 10^6 \times \frac{44}{12}$ or 513×10^6 t of CO_2. The current global estimate of CO_2 emission from fossil fuels is 22×10^9 t. Thus India's contribution amounts to 2.33% of global CO_2 emission.

Besides CO_2, which is the most important greenhouse gas, it is now recognized that non-CO_2 greenhouse gases, namely, methane (CH_4), nitrous oxide (N_2O), Ozone (O_3), CFCs and water vapour (H_2O) together contribute almost as much as CO_2 itself, the respective percentage contribution of which to the greenhouse effect integrated over a time span is given in Table 2.

Table 2 Contributions to the greenhouse effect*

	CO_2 emissions 1988		Greenhouse effect, %	
	GIC/y	%	over 1 y	over 100 y
Coal	2.4	37-28	20-16	23-17
Oil	2.4	37-28	20-16	23-17
Gas	0.9	14-11	8-6	8-7
Fossil fuel	5.7	88-68	48-37	53-41
Cement manufacture	0.2	3.1-2.3	1.7-1.3	1.9-1.4
Deforestation and land use	0.6-2.6	9-31	5-17	6-19
Total CO_2	6.5-8.5	100	55	61
Other greenhouse gases:				
CH_4			15	15
N_2O			6	4
CFC			24	12
Others			—	8
Total			100	100

**Source: WEC Journal*, December 1992, p 41

Concentrations of pre-industrial and 1990 greenhouse gases are represented in Table 3.

Table 3 Concentration of Greenhouse Gases in the Atmosphere*

Gas	Concentration, ppmv	
	Pre-industrial	1990
CO_2	280	353
CH_4	0.8	1.72
N_2O	0.288	0.31
CFC-11	0	0.00028
CFC-12	0	0.000484
O_2 (tropospheric)	—	0.02-0.1
H_2O (stratospheric)	—	3-6

**Source: WEC Journal*, December 1992, p 38.

Despite some uncertainities in the estimation of greenhouse gas emissions, it is believed that the human activity derived emissions arc over 50% CO_2 out of which upto 80% originates from the production, transportation and consumption of energy.

It is well to recognize that had there been no atmospheric greenhouse effect, the surface temperature of the earth would have been - 18ºC, too low to sustain life. The natural greenhouse effect maintains the earth's surface temperature at around 15°C. Thus the greenhouse effect by itself is not the concern is due to the enhancement of the greenhouse effect resulting from human activity generated emissions and the changes in the atmosphere that used to occur over a century are now occuring in a decade. If the emission of greenhouse gases continue to increase at the present rate, IPCC scientific assessment indicates an increase of the global mean temperature of about 0.2-0.5°C per decade and the atmosphere may be warmer by about 1.5 to 4.5°C in about 50 years.

GDP and CO_2 Emission

This growing environmental pollution and thermal imbalance have apparently been caused by the accelerating pace of industrialization since the industrial revolution about 200 years ago based largely on the use of fossil fuel energy resources. There appears to be a mad race amongst both the developed and developing countries for attaining higher and still higher GDP (Gross Domestic Product), which is the yardstick for measuring the economic growth of a country. In the process, it has been forgotten that the higher GDP is being attained at the risk of increased environmental pollution, for a higher GDP index is invaribaly associated with higher emission of polluting agents like CO_2, NOx, SO_2, etc. The Economist Book of Vital World Statisitcs (1991) shows that the per capita GDP increase is inveriably accompanied by an increase in per capita carbon emission. This will be evident from Table 4.

Table 4 GDP and Carbon Emission*

	GDP, Billion US $	Per Capita GDP, US $		Per Capita Carbon Emission, t	
	1988	1970	1988	1960	1987
USA	4881.00	4922	19,815	4.38	5.03
Japan	2859.93	1938	23,325	0.69	2.12
West Germany	1208.29	3049	19,743	2.68	2.98
France	949.99	2831	17,004	1.64	1.70
Russia	583.00	—	2,055	1.85	3.68
Canada	488.75	4107	18,834	3.05	2.73
England	826.32	2209	14,477	3.05	4.00
Australia	232.80	2520	14,083	2.33	4.00
China	332.79	120	301	0.33	0.56
India	267.24	100	335	0.08	0.19

**Source*: Economist Book of Vital World Statistics, UN (1991).

The CO_2 emission per GDP, however, is much higher in less developed countries than in OECD (Organisation of Economic Cooperation and Development) countries where population is much less while the GDP is much higher and the energy-use is much more efficient. This is reflected in Fig 1 giving tonnes carbon emission per head and per million US$ GDP.

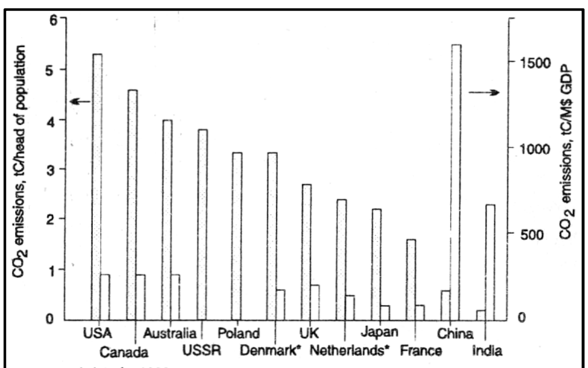


Fig 1 CO^2 emissions per head of population and per US$ GDP in 1988*
Source: WEC Journal, December 1992, p. 50

Enhancement or reduction of gas emissions from use of coal in power generation will depend on abatement measures involving both conventional and advanced technologies that can be adopted now and in the immediate future.

Environmental Impact of Hydro-energy

Till recently, hydropower has been considered as one of the most valuable and reliable environment friendly dean renewable source of energy. It is only financial constraints that prevented greater exploitation of major hydropower potential in developing countries. Of late, however, under the new environmental agenda, the effect of hydropower exploitation on human settlements, laud and flora and fauna are being seriously reviewed. Mass awarness and agitation in this respect has already led to the cancellation or freczing of many projects in Brazil, United States, Sweden, India, Czech and Slovak Republics, Hungary, etc.

Three mega dam hydro projects in India, namely, the Sardar Sarovar Project on the river Narmada in Bharuch District of Gujarat, the Indira Sagar Project again on Narmada in Khandwa District of Madhya Pradesh and the 260.5 m high Tehri Dam Project on the Bhagirathi in the Tehri Garhwal District of Uttar Pradesh have raised so much controversy and generated so much of data against the environmental viability of the projects that the wisdom of going ahead with the projects is still in doubt.

For instance, according to official figures, the construction of Sardar Sarovar and Indira Sagar Projects would jointly displace over 300000 people of the Narmada valley from their centuries-old ancestral land, submerge about 130482 ha of land of which 55681 ha is prime agricultural land and 56066 ha forests affecting seriously (as per assessment of the Forest Conservation Advisory Committee of the Ministry of Environment and Forests) the ecological balance of the area with change in climate, rain cycle upset and decrease of vital oxygen content in the air.

Large parts of the India u sub-continent arc quake-prone particularly the vast Himalayan zone and the North-East region, which is seismically one of the most active regions with recorded history of several earthquakes. The approximate energy released by an earthquake of magnitude 7 on the Richer scale is equivalent to the explosive power of 90700 t of TNT and that of magnitude 8.5 equivalent to 28 615 850 tonnes of TNT. The Tehri dam is being constructed in this highly quake-prone region ignoring the advise of experts and recommendations to the contrary by various committees set up for the purpose. If there is it disaster at Tehri dam, the destruction to life and property can only be imagined. According to the estimate of Dr Narasimhan, following failure of Tehri Dam, Deoprayag, Rishikcsh and Hardwar and their environs will be wiped out by a 70 m high flood surge within 1 h 20 min, Meerut and its environs destroyed by a 10 m flood wave witbin6 hand Bulandshahar by a 7 m flood Water within 12 h.

Also, in case of large dams the possibility of high intensity earthquakes due to Reservoir Induced eismicity (RIS) created by the pressure of huge quantities of water stored in large dams is of late being increasingly recognized.

It would thus be apparent that the current technology for exploitation of natural resources for energy generation alone has created environmental problems that are causing concern and woory for the health of this planet. When the environmental and ecological impacts of industrial and agricultural activities, transportation systems, urbanization and particularly population growth rate are added to the effects of energy generation, the concern becomes a headache.

IMPACT OF POPULATION GROWTH RATE

The problem has been further aggravated by the growth of population, particularly in developing countries. In 1830 AD, the population of the earth was 1 billion. In 1930, it grew to 2 billions, in 1960 to 3 billions, in 1990 to 45 billions and by 2000 AD, the population is estimated to be about 6.2 billions. The population growth rate in India is still more alarming. From 440 million in 1961, it grew to 844.4 million in 1991 and is projected to reach the 1000 million mark by 2001 AD. Our techno-economic development system is being stressed beyond limit to meet the increasing demand for food, energy, shelter, employment and other infrastructural needs resulting from the staggering increase of population. The basic life support systems are under severe stress with the risk of disrupting the future of man.

All the environmental risks and ecological imbalance noted earlier are appearing on the horizon of the earth with more than 50% of the world population of about 5 billions livir far below the standard existing in Europel, North America and Japan. Can we conceive of the pressure to which the finite resources of the earth will be subjected and the resulting environmental pollution when the below-standard 50% of the 5 billion try to make a quantum jump to attain equivalent standard of living?

What is even more alarming is to find that whereas, in the industrialized countries, the population growth rate has almost fallen to zero, this is growing almost exponentially in India and some developing countries. This near exponential population growth rate, unless ruthlessly checked and controlled, would lead to crisis states in all fronts - air, water, energy, food, shelter, etc

SUMMARY OF ENVIRONMENTAL PROBLEMS

It would be clear from what has been discussed above that existing technology-oriented exploitation of land, Willer, forest and minearl resources by man for ever increasing agricultural production, energy generation, industrialization and urbanization have resulted in-

(a) Degradation of the quality or soil surface and ground water and of soil fertility through increasing use of chemical fertilizers and pesticides;

(b) Large-scale denudation of forests leading to desertification, soil erosion, increase in frequency of floods and draughts;

(c) Increasing land degradation due to deforestation, bad mining processes and pollution or rivers, lakes and waterways caused by harmful and hazardous wastes relased into the water bodies, many of which can nolonger support marine life;

(d) Enormous pressure on land due to increased population and land degradation reducing in the process the per capita cultivable land in India from 0.48 ha in 1951 to an estimate 0.11 ha in 2000 AD;

(e) Massiva air and water pollution due to large scale industrialization, with acid rain, depletion of ozone layer, increase in greenhouse effect, etc as the outcome; and

(i) Pollution of the food cycle due in turn to pollution of ground water by penetration of acid rain and other toxic wastes.

Even then, any thought of slowing down the pace of development would be simply unacceptable to both developing and developed societies for development in needed to improve standard of living and quality of life.

THE PHILOSOPHY OF DEVELOPMENT IN RELATION TO ENVIRONMENT

If mankind is to survive and life on earth is to be sustained with continued development activities, there is an urgent necessity to reorient our thinking in respect of use and processing of our resources that would satisfy human needs with minimum resource waste while sustaining economic growth and development within the carrying capacity of the eco systems.

A change in our collective outlook and approach towards societal development process is necessary. It must be realised that there exists a dose link between all components of the earth - living and non-living, animate and inanimate - which has been a basic feature of Indian thought since ancient times and it is important to protect and preserve such concepts. It is well to recall here the classic words of Adlai Stevenson in his last speech made in the U N Economic and Social Council in Geneva on July 9, 1965. He referred to the earth as a little spaceship on which we travel together 'dependent on its vulnerable supplies of asir and soil' and advised careful husbandry of the earth as 'sine qua non' for the survival of the human species and for the creation of decent ways of life for all the people or the world.

Our resolve should be to make sustainable management of natural resources of the earth a reality rather than a cliche. Dissipation of resources of the earth for short-term gain to cater to the ever increasing demands of a consumerist society must he stopped. The philosophy of approach should be, to quote Mahatma Gandhi: "Earth provides enough to satisfy every man's needs, but not every man's greed".

The limiting factor is not human ingenuity or Jack of scientific and technological ability but obstacles within the social and political structures. The success of our effort to sustain life on earth through least wasteful and least harmful use of natural resources will depend upon how in future-

- We transport ourselves and our products
- We heat our homes and work places
- We produce our crops
- We manufacture our products
- We handle the wastes

• We get our energy, and the like

and adopt other measures to attain the prime objective of judicious and justifiable use of our natural resources with minimum of waste and environmental degradation.

THE CHALLENGE AHEAD

Technology in its present form based primarily on non-renewable resources is the outcome of the efforts, ingenuity, creativity and innovative ideas of scientists, engineers and technologists. There is, therefore, no reason to doubt the capability of the same scientists, engineers and technologists to take the technology in the other direction, away from the state of increasing depletion of nature's store of non-renewable resources, away from the environment degradation effect of today's technology and towards a more nature-friendly and environmentally benign technology. The imperatives of a fundamental change in our historical patterns of production and consumption pose serious challenges to the scientific, engineering and technological community.

The challenges involve

1. Management of land, water and air to ensure least disruption of the earth's natural cyclic processes.
2. Technology and processes to reduce wastage of mineral resources and energy consumption.
3. Reuse and recycling of wastes in all forms.
4. Mining processes integrated with restoration of land in its original form.
5. Energy generation beyond the conventional concept with the simultaneous aim or resource conservation and pollution reduction.

To quote United Nations Conference on Environment and Development (UNCED) regarding the role of scientific and technological community as spell out at the Rio-de-Jeneiro Conference held in June 1992, "The scientific and technological community, with its enormous capacity for generating possible solutions to the many problems the Earth faces today, can greatly contribute towards environmentally sound and sustainable development. Yet its potential has been far from fully realized, due in large part to insufficient communication. It is imperative that links between this valuable human resource and both decision makers and the public be expanded and strengthened".

CONCLUDING OBSERVATIONS

The silver lining in this otherwise deteriorating environmental scenario is that the risks for the planet and its inhabitants have been realised and the process of saving the planet from disaster, started a little more than two decades back, has now gathered such momentum as to generate hope in mankind that the situation is not beyond redemption.

National Environmental Engineering Research Institute (NEERI) at Nagpur has recently reported development of desulphurization processes for coal, crude oil and gases. The technology developed when fully exploited would ensure that when fossil fuels are burnt sulphur will not be released into the atmosphere thus practically eleminating the problem of acid rain.

Centuries old tribal practice in Andhra Pradesh of using powdered seeds of the tree Chila Ginjalu (Strychnos Postatorm) to purify drinking water because of the flocculation property or ability of the powder to bind itself with impurities and remove them has now been converted by the scientists of Andhra Pradesh Girijan (Tribal) Cooperative Corporation into a wonder anti-polluting agent by isolating a bio-flocculant from the seed. The substance, which is non-toxic and bio-degradable, can bind 18 metals like gold, silver, copper, nickel, uranium, thorium, cobalt, ere besides helping in cleaning effluents from factories containing toxic mercury and cadmium as well as reactor effluents containing traces of uranium and other metals. Its ability to remove cobalt is particularly useful in nuclear engineering since the steel used in the area must be cobalt-free.

The metal binding ability of bio-flocculant is due to the presence of proteins. Plans for collaboration lire on to further purify the proteins in the bio-flocculant and improve its metal binding ability.

Intensive research and accelerated pace of development-work are being carried out by major automobile manufacturers in the USA, Japan and Germany, notably GM, Nissau and BMW to produce commercially viable electric vehicles that would provide the range, performance, safety, passanger comfort , trouble-free operation, etc ell rreutly.ava liable with gasoline/diesel powered vehicles and at a competitive price. Commercial EV's with comparative performance goals may be on the road by end 2000 AD or early 2001 AD which will help to reduce dramatically air pollution in congested urban areas.

These and similar such works going on throughout the world in industries, institutions and research laboratories give the man hope for a cleaner and safer world environment in the near future.

REFERENCES

1. Barbara Ward and Rene Dubos. 'Only One Earth,' Andre Deutsch.

2. E F Schumacher. 'Good Work,' B I Publications, New Delhi.

3. E F Schumacher. 'Small is Beautiful,' Blond & Briggcs Ltd, London.

4. "Technology for a Beller World Environment.' Digest on 2nd World Congress on Engineering and Environment. The institution of Engineers (India).

5. 'Energy for Tomorrow.' Summary of Digest on 14th World Energy Conference, Montreal, The Institution of Engineers (India).

6. Dr B B Sundaresan. 'Need for Environmental Impact Appraisal of Development Projects.' Bulletin of the Institution of Engineers (India), vol 37. no 2. August 1987.

7. P Khanna. 'Policy Options for Environmentally Sound Technology." Bulletin of the Institution of Engineers (lndia), vol 41. no 10, January 1992.

Il. I M Smith and K V Thamhimuther. 'Greenhouse Gas Emissions and the Role of Coal.' Journal of World Energy Council, December 1992.

9. R T Watson. H Rodhe, H Oeschger and U Siegenthaler. 'Greenhouse Gases and Aerosals. 'Climate change: the IPCC Scientific Assessment. Cambridge University Press, Cambridge. ux.

10. P N Bhagwati. 'The Crucial Conditions.' The Hindu Survey of the Environment, 1991.

11. P S Ramakrishnan. 'Striking a Balance.' School of Environmental Sciences, JNU. The Hindu Survey of the Environment, 1991.

Present Energy Scenario in India

Dr S Z Qasim

Member (Science), Planning Commission Yojana Bhawan, New Delhi

INTRODUCTION

Let me begin by thanking Prof H B Khurasia, Chairman of the Institution of Engineers (India), Madhya Pradesh State Centre, for his kind invitation to me to deliver the Fourth S C Bhattacharyya Memorial Lecture. Before I start the topic of today's lecture, I would like to pay my homage to Dr Satish Chandra Bhattacharyya who had a unique distinction of establishing mechanical engineering as a subject for advance education in the country. Being an educationist and a scholar par excellence, he could visualize the potential which mechanical engineering could offer for the growth of industrial development in the country. It is really amazing that in the early part of this century, he could conceive the importance of applied mechanics, strength of the material, design of machine tools and thermodynamics, which could find their large scale use in the post-independence period. It is in the memory of such an eminent engineer, academician and a teacher of outstanding merit that this lecture has been dedicated.

The topic of the lecture has been carefully selected for two reasons. Firstly, because the theme of this year's Convention is 'Tribology for Energy Conservation in Industries'; and secondly, because the energy sector and particularly energy generation, its transmission and distribution, which really call for considerable skills and innovations in mechanical engineering, are the fields which were very dear to Prof Bhattacharyya.

HISTORY OF ENERGY PRODUCTION

Power is generated from a number of sources, namely, coal, lignite, natural gas, liquid fuels (diesel, etc), hydel, nuclear, solar, wind energy sources, and biomass. The total energy production has increased from 1712 MW in 1950-51 to 81 230 MW in 1994-95. By the end of the Eighth Plan, ie, by March 31, 1996, our expectations were to reach 100 000 MW of energy production, but it seems this target we will not be able to achieve. However, we expect there will be significant additions during the period 1995-96 to the total energy production. Gross generation of electricity has increased from 5.1 billion kWh to 353 billion kWh during the same period that is from 1950-51 to 1994-95 respectively. The present generation capacity from thermal source is 72%, hydel 26% and nuclear 2%. The per capita electricity consumption has increased frpm 15.6 kWh in 1950-51 to about 300 kWh in 1994-95.

The share of hydel capacity has come down from an all-time high of 50.62% in 1962-63. to 26% in 1994-95, it and is likely to go down further in the coming years. The transmission and distribution losses have increased from about 14% to over 23% in 1991-92. The Plan-wise targets and achievements in the generation capacity are shown in Table 1 and the total expenditure on the energy sector is given in Table 2. It may be seen that the percentage achievement of the target for capacity addition was the highest in the Seventh Plan. This became possible, to some extent, by a greater use of natural gas for power generation during the mid-80's. From Table 2 it is clear that the allocations of resources for the energy sector have been increasing substantially with each Plan reaching more than Rs 434 000 crores in the Eight Plan.

Major sources of power generation are as follows.

Coal

Coal is the most important primary source of commercial energy. The gross reserves of coal are presently estimated to be around 200 billion tonnes. About 70% of the coal reserves are located in the Eastern Region comprising the States of Bihar, West Bengal and Orissa, while another 20% of the resources are located in Madhya Pradesh. However. the current coal production pattern is very different. At present. a little less than 50% of the total production comes from the Eastern Region, while around 38% is contributed my Madhya Pradesh.

The annual production of coal has increased from 33 million tonnes in 1950-51 to 253.8 million tonnes in 1994-95 at an average annual growth rate of 47.4%. Most of the coal being produced today in the country is from opencast mines. This has led to a gradual decline in the average quality of coal. It was 6600 kcal/kg in 1950-51 and it has become less than 4400 kcal/kg in 1994-95. The average quality of coal supplied to power station, which account for around 70% of the present coal consumption, has also gradually declined to about 3880 kcal/kg. There has also been a decline in the quality of coking coal which is mainly used in steel plants. As a result, there has been an increasing trend in the imports of superior quality coal during the last few years. The coal imports are reported to have touched 8.13 million tonnes during 1994-95.

TABLE 1
TARGETS AND ACHIEVEMENT IN GENERATION CAPACITY ADDITION, MW

Plan	First	Second	Third	Fourth	Fifth	Sixth	Seventh
Target	1300	3500	7040	9260	16 550	19 666	22 245
Actual	1100	2250	4715	4610	10 983	14 226	21 401
Ach, %	84.6	64.3	67.0	49.8	66.4	72.3	96.2

TABLE 2
EXPENDITURE ON THE ENERGY SECTOR IN EACH FIVE YEAR PLAN

Plan	Period	Plan Expenditure, Rs Crores
First	1951-56	1 960
Second	1956-61	4 670
Third	1961-66	8 580
Fourth	1969-74	15 780
Fifth	1974-79	39 430
Sixth	1980-85	109 290
Seventh	1985-90	220 220
Eighth	1992-97	434 100

Lignite

Lignite mining started in 1960-61 with a production of 0.05 million tonnes in that year. The production of lignite has gone up to 19.1 million tonnes in 1994-95. Lignite deposits are located far away from the coal-bearing areas. The power sector is the major user of lignite.

Crude Oil

The projected reserves of hydrocarbons in India are placed at around 20 billion tonnes. The recoverable reserves of crude oil, which were 806 million tonnes in the beginning of 1991, are now estimated to be 765 million tonnes as per the 1994 figure. The indigenous production of crude oil, which was less than 0.5 million tonnes in 1960-61, steadily went upto 10.5 million tonnes in 1980-81. With the discovery of Bombay High, the production increased to over 34 million tonnes in 1989-90. The production from Bombay High declined thereafter in view of the planned containment of oil and gas production from Bombay High fields because of the control measures taken up to restore the health of these fields. As a result, the self-sufficiency in oil declined as large imports of oil had to be continued in the wake of increasing demands for petroleum products.

The degree of self-sufficiency in oil production which was 35% in 1975-76 started increasing with the increase in the domestic production of crude oil through exploitation of the Bombay High fields in the early 80's. The degree of self-sufficiency (measured as the ratio between indigenous production of curde oil and the consumption of total petroleum products in the economy in terms of crude oil equivalent) was the highest at around 70% in 1984-85. It showed a declining trend after 1984-85 due to a sharp increase in the demand of petroleum products and a decline in the crude oil production from the Bombay High. With the restoration of the sick wells, the indigenous production has started increasing now.

As per the current projections, the degree of self-sufficiency will be only around 50% by the turn of the century as the oil production may reach a plateau of around 50 million tonnes a year.

Natural Gas

Natural gas is another important source of primary energy which has been increasing sharply with time. The balance recoverable reserves of natural gas the presently estimated at 707 billion m^3, The production of natural gas has increased to 1.445 billion m^3 in 1994-95 at an annual growth rate of 11.42%. A large volume of natural gas had to be flared in the past due to lack of majorfacilities for its utilisation. However, the flaring rate has now come down to 10.3% in 1994-95 from 52.7% in 1970-71 because of the launching of a number of projects to control flaring. There has been a change in the pattern of use of natural gas with time. Apart from being used as a raw material for producing fertilisers and other petrochemicals, the natural gas has found an increasing use in power generation. It is being used as an industrial fuel since the mid - 80's.

NEW AND RENEWABLE SOURCES OF ENERGY

The renewable energy programme was initiated on a moderate scale in wake of the energy crisis in 1973. The programme was slow to take off initially but has picked up considerably with the passing years. A resource survey has indicated a large potential for exploitation of renewable sources of energy. Potential estimates of different sources are available at the Ministry of Non-Conventional Energy Sources and these have been given in Table 3.

TABLE 3
POTENTIAL FOR RENEWABLE SORUCES ENERGY IN THE COUNTRY

Source/Techology	Potential/Availability	Potential Exploited
Biomass plants, million	12	2
Biomass-based power, MW	17	Marginal
Efficient woodstoves, million	120	18.5
Solar energy, Wh/year	5×10^9	
Small hydro, MW	10 000	250
Wind energy, MW	20 000	275
Ocean thermal, MW	50 000	
Sea water power, MW	20 000	
Tidal power, MW	9 000	

PATTERN OF ENERGY CONSUMPTION

Table 4 gives the pattern of energy consumption from commercial and non-commercial surces of energy. Non-commercial sources include wood, residues from agriculture, cowdung, etc.

As may be seen from Table 4, the share of non-commercial surce has been declining and the share of commercial energy consumption has been steadily increasing. This trend is likely to continue in the future.

TABLE 4
CHANGES IN PATTERN OF ENERGY CONSUMPTION

Period	Primary	
	Commercial	Non-commercial
1953-54	28.6	71.4
1960-61	34.6	65.4
1970-71	40.6	59.4
1980-81	47.5	52.5
1990-91	59.9	40.1
1993-94	63.2	36.8

PERFORMANCE OF THE ELECTRICITY INDUSTRY

The highest body in the power sector is the Central Electricity Authority (CEA) which plans the growth and expansion at the national and regional levels. The thermal power production is being looked after by the National Thermal Power Corporation (NTPC) and the hydroelectric power is being dealt with by National Hydroelectric Power Corporation (NHPC). Both these are public sector undertakings (PSU). Another public sector, namely,· the Powergrid has been set up primarily for the transmission and distribution of power at the regional and state levels. In addition to these there are Regional Electricity Boards (REBs) and State Electricity Boards (SEBs) in each state.

The performance of the NTPC has been good during the last few years and it is improving with time. This corporation has been able to generate its own resources from the market. The progressive decline in the hydel power generation in itself speaks of the state of health of the NHPC which needs a lot of extra resources to improve. The Powergrid is doing its best to reduce the transmission and distribution losses.

The State Electricity Boards (SEBs), on the other hand, have been running into financial difficulties and most -of them, except the Maharashtra State Electricity Board and a few others which are making profits, the others have been running at huge losses. They owe large sums of money to be paid to the NTPC, NHPC, Powergrid and also to a few private undertakings. There is a lot of improvement needed in the SEBs to function as service and commercial organisations which was the very purpose of their creation.

RURAL ELECTRIFICATION

Rural electrification programme was started as a plan programme since the First Plan. The main components of the rural electrification programme are village electrification and pumpset energisation. This has helped in increasing the intensity of irrigation in the agriculture sector and has led to the success of the 'Green Revolution' through the high yielding varieties (HYV) of seeds. The HYVs need a lot of fertilizers and irigation. As a result the consumption of electricity in the agriculture sector has increased with time, directly through fertilisers. Consequently, out of the total electricity sold by the utilities, the share of electricity consumption in the agriculture sector for irrigation purposes alone has increased from 3.9% in 1950 to over 28% in 1991-92.

The number of villages electrified before the commencement of the First Five-Year Plan was only 3061 out of the total villages of around 5.76 lakhs (1971 census). During the period of ten years (1951-1961), an additional 18700 villages were electrified. Village electrification received a major impetus from the Third Plan onwards and during the period 1961-91, the village electrification rose from 8% to 85%.

The rural electrification programme has played a key role in mitigating the adverse effects of drought especially during the years 1965-67, 1979-80 and lately 1987-88. At present against the total estimated potential of 1451akh pumpsets around 100 lakh pumpsets have been energised in the country. The large scale extensive use of pumpsets has contributed significantly in containing the loss of food grain production during the periods of drought.

The present rural electricity distribution system is characterized by long low voltage lines which are usually extended on an ad-hoc and haphazard bais mainly to meet the requirement of the loads of agriculture pumpsets.

The phenomenal growth of the rural electrification system, particularly during the last two decades, has not been accompanied by a commensurate strengthening of distribution and sub-transmission network. The all round scarcity of resources have resulted in under investment in the sub-transmission and distribution system which in turn has increased system losses and consumers complaints due to low voltage, frequent break-down, burning of motor/ equipment, etc.

The uncertain power supply and poor condition of the distribution network have been forcing the rural beneficiaries to depend on diesel pumpsets for irrigation as stand by. The population of diesel pumpsets has continued to proliferate despite the large scale investments being made in the rural electrification programme.

PROGRESS MADE IN NON-CONVENTIONAL ENERGY SOURCES

Wind energy programme is aimed at promoting the development of efficient, reliable and cost-effective technologies for harnessing the vast wind potential in the country, for various applications such as wind power generation, water pumping and wind battery charging. The programme comprises wind resource assessment, research and development and demonstration projects pertaining to wind pumps, grid-connected and stand-alone wind electric generators, and wind battery chargers.

Although wind power generation compares favourably with the conventional power plants, wind generation is site specific and cannot be used for peaking purpose. However, wind potential can be harnessed and fed into the grid wherever it is available through the setting up of wind farms. Tamil Nadu and Gujarat have been specially successful in promoting wind farms through involvement of the private sector. Out of the estimated wind generation potential of 20 000 MW in the country, only 56.13 MW has been tapped through demonstration projects and another 50 MW has been tapped by private entrepreneurs.

Mini/micro/small hydro are old and reliable renewable sources of energy, used both for mechanical applications as well as for generation of electricirty. Power from small hydel projects can provide energy for the rural, remote and hilly areas of the country in a decentralised and cost-effective manner. The mini/micro hydel programme, however, is facing problems due to the non-availability of grid for transfer of surplus power and also because of the present tariff policy for the purchase of power. These issues have to be urgently resolved to enable large scale exploitation of micro hydel potential, in which private participation would have to play a key role. Out of the potential of 5000 MW, only about 100 MW has been tapped through this programme so far.

The objective of Solar Photovoltaic (SPV) programme is to promote rapid development and application of solar pv technology for rural electrification in unelectrified areas especially through promoting the use of stand-alone SPY systems. Photovoltaic systems are currently being used in the country on a commercial basis for powering a variety of low power applications such as telecommunications, railway signalling, telemetry for off-shore oil platforms, cathodic protection, microwave repeater stations and TV transmission.

Besides the high cost, the other major problem in the promotion of solar photovoltaics in the rural electrification programme has been the operation and maintenance especially the maintenance of batteries.

This problem can be tackled only through the training of the beneficiaries and by the involvement of local and village organizations is this programme. So far about 5 MW of SPV have been installed.

Solar thermal power generation in MW ranges has not been commercialised in the country, although operational power plants are in existence in the USA and Israel. The installation cost of solar thermal power project would be around Rs 14 - Rs 15 crores per MW based on the existing cost projections. At present there are no operational MW range projects in the country. Only experimental solar thermal power plants of the capacities 20 kW and 50 kW have so far been set up in the country. A 30 MW solar thermal power plant is proposed to be taken up in Rajasthan based on the experience in California, USA. In view of the prohibitive cost it would be appropriate to set up pilot plants and gain operating experience from them before taking up the solar thermal route for production.

ENERGY CONSERVATION

Energy conservation does not imply reduction in the energy consumption. Rather, it involves an efficient use of energy without adversely affecting the economic and social growth. Further, energy conservation involves improving the efficiency in energy extraction, its conversion, transmission and distribution, optimizing the fuel use pattern, reducing the energy intensity by bringing about structural changes in the economy, and changing the energy use habits of consumers through life-style changes, and demand side management, as well as increasing productivity of the energy use in various end-use sectors.

Energy conservation is not limited to electricity saving alone, but involves all forms of energy, whether in the commercial sector like coal, oil, petroleum products or in the form of non-commercial energy like cowdung, firewood, agricultural wastes, etc. This account however provides information on some energy conservation technology.

Significant potential exists for energy conservation in all the sectors of the economy including industry, agriculture and domestic sectors.

Table 5 gives the potential for energy conservation in these sectors, and specifically for the large energy-intensive industries.

PRIVATE SECTOR PARTICIPATION

A package of fully cleared projects has been identified to be offered to the private investors. The total capacity so far advertised for the private participation is 33854 MW as indicated in Table 7.

PRIVATE INVESTORS' RESPONSE

It is reported that by December 1992, proposals for 40 private power projects involving 197 12.5 MW capacity and investment of about Rs 46483 crore have been received and that the Ministry of Power have so far short-listed eight of these proposals as 'fast track projects' and the remaining as 'expressions of interest.' Many of these parties are reported to be interested to set up joint ventures with the Central and State power undertakings. In spite of the initial euphoria witnessed in the form of a large number of proposals, the actual progress in the private sector participation in power development has not been upto the levels anticipated when policy changes were announced in 1991.

TABLE 5
POTENTIAL FOR ENERGY CONSERVATION IN DIFFERENT SECTORS

Sector/Industry	Conservatio Potential %
Industrial Sector	upto 25
Agricultural Sector	upto 30
Domestic Sector	upto 20

TABLE 6
POTENTIAL FOR ENERGY CONSERVATION, %

1.	Iron and steel	8-10
2.	Fertiliser and pesticides	10-15
3.	Textiles	20-25
4.	Cement	10-15
5.	Chlor-alkali	10-15
6.	Pulp & paper	20-25
7.	Alumunium	8-10
8.	Ferrous foundry	15-20
9.	Petrochemicals	10-15
10.	Ceramics	15-20
11.	Glass	15-20
12.	Refineries	8-10
13.	Ferro-alloys	8-10
14.	Sugar	70-80

TABLE 7
UNITS IDENTIFIED FOR PRIVATE SECTOR PARTICIPATION

	Type of Units	Nos	Capacity, MW
1.	Thermal (coal)	31	19755.0
2.	Thermal (gas)	15	6117.5
3.	Hydel	53	7612.3
4.	Wind energy	8	62.0
5.	Solar energy	1	30.0
6.	DG sets	3	278.0
Total	111	33854.8	

CONCLUDING REMARKS

From the foregoing account of the existing power scenario it is clear that the entire power sector of the country is in a precarious state at present and demands immediate attention of the Government. The total power production of about 81 000 MW, which we have achieved in about 45 years will have to be repeated in 10 years time if we wish to continue and maintain the accelerated pace of socio-economic development in the country. Unless there is a political will on the part of the country as a whole to improve the power sector, so vital for the country's economy and prosperity, it is feared that the economic development of the country may face an inevitable crisis and setback. Therefore, the cooperation of the engineers, technologists and scientists is required to achieve our desired objectives in all sectors of power in the country.

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

The Nature and Scope of Innovation and Innovation Management

Prof R Natarajan

Director, Indian Institute of Technology – Madras, Chennai

ABSTRACT

Innovation is increasingly being recognized as the key to competitiveness. This paper explores the anatomy of Innovation, and attempts to identify the key success factors promoting innovation, as also barriers and impediments to innovation. Managing innovation requires a well planned strategy and commitment from top management. Hi-tech industries are essentially knowledge-intensive and knowledge management is emerging as an important area of concern; at least one successful company is exploiting the concept of Electronic-Body-of Knowledge. Particularly for our country, the emerging Technology Denial Regimes must act as motivation for promoting innovation. The recent Germany's Technological Performance Report, Mckinsey studies and Peter Drucker's wisdom are reviewed to provide valuable lessons.

1. THE ANATOMYOF INNOVATION

Innovation stands for new products, information, knowledge and services. It stands for Renewal ; recreating oneself It requires Imagination and Insight. It is more than just invention and marketing ; it should extend the realm of possibilities of the organization and its people. It implies "thinking beyond traditional boundaries ". One creative artist explained: " Creativity is in that which I do, and not in me ". There is also no proven scientific theory about Creativity or Innovation.

Creativity is for more than a grandiose flash of inspiration. It is a process, a discipline, an ability which goes beyond simple improvements. Creativity has a sisterly bond with curiosity. The following two quotations capture the essence of Innovation:

- The old is always yesterday's innovation. Innovation is tomorrows redundancy.
- The future can best be predicted by inventing it» - Alan Kay, Xerox Palo Alto Research Centre, the legendary Power House of ideas in California.

Table I provides a summary of major differences between Creativity and Innovation; which are often employed synonymously.

TABLE I

SOME DIFFERENCES BETWEEN CREATIVITY AND INNOVATION

CREATIVITY	INNOVATION
Dictionary definition : The ability to produce new and original ideas and things ; imagination and inventiveness.	A new idea, method or invention ; the introduction of new things.
✪ Intrinsic to all humans and can be 'triggered off' in a variety of ways.	✪ Requires specific conditions to be created in Cos. where strategic, organisational issues are creatively resolves through the involvement of people.
✪ Individual creativity associated with flashes of insight.	✪ Requires a focussed search for the resolution of clearly identified issues.

It is frequently observed that the same creative individuals will be more creative in certain environments than others. A case in point is that three of 'our' recent Noble Prize Winners, Chandrasekhar, Khurana and Amartya Sen were awarded the coveted honour in recognition of work done abroad, not in India. Our high-quality manpower which prefers to go abroad to pursue their professional careers, characterized as Brain Drain, cite the lack of a challenging and fair work environment as the principal (push factor' for their decisions. It is pointed out that the demanding environments abroad provide: .

- a strong focus
- a general awareness of new ideas
- an open atmosphere for discussion, and
- a healthy balance between individual competition and social cooperation.

Mckinsey considers Innovation to be much more than product development or R&D. Innovation is at the heart of sustaining corporate performance through the process of continuous change and renewal. It is what it takes corporations to create and sustain leadership and competitiveness. It has far more to do with continuously challenging the status quo and pushing for corporate self-renewal than it has to do with creativity and ingenuity per se.

Kito de Boer believes that Innovation per se is not a 'good thing'. The only universally 'good thing' is performance. Good Innovation must be both new and also create wealth. Newness can come from 3 sources - preferably in combination;

- New to the consumer
- New to the producer
- New to the channel.

According to him, Innovations incorporate new <u>Insights</u> about the consumer, new <u>Technologies</u> that reinforce 'the producer's competitive capability, and new <u>Business Processes</u> to improve the ability of the corporation to deliver value. Depending upon the amount of newness and wealth generated, he provides a taxonomy of innovation:

- <u>Incremental Innovation</u>: creates products; it is the basic price of survival in most markets. Individually small, they are collectively important. An example is a new improved version of Rin detergent with an improved optial brightness.

- <u>Step change Innovation</u> : creates businesses ; it is the major engine of growth, and can create significant- shifts' in competitive advantage. - An example is the entry of Nirma, which incorporated -new insights 'about consumers, in addition to new business processes to deliver large volumes at lower cost. Titan watches is another example, combining new quartz technology and new business processes, creating the Titan shop.

- <u>Transformational Innovation</u>: Creates industries; corporations can capitalize on market transformation by riding the wave of change. An example is the emergence of powerful and efficient retailers, which has transformed the consumer industry for big companies like P & G and Unilever. It is also expected that the emergence of electronic shopping on the internet will transform retailing in the future.

2. KEYSUCCESSFACTORSFOR INNOVATION

- Top management commitment;
- A formal innovation process management with periodic reviews of progress and achievement;
- Consumer understanding coupled to idea generation;
- Dedicated resources and cross functional project team - working. This takes care of doing too many things at the same time; and finally
- A Culture that encourages creativity.

These lessons can be summarised as :

- Innovation is the business of Business
- Innovation is the driving force for survival
- Innovation requires a cooperative mode of management.

3. WHAT COMPANIES MUST DO TO CREATEAND SUSTAIN A CULTUREFOR INNOVATION

Sometimes companies benefit from Serendipity, which refers to accidental discoveries or brainwaves that can be readily converted to a commercially viable outcome, but such occurrences are more the exception than the rule.

Companies must create an environment where innovative thinking becomes the norm. Irani has identified the following factors which are essential conditions that can stimulate Innovation in organisations :

- A culture that empowers people
- Recognition of innovative thinking, and
- Prevalence of outstanding leadership.

In an organisation promoting Innovation, problems are looked at as opportunities turned inside out. Commitment from employees is created by sharing information with them and thereby creating trust. The ability to think autonomously, and in an environment free from fear lays the Foundation for collectively tapping the innovative potential of people.

A formal system of recognition and public encouragement for innovative thinking helps to communicate to the organisation what it expects from its members.

Leaders can transform organisations, and make the difference between an ineffective bureaucracy or a dynamic organization exploiting innovation. Leaders who can inspire and sustain change possess certain special qualities.

- Are not satisfied with the status-quo.
- Believe that things can always be made better than they are today.
- Carry people successfully over uncharted paths.
- Believe in cultivating the spirit of adventure and of taking calculated risks.

4. FACTORSINHIBITING INNOVATION

- Managing the present as the principal focus, ignoring the learning that occurs from making mistakes.
- Not having the will to initiate desirable change
- Choice of (wrong) leader.
- Absence of a commitment to use innovation as a competitive tool; easier to invest in proven approaches;
- Business managers do not find it necessary to provide leadership for the successful exploitation of innovation;
- The Not Invented Here (NIH) syndrome which smacks of intellectual arrogance.
- A tendency to work on a large number of projects with no relationship to the resources available.

5. BARRIERSTO INNOVATION - WITH SPECIALREFERENCETO OUR COUNTRY

5.1 COUNTRY- SPECIFIC BARRIERS

- Lack of consistent and sustained policy support
- Lack of sincerity of purpose and transparency
- Tradition of rote learning
- Technology is alien to the majority of the population
- Ideological hang-ups
- Gap between public announcements and practices
- Lack of entrepreneur - friendly ambience
- Too much reliance on routine jobs.

5.2 EDUCATION- SPECIFIC BARRIERS

- Too much regimentation and rote learning
- System aimed more at solving social equity problems than at nurturing merit
- No specific efforts to promote Creativity and Innovation
- Acute scarcity of motivated) committed and trained teachers.

5.3 INDUSTRY - SPECIFIC BARRIERS

- Lack of self-confidence - in Indian academic and industry capabilities
- Product volumes too small to afford investments In innovation promoting activities
- Industry is largely oriented to domestic markets and not to export markets.
- While India has a large body of educated and trained manpower, the extra bit required to create innovation products is lacking
- Indian Industry is pre-occupied with problems of infrastructure, raw materials, cash flow, procedures, bureaucracy, politics.

6. INNOVATION MANAGEMENT

Managing innovation is not an oxymoron. It is found that highly innovative companies manage the actual process of generating, developing and implementing innovative ideas better than their competitors.

According to Siemens, their measure of success is that "90% of the products we well are not older than 2 years". The 3M Co. are proud of the fact that 30% of their profits come from products less than 3 years old.

Two main stumbling blocks in drafting a structured process for managing Innovation are:

- The piecemeal approach taken to Innovation, which needs to be overhauled.
- The types of products brought to market tend to be Technology-driven, reflecting the features that Engineers were promoting, rather than what Customers really wanted.

Banga points out that there are two critical legs in innovation management;

- doing things right; i.e., managing projects efficiently
- doing the right things; i.e. optimising the portfolio of projects in a business.

He has compiled the following list of principles for Innovation Management:

- Less is more: Resources are always limited ; accordingly, more the number of projects, the less the resource for project, leading to drop in productivity.
- Business - led Research Programs:
- Easily involvement of senior management
- Resource Commitment
- Progress evaluation
- Innovation Culture: a system to encourage and capture ideas from all over the organisation. Innovation is a risky business, and the environment should encourage people to take risks. Success must be rewarded; failures must be learned from but not feared.

7. THE KNOWLEDGEBASIS OF INDUSTRY AND BUSINESS

It is estimated that one in every 3 or 4 gainfully employed persons works with knowledge - intensive technologies in industrialized countries. Increasingly, traditional manufacturing jobs are being replaced by new occupations in software engineering, services and consulting. In Siemens, for example, over 50% of value added stems from knowledge - intensive services. In IT or telecommunications, in which the product cycles are particularly short, the share of knowledge - intensive value added is considerably higher. The ratio of hardware to software on the world IT market has shifted from 51:49 to 41:59 in 10 years. Today, a new chemical formula is discovered every minute, a new physical relation every 3 minutes, and a new medical finding every 5 minutes. More information is printed everyday than in the entire period between the invention of printing and World War - I.

As our knowledge expands, two key factors come to the fore:

- Our capacity to find our way through this material, to identify and define problems, and to absorb knowledge in a focussed manner.
- The technical means needed to obtain access to all this knowledge quickly, precisely, and in a manageable form.

Today's employees are responsible for managing knowledge themselves. They have to both acquire and apply knowledge in parallel throughout their working lives. We have to change the established sequence:

- first taking a degree to acquire knowledge,
- then finding a career in which to apply it.

We need to establish a culture of life-long learning. There can no longer be any way of completely acquiring all the knowledge in a given area of specialization. Rather, the focus must be on acquiring a basic store of knowledge that facilitates the assimilation of the relevant parts of a specialized field at a later stage. We need need based education and training ; very much like the just-in-time concept in manufacturing, we need it in education and training also.

The requirements of the new knowledge society are:

- ability to organize knowledge - base.
- Provide high-speed access to large amounts of it.
- Select and prepare it.

The desirable changes in our S&T dominated world are brought about not only by the revolutionary idea of a few, but also, and above all, by the evolutionary contributions of many.

8. KNOWLEDGEMANAGEMENT

In their search for a sustainable advantage, Executives are asking:

- what is it that makes our firm unique?
- what can we play on that is not bought and sold in the market place?

According to Larry Prusak of IBM, the answer turns out to be : what a company knows, and how it knows what it knows, plus a culture that sustains knowledge.

One of the strategic issues around Knowledge Management is Resource - based Theory ; the idea that a firm is a collection of resources built up over time, and that the collection bounds what the Firm can do. For better or worse, history counts. It is important to ensure that knowledge assets are not under-optimized; to capture and retain knowledge. It is becoming difficult for large, dispersed Firms to know what they know, and to know where the knowledge is. Unfortunately, there are more demands on people's time, which constrains the sharing of knowledge.

Once a reporter asked Prusak: "Tell me everything you know about Knowledge Management in one sentence", Prusak answered: "Hire smart people, and let them talk", A soft answer, but it illustrates a Knowledge Principle.

The conventional Business model is a Machine: lean, efficient. But, Prusak calls it the wrong model. Machines don't need to learn; they just need Energy. Human beings need to learn; they need to reflect. So a firm has to build in Time for that. Many aspects of knowledge are not systematic; a lot of knowledge gets. generated and transferred while having a cup of coffee with a colleague in the hallway.

8.1 ROLEOF DOCUMENTSANDDATABASES

Documents, databases and reports are sources of information. They can convey discrete bits of knowledge; the advantage is that these are efficiently shared, especially with IT. But information is bounded; it is just a message. It is valuable, but it is one-way.

8.2 THEATTRIBUTESOF KNOWLEDGE

Knowledge is alive, not dead, which means we can query it. It has sub-text and interaction. Some kinds of knowledge just aren't easily captured in documents. Michael Polanyi points out: "Try explaining to someone how to ride a bike. Try to write a report on it. It would be a waste of time, because it is not documentable. It is tacit knowledge, and it can be so difficult to articulate that it generally requires interaction between people". The more multi-dimentional knowledge is, the more difficult it is to stuff it into a flat report. It flourishes and is nourished by conversation.

8.3 HOWTO ADDVALUETO INFORMATION

It is so important to transform information into knowledge, by adding value. There are several means of doing this:

- By including authors who can be contacted, so you can follow up with questions
- By adding Multimedia
- By providing the context:
  - Why something was done
  - What the results were
  - What the rich understanding of what occurred was.

Context is often more important then content. The plotonic ideal is: Space Conversation. This offers an opportunity for Technology to play a role: it can simulate a conversation when a conversation can't be had.

8.4 HOWA COMPANYCAN(MANAGECJ ONVERSATION

What many people do not recognize is that people have only so much Time; they therefore don't just give knowledge away. "Knowledge does not flow like water, smoothly and for free", "There is actually a Market for knowledge; it has buyers and sellers; it has brokers; and it has a price system".

The economics of attention is at work: why should I spend my time giving what I know to you ? Knowledge is scarce, because time is scarce. In Economics, where there is a scarcity, a price system would evolve, so that equilibrium is approached. The price system of Knowledge in a firm is Reciprocity: I will help you because you will help me in the future.

There are a few things that a company should do for better Knowledge Management. It can create electronic 'yellow pages' : directories or maps of knowledge - holders across the company, so people can make connections ; then provide them the time, resources and assistance to tranfer and absorb knowledge. The company can also create a knowledge market place. This can be a physical place; like the Japanese "talk rooms" or more structured environment like Knowledge Fairs, the company's internal trade show or open-house, where the employees or staff can swap expertise and experience. It can also be cyberspace, a discussion database or intranet, a place for groups to raise and answer questions, for discussions, or tackle specific projects.

Knowledge manifests itself in three places in a firm:

- It is embodied in people gathered in networks and communities
- It is embedded in work routines and processes
- It is represented in artifacts like Reports.

Firms are applying knowledge principles to understand the sources of hidden value; looking at things from a knowledge prospective. The role of Teams is increasingly recognised. It is realized that giant, far-flung teams don't always work well. It is wrong to believe: "Just give them Technology, and they will act as a Team", but they don't.

The bottom line is : Knowledge is Power. Knowledge is much more than Information, Databases, Documents, Reports. There are several important players in Knowledge Management : People, Teams, Interaction, Conversation, Analysis, Synthesis, Innovation, Corporate Culture.

9. ELECTRONIC BODYOF KNOWLEDGEAND ITHINK

Infosys has been employing this concept to advantage, not only to enhance productivity, but also to enhance re-usability. The principal features of this concept are:

- An electronic repository of all the learning in the organization o Provides instant access to the organizational wisdom and knowledge.
- Logging of the data on the Do's, the Don'ts, the tricks to use, the tricks to avoid in anything that they do the first time.
- Reusability improves productivity.

Infosys also uses a systems dynamics tool, I think, developed at MIT, to help them with their strategic planning. Infosys employs this tool to model the planning and operations of the company and to teach project management to staff. It is a process mapping simulation tool, and uses closed loop, causal relationships in modelling.

In this process, Infosys has elicited the following experience and response from the system:

- Force and diktats do not work In a white-collar environment.
- People need to see benefits.
- Electronic systems require discipline. Since the majority of the workforce is young and on their first job, indiscipline is an issue.
- Younger people accept changes better.
- People in operational areas resist change.

10. TECHNOLOGYDENIALREGIMESAS MOTIVATION FOR PROMOTING INNOVATION

Bijlani has clearly brought out the necessity for India to undertake and promote Innovation in Technology Development in the current and emerging scenario of Technology Denial Regimes, WTO imperatives, etc. It is increasingly being realized that it is technology, not tariffs, which will keep competition at buy. Technology transfer has long been relied upon in our country for acquisition of advanced technology. It belies a lack of understanding of what technology is all about, and what the emerging imperative are.

Most of what has been acquired as technology through technology transfer agreements is in the nature of acquisition of drawings and process know-how for manufacture of goods. It did not include the knowledge of materials, procedure for product development) specifications and standards. Bijlani points out that Technology, in the final analysis, is the ability to develop, to make things we have not seen before, the ability to systematically develop new products, keeping in mind their life cycles.

Some of the technology denial regimes which are closing in around us, and which will make it difficult, if not impossible, for us to procure technology, are:

- EU policy on export of dual-use, equipment, materials and technology
- The erstwhile COCOM) which coordinated multilateral export control regime during the cold war against the Eastern Bloc countries in Europe, is now being given sharper teeth.
- European controls for items such as AC servomotors, preloaded ball screws, limit switches and bearings, which have already affected Indian machine tool manufacturers.
- The Dual-use and Related Goods Regime introduced by the UK in 1995.
- Japan has created a new database to cover information on 'suspect buyers', of technology.
- Germany has banned export of 'sensitive items'.

It is thus seen that denial of technology is not confined to military goods. The TDR is expected to cover more technologies and products in the coming years. Bijlani points out that "Purchasable Technology is out of date and Contemporary Technology is not purchasable", and calls for a "new urgency to technology development by Indian Industry".

11. LESSONS FROM GERMANY'S TECHNOLOGICAL PERFORMANCE REPORT TO BMBF, 1997

The recent report on Germany's Technological Performance to BMBF, the German 'Super-Ministry' of Education, Research, Science and Technology, has reviewed their past performance and has explored future opportunities commensurate with their strengths. It foresees good prospects for the future because of the foundation provided by 5 factors :

- Highly skilled labor force, particularly in fields that are key to Innovation in the Technological and Organizational areas.
- Productive, high-powered R&D facilities that produce marketable S&T findings.
- Broad store of know-how in forms
- Intensive application of know-how in Industry, and integration of generic technologies into the broad industrial spectrum
- Industry's highly developed ability to translate knowhow into technological innovations, products for global markets, and top-quality services processes.

The Report makes a distinction between 'cutting-edge' and 'advanced' technologies, on the basis of 'research-intensiveness'. The major differences are compiled in Table 1.

The Report identified some special characteristics of the German Education, Industry and Innovation Systems.

11. 1 EDUCATION

Education, Technology and Know-how are the fundamental factors for ensuring high income and employment levels in Germany. Recently, a shortage of graduates in S&T fields is beginning to develop. The Education Policy faces the challenge of creating new opportunities for people who have seen their job options reduced as a result of structural change.

11.2 R&D AND INNOVATION SYSTEMS

It is pointed out that decoupling R&D efforts and successful innovation would only work for a short time. A good business outlook is a vital pre-requisite for expanding R&D capabilities. Internationalisation of R&D is progressing rapidly in research intensive industries) such as Telecommunication and Semiconductor products. "Mature technologies" seek proximity to leading users who set global standards. Standards must be set that they are geared to the "potential of technology", rather than to the "state of technology". Innovations in the German system are likened to the progress of a centipede : their many legs move them slowly, but surely forward.

11.3 GROWTH AND EMPLOYEMENT

International competition in hi-tech industries has become tougher and demands high efficiency levels. Despite high growth rates, jobs continue to be shed — especially in all fields of Mechanical and Electrical Engineering, Chemistry, and traditional consumer electronics. A similar trend is evident in Japan and Italy. But the situation is different in USA, Great Britain and France, where hi-tech industries have been generating jobs. In Germany, the major exception is auto industry.

11.4 NEWCLUSTERS- INNOVATION INDUSTRIES AND SERVICES

New jobs are being created in the service sector. Industrial products are increasingly defined in terms of their attendant services Development, software, Marketing, Training, Consulting, Financing, Maintenance, Logistics. The service sector is the sole source of innovation in cutting - edge fields such as I&C Technologies, Medical Engineering and Pharmaceuticals and aviation industry. Such impetus is also expected from other service fields such as Transport, Health and Energy.

11.5 INNOVATION'S SELECTIVEIMPACT ON JOB MARKET

Innovation has a selective impact on the job market. Employment among the highly qualified is rising, whereas unskilled labor is experiencing a worsening situation. This trend is found also in the service sector, which is looked upon as the magic remedy for alleviating unemployment problems. This is also the case in USA, where even a booming job market cannot close the growing gap between rich and poor. Innovation leads to job cuts because it raises productivity levels. On the other hand, without innovation, international competition would be a direct threat to unproductive jobs. Hence, it is concluded that there is no alternative to innovation-oriented policies. The job market's biggest problem is not overly qualified persons, but those with little training or wrong type of training, whose work is increasingly easy to automate. The Education Policy must deal with two challenges.

- It must create new opportunities for people who have seen their employment options reduced as a result of structural change.
- It must develop training opportunities for people who do not meet the requirements of Germany's dual education system.

Education is the best insurance against unemployment.

11.6 KEEPINGPACEIN KEYTECHNOLOGIES

Some research-intensive fields evidence themselves less as final products than as basic and generic technologies, that have widespread impact in the form of components and intermediate products, which are integrated into final products, and are then scarcely traceable at product level. Technologies which have a strong impact on Growth and Employment include new technologies such as biotechnology, multi-media technology, as well as mature technology such as micro-electronics and environmental engineering.

11.7 INNOVATION - INCHING AHEADOR TAKING A LEAP FORWARD

Germany's national innovation system is described as "a model of cooperative consensus". It does not produce as may "radical innovations", as in the U.S., where new technologies have only loose ties to prevailing industrial structures. In Germany, innovation develops primarily on an "incremental" basis, as the result of close cooperation between Science, Research and Industry. Innovators in Germany are compared to a centipede: they move forward slowly, but systematically and surely, on their many legs.

12. McKINSEY WISDOM

Mckinsey attaches more - much more - importance to Performance than Innovation, per se. "Who cares if a company is great at innovation if it doesn't perform". It talks about "earning the right to grow": if a company is performing badly, growth will only drive it deeper into the hole. Sustainable high performance is the true hallmark of corporate success.

McKinsey has performed a study of us companies - the best and the worst performers over the past decade; it examined them through the prism of innovation to determine whether Innovation plays significant role in driving performance and to establish whether 'culture' emerged as a key enabler. They took shareholder value addition as the primary performance measure.

Their study revealed the following interesting results. The top 10 companies in the us over the past decade in descending order are: Coca Cola, General Electric, Wal Mart Stores, Merck, Microsoft, Procter and Gamble, Philip Morris, Johnson and Johnson, AT&T and Motorola. This list includes $3^1/_2$ consumer goods companies, 1% pharmaceutical businesses and 1 each from retailing, telecom services, telecom equipment, software and a conglomerate. Together these 10 companies added $ 330 billion of shareholder value.

The bottom ten starting from the worst are: General Motors, Ford Motor, RJR Nabisco, IBM, Digital Equipment, Chrysler, Westinghouse, K Mart, Federated Department Stores, and Occidental Petroleum. Together these 10 companies destroyed $ 70 billion in shareholder value. An interesting observation is that with the exception of the auto companies, the bottom 10 come from the same industries as the top 10. This suggests that there are no bad businesses just bad companies.

At first sight, Innovation does not suggest itself as the reason for success : The only time Coca Cola tried to change their product, their consumers revolted. A close look reveals, however, that all of the winners have actively fostered a culture that stimulates innovation, and consider it as their source of life. Mckinsey has synthesized the cultural attributes into a framework, named L.E.A.P.

- Leadership
- Environment
- Aspiration
- Processes

It is found that leaders who foster a culture of innovation have 3 key attributes:

- Willingness to destroy what exits:

" It is important to show some insensitivity to your past in order to show proven respect for the future" - Goizueta.

- Powerful sense of purpose.
- Personal involvement in sustaining a stretching but supportive innovation culture.
- Innovation is full of paradoxes and contradictions:
    - In order to succeed it is essential to fail
    - Creation involves destruction
    - Long-term success may depress short-term performance
    - Performance today is the best predictor of performance in the future
    - The more successful you are, the most help you want.

There appear to be 3 key components toward creating a supportive innovation culture:

- Relentless pursuit of performance.
- Outward - looking
- Learning by doing

Raising aspirations is a powerful motivator and catalyst capable of liberating hidden powers; such companies set unreasonable targets, then expect to fulfil them. The best known example is that of Jack Welch's (stretch' targets; this involves using dreams to set business targets, with no real idea of how to get there.

13. PETER DRUCKER'S NEW RULES FOR R&D

Peter Drucker , who has been quite successful In advising the corporate sector to successful performance and in defining the future course of management paradigms, has proposed some new rules for R&D. He proclaims that R&D should be business-driven, not technology-driven. According to him, the starting points of the new R&D paradigm are the business goals and strategy of the firm; for example, RCA color TV, and Sony VCRs, fax machines and copiers. First-rate R&D labs need to be set up as free-standing businesses. The R&D function would be better managed by a 'Technology Manager' than a "Research Director'.

Every new product, process and service begins to become obsolete from the time it breaks even. In the context of result-based approach to R&D, any distinction between 'Pure' and 'Applied' research is meaningless. In effective research, Physics, Chemistry, Biology, Maths., Economics, etc. are not 'disciplines' with determinate boundaries; they are tools and resources for creative use towards accomplishing performance objectives.

R&D work comprises three different but complementary dimensions of effort : Improvement, Managed evolution, Innovation. R&D efforts should aim high to make a real difference in the customer's life or business. Effective R&D requires both long-range and shortrange results. Effective R&D requires 'organized abandonment' of products, processes, services and research project, when:

- There are no more significant improvements
- New products, processes, markets or applications no longer come out of managed evolution '
- Long years of research fail to produce commercially useful results.

Appendix I lists some interesting quotes and points relating to Innovation. Appendix II shows an unlikely nexus between ice-cream and Computational Fluid Dynamics (CFD).

******

APPENDIX- I

SOME INTERESTING AND RELEVANT QUOTES / POINTS

- Innovation tells us where to go ; we don't tell innovation where to 1,0 - De Simone (3M)
- We don't' have a strategy, we have a process and a culture welded to a discipline - De Simone
- We get paid to produce results. We don't' get paid to be right - Goizueta (Coca Cola)
- It is important to show some insensitivity to your past in order to show proper respect for the future - Goizueta
- We're going to do 2 principal things; be very innovative and satisfy customers in all aspects - De Simone
- The way to beat Bobby Fischer is don't play him at chess. Pick another game. Don't play with businesses that you can't win. As I constantly tell my executives, if you can't be no.1 or no.2, we will either fix you, sell you or close you.
- 3M is single - mindedly focused on performance. It is committed to generating 30% of its sales from products launched in the past 4 years, coupled to 10% sales growth, 20% return on equity, and 27% return on capital.
- The World is expecting more from India than India is expecting of itself - M. B. Athreya.
- No one gets hired at Mckinsey who says that India is different - Mckinsey policy
- Innovation is the central issue in economic prosperity – Michael Porter
- Innovation is more likely to happen if there is a visionary leadership - Akio Morita (Sony)
- The Innovative process does not begin by bubbling up from the R&D lab. It begins with a mandate which must be set at the highest level of the corporation - Akio Morita.
- Be better than competition; and if you cannot be better, be different - Japanese Paradigm
- Change is not a sideline of business leadership; it is integral to the whole idea - Bijlani (Mar)
- Changing things is central to leadership; changing them before anyone else is creativeness.

APPENDIX- II

THE NEXUS BETWEEN ICECREAM AND CFD

Unilever employed CFD in order to design their chocolate ice cream bar. Its quality problems related to incomplete chocolate coating on bars, melting out of ice cream at the corners, air bubble entrapment, etc. The process entailed the passing of ice cream bars at -25°C under a curtain of molten chocolate at 40°C which was subsequently recycled. CFD was employed to study the velocity and temperature profiles, which, among other things, showed a hot spot at the top right hand corner, and helped to redesign the shape of bars.

BIBLOGRAPHY

1. JJ. Irani "Creating and Sustaining a culture for Innovation", in "Innovation for Corporate Renaissance", All India Management Association Excel Books 1997

2. Kito de Boer "Innovation Myopia - The Great Leap Forward " Ibid.

3. P.K. Chadha "Contemporary Trends in Manufacturing and Technology", Ibid.

4. S.K. Bijlani, "Contemporary Trends In Manufacturing Technology", Ibid.

5. M.S.Banga, "Managing Innovation", Ibid.

6. N.R. Narayanamurthy, "Innovations in systems", Ibid.

Manufacturing Technologies of the New Millennium — The Need for Speed

Shri C J Aneje, *FIE*

Executive Director, HMT Ltd., Hyderabad

I Deem it as an honour to have been invited by the A.P. State Centre of Institution of Engineers, to deliver the.S.C. Bhattacharya Memorial Lecture.

Although, I never had the opportunity to meet or interact with this distinguished mechanical engineer, highly respected educationist and teacher of our country, I still have some lingering memories of my professors narrating about him and his contributions in the field of thermodynamics, applied mechanics, theory of machines, strength of materials, machine design etc. I also remember to have referred some of the books authored by him during my engineering.

At the outset, I would like to caution this august gathering that they may find my views having a bias towards Machine Tool Industry. Well, I am basically from the Machine Tool Industry, having worked in the same or in related industry for the last 3 decades and hence the tilt. This is not deliberate but basically meant to draw and rely on my experience.

We all know that since the beginning of 1990, the country has witnessed sweeping changes taking place in many fields. Bold and innovative measures have been adopted by the Government to liberalise our economy and integrated it into world economy.

These reforms continue to take place even today. The new liberalised policies of the Government have exposed the Indian Industry to :

- Global competition.
- Increased and aggressive competition among
- Indian Manufacturers.
- Free market environment.
- Demanding customers, in terms of :
  - Higher Quality
  - Reduced Price
  - quicker deliveries
- Rapid Technological developments.
- Competitive prices for Goods and Services.
- Lifting of tariff protection for imports.

Consequent to liberalisation, the customer have several alternatives to choose any product, be it indigenously manufactured or imported. Thus, the end product coming out of an organisation be it industrial equipment or consumer durables, has to match international standards of technology, performance and value, to meet the customer requirements.

CHANGED MARKET SCENARIO (NEED FOR CHANGE)

Due to this volatile market diktat, innovations for product configuration, cost and delivery are the main factors which will determine the manufacturing processes to be adopted.

Industrial products, Consumer Goods and Consumer Durables are the three major sectors where manufacturing activities take place, in addition to the infrastructural sectors like Power, Transportation, Steel, Aero-Space etc. All the changes that are happening in the market place, have undoubtedly, put us in an exciting period of manufacturing that is unmatched in history. The speed of change in both markets and the workplace, is driven relentlessly by Mechatronics, digital technology and globalisation. In this changing environment the manufacturing technology/process should be able to cater to :

Higher productivity

Enhanced flexibility

Cost effectiveness

Quicker deliveries

and thus support the organisation to sustain a competitive edge in the market place. In today's business there are quite a few factors that are influencing the dynamic changes in the market place, which are predictable. The major factors are change and rate of change.

An environment of change means opportunity, but for only those companies that identify the changing needs of their customers and understand the relative strengths of their competitors.

All the above suggest that in the new millennium the manufacturing industry will undergo a paradigm shift from complacency to struggle for existence. The manufacturing climate, is going to dictate that shops must stay abreast of any advancements that can offer gains in productivity or streamline processes and offer flexibility.

STATUS OF DEVELOPMENS

With the advent of new technologies, today;

• Genetics can create a tailor-made man.

• Bio-technology can produce a new plant variety or drugs with alarming effects.

• Computerised scanning can diagnose and monitor any disease.

• Star-wars can be fought sitting at home.

• Atomic energy can benefit mankind beyong imagination.

• Production of Synthetic/Composite materials exceeds that of steel by volumes.

• Unmanned factories have become a reality.

The modern scenario of development in new technologies, is marked by the advent of computers, the off-shoots of genetics, application and laser, fiber optics, robots, composite materials, new sources of energy, break throughs in space and ocean technologies and the vast strides made in the field of communication. Computerisation has brought quantum jump in automation of manufacturing methods and management a reality, and in the coming days computers will continue to get faster, smaller and less expensive, thus throwing up many more opportunities to the users.

CHRONOLOGY OF DEVELOPMENT

Before I proceed further to say more about the requirements of the new millennium, a brief look at the evolution of machines in the last 4-5 decades.

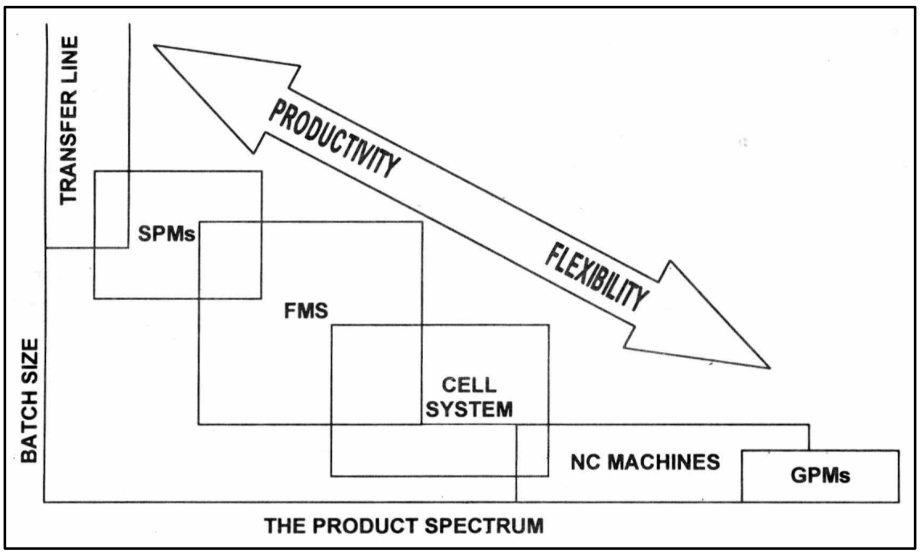
— Machines (Machine Tools) first took shape in the beginning of the 19th Century.
— The basic configuration of manually oprated machines (Machine Tools) has changed very little over the past couple of decades.
— These machines, though, labour intensive, had high flexibility for a minimal capital outlay.
— Early in the twentieth century, the mass market demand for motor cars stimulated the development of hard automated machines.
— These automatic machines had limitations of mechanical and relay logic technology. Flexibility could not be incorporated into these machines.

Nevertheless, these machines adequately served the needs of the day, manufacturing large quantities of identical components, with moderately high productivity.

The options for the user were either flexibility without productivity or productivity without flexibility. Since neither offered a truly satisfactory solution, most of the manufacturers, world wide, compromised by installing mixture of two types of machines.

— However, with the invention of low-cost micro-chips in mid seventies, the complexion of the manufacturing industry underwent a change. With the introduction of computerised numerical control based on microchips, a new technology has been implemented , which provided both productivity and limited flexibility. Thus, the birth of NC and CNC Machines took place.

— While a conventional Non-CNC machine costs less, it has a medium product flexibility, low volume flexibility and low productivity. A CNC Machine which entails a medium cost has high product flexibility, low volume flexibility and medium productivity. An FMC (Flexible Manufacturing Cell) which involves a medium to high cost has a firly high product flexibility, high volume flexibility and high productivity. An FMS (Flexible Manufacturing System) which definitely costs the highest as far as initial investment is concerned, offers medium product flexibility, a high volume flexibility and a very high productivity. This is graphically shown below;



CNC MACHINES

— In a conventional machine shop, only 5% of the job time is spent on the machine and 95% in moving and waiting. Again 70% of the time on the machine goes in positioning, loading, gauging and idle conditions, only 30% of the time is spent in cutting the material.

With the introduction of flexible manufacturing systems (FMS), which controls loading, transport between machines, tool changing and automatic positioning, one can achieve 75% of the job time on the machine. 60% of this time goes to material cutting and 40% goes to loading, gauging and idle time.

— CNC machines which have capabilities of programming and machining a part in a single set-up have facilitated fewer and simpler claiming fixtures. Drill Jigs are completely eliminated.

— Likewise in CNC machines, quick-change tooling systems have proven to be rigid and accurate, allowing the use of standard tool holders, cartridges and boring bars, in quick change adapters. This has resulted in reduction in variety and inventories.

— Similarly, CNC Machine which replaces several machines by one machine, has reduced the requirement of floor space quite significantly.

Developments have taken place in every sphere of manufacturing from raw material storage & retrieval systems to inspection of finished products, All these developments aimed towards improvement in manufacturing processes and using higher degree of automation.

Likewise, developments have taken place in the fields of tooling, inspection and quality control techniques, materials, painting techniques, metal forming design processes etc. All these have helped the India Industry to grow (though not at the desired rate) in pockets. Thus we have areas of excellence but the overall growth of Indian

Industry in terms of adoption of new technologies, has been far from satisfactory. This backwardness in technology, did not effect the producers much till mid nineties, because the industry was protected against global players.

With the onset of reforms, in terms of opening-up of the Indian Market to the world producers, the entire scene in the market place changed at a very rapid pace. These reforms exposed customers and users to world markets, thus providing alternatives, in almost every field. The days of "customer is the king" were ushered in. This caught most of the producers off-guard, excepting those clever ones, who kept abreast with the changing times and technological developments. Demand for level playing fields were made by the Industry (this demand continues even today). Producers who had the will to survive in the changed situations, adopted themselves to the developments and continue to compete in the markets.

As, the world enters into the new millennium, the advancements in technology in the coming years are going to take place at a much faster pace than earlier times.

As mentioned in the beginning, manufacturing is going to demand Higher Productivity, Flexibility and Cost effectiveness, in the coming years, which is going to be an environment of continuous change.

THE TRENDS

Thus manufacturing technology is going to demand: High speed machining (by using high frequency spindles) - for CNC Turning the spindle speeds of 8000-10000 rpm and for Machining Centers this could be around 20000-40000 rpm.

• Reduction in non-cutting time or unproductive function:

  — High speed turrets with indexing time of 0.2 to 0.3 sec.
  — Rapid traverses up to 60-120 m/min. (by using of linear motors)
  — Reduced tool change times - less than one second.

• Concurrent Engineering for reduced development times.

• Multi-task machining.

• CNC multi-axis machining.

• Higher spindle power for increased metal removal rates.

• Machines to machine hardened parts that once needed grinding and hand polishing.

• Higher feed rates without losing finishes.

• Thrust on dry machining.

• High end PC based CNC systems.

• Digital drivers.

• Laser cutting and machining.

• Use of carbide drills, coated carbide tools, cubic baron nitride (CBN) tools.

• Super finishing cutters for milling.

• In cycle gauging.

• Multi gauging.

• Non-contact multi gauging.

• Total engineering solutions including automation.

• Excellent styling etc. etc.

Tooling technology is very important for any manufacturing. It is said that modernising the tooling improves productivity by 50% and similarly modular tooling can increase machine utilization by more that 50% and throughput more than 30%.

Although tooling costs are less relative to machine costs, selection of proper tooling can make a significant difference in throughput and efficiency.

Manufacturers face challenges every day. In the coming years, customers are not going to machine one single part 24 hours a day, seven days a week. They will be running dozens of different parts each day throughout their manufacturing operation.

Hence, the machine builders need to give their customers the performance and flexibility they need. In the end, I am reminded of what Mr. Bill Gates, the legendary figure in the computer world has said and I quote :

"If the 1980s were about Quality and 1990s were about Reengineering then 2000s will be about Velocity (Speed)"

Ladies & Gentlemen - We are at the threshold of new millennium an era which will throw number of challenges and equal number of opportunities - An occasion to draw up action plans and implement with a resolute approach.

Manufacturers in particular shall devise plans for assimilation. of technology and probe the possibilities of joint working arrangements with established leaders in the market.

I am confident that, India, with its vast infrastructural facilities & in-built resilience can achieve accelerated growth in every sphere in the new millennium.

Thank you.

Molecular Nanotechnology

Mr Pradeep Chaturvedi

Chairman
The Institution of Engineers (India), Delhi State Centre

'Nanotechnology' is the word coined by Norio Taniguchi at the University of Tokyo, Japan. Nanotechnology is the rapidly emerging technology of building machines and mechanisms at the next level of precision and miniaturization. It uses a basic unit of measure called a nanometer. Nanotechnology is gaining popularity and is used to describe many types of research where the characteristic dimensions are less than about 1,000 nanometer.

Manufactured products are made from atoms. The properties of those products depend on how those atoms are arranged. If we rearrange the atoms in coal we can make diamond. If we rearrange the atoms in sand (and add a few other trace elements) we can make computer chips. If we rearrange the atoms in dirt, water and air we can make potatoes.

Today's manufacturing methods are very crude at the molecular level. Casting, grinding, milling and even lithography move atoms in great thundering statistical herds. We'll be able to snap together the fundamental building blocks of nature easily, inexpensively and in most of the ways permitted by the laws of physics. This will be essential if we are to continue the revolution in computer hardware beyond about the next decade, and will also let us fabricate an entire new generation of products that are cleaner, stronger, lighter, and more precise .

Nanoscale science and technology involve building devices and structures at nanoscale - the scale of atoms and single molecules. They can form gears, bearings, cantilevers, switches, machines, can direct electrons along one path rather than another, deviating from their pattern, design and habit. Nanotechnology lends a capability not only to image and view atoms, but also to move them that do the manual and the intelligent routines and chores; nanowheels that rotate; processors that can be injected in the individual's blood stream as super-diagnostic probes, and devices of the size of a sugar cube that can store one netre resolution maps of the entire globe.

It's worth pointing out that the word "nanotechnology" has become very popular and is used to describe many types of research where the characteristic dimensions are less than about 1,000 nanometers. For example, continued improvements in lithography have resulted in line widths that are less than one micron: this work is often called "nanotechnology." Sub-micron lithography is clearly very valuable (ask anyone who uses a computer) but it is equally clear that lithography will not let us build semiconductor devices in which individual dopant atoms are located at specific lattice sites. Many of the exponentially improving trends in computer hardware capability have remained steady for the last 50 years. There is fairly widespread belief that these trends are likely to continue for at least another several years, but then lithography starts to reach its fundamental limits.

If we are to continue these trends we will have to develop a new "post-lithographic" manufacturing technology which will let us inexpensively build computer systems with mole quantities of logic elements that are molecular in both size and precision and are interconnected in complex and highly idiosyncratic patterns. Nanotechnology will let us do this.

Molecular nanotechnology or molecular manufacturing will have the following objectives:

- Get essentially every atom in the right place.
- Make almost any structure consistent with the laws of physics that we can specify in molecular detail.
- Have manufacturing costs not greatly exceeding the cost of the required raw materials and energy.

There are two more concepts commonly associated with nanotechnology:

- Positional assembly
- Self replication

There is no single method that can simultaneously serve all the three objectives. However, this seems difficult without using some form of positional assembly (to get the right molecular parts in the right places) and some form of self replication (to keep the costs down).

The need for positional assembly implies an interest in molecular robotics, e.g. robotic devices that are molecular both in their size and precision. These molecular scale positional devices are likely to resemble very small versions of their everyday macroscopic counterparts. Positional assembly is frequently used in normal macroscopic manufacturing today, and provides tremendous advantages.Imagine trying to build a bicycle with both hand tied behind your back! The idea of manipulating and positioning individual atoms and molecules is still new and takes some time for getting used to. We need to apply at the molecular scale the concept that has demonstrated its effectiveness at the macroscopic scale: making parts go where we want by putting them where we want!

The requirement for low cost creates an interest in self replicating manufacturing systems, studied by von Newmann in the 1940s. These systems are able both to make copies of themselves and to manufacture useful products. If we can design and build one such system the manufacturing costs for more such systems and the products they make (assuming they can make copies of themselves in some reasonably inexpensive environment) will be very low.

MOLECULAR NANOTECHNOLOGY

Molecular nanotechnology is the name given to a specific sort of manufacturing technology. As its name implies, molecular nanotechnology will be achieved when we are able to build things from the atom up, and we will be able to rearrange matter with atomic precision. This technology does not yet exist, but once it does, we should have a thorough and inexpensive system for controlling of the structure of matter.

Other terms, such as molecular engineering or molecular manufacturing are also often applied when describing this emerging technology.

The central thesis of nanotechnology is that almost any chemically stable structure that is not specifically disallowed by the laws of physics can in fact be built. The possibility of building things atom by atom was first introduced by Richard Feynman in 1959 when he said: "The principles of physics, as far asl can see, do not speak against the possibility of maneuvering things atom by atom."

Scientists have recently gained the ability to observe and manipulate atoms directly, but this is only one small aspect of a growing array of techniques in nano scale science and technology. The ability to make commercial products may yet be a few decades away. But theoretical and computational models indicate that molecular manufacturing systems are possible - that they do not violate existing physical law. These models also give us a feel for what a molecular manufacturing system might look like. Today, scientists are devising numerous tools and techniques that will be needed to transform nanotechnology from computer models into reality. While most remain in the re:alm of theory, there appears to be no fundamental barrier to their development.

ACHIEVING THE PRECISE CONTROL

Using macro-manufacturing techniques as a guide, we know that managing fleets of nanomachines is no insignificant task. To name just a few essential requirements: we need a location for storing our atom inventory, a method for delivering an atom or molecule from inventory to the manufacturing floor, machines for assembling the various parts; and a way for controlling these processes, to ensure that the right quantity of parts is in the right place at the right time. By creating systems that work together to ensure each atom is properly placed, we will be able to manufacture products of high quality and reliability.

Upon considering these issues, K. Eric Drexler proposed a device called an "assembler", which at first might be little more than a submicroscopic robotic arm. Assuming this arm can be built and is controllable, we should be able to use it to secure and position compounds in order to direct the precise location at which chemical reactions occur. This general approach should allow the construction of large, atomically precise objects by initiating a sequence of controlled chemical reactions.

In order for this to function as we wish, each assembler will require a process for receiving and executing the instruction set that will dictate its actions. We have already created a system that does just that: the computer. Integrating computer technology with nanotechnology gives us a model that will allow the kind of manufacturing proposed. In time, molecular machines might even have onboard, high speed RAM and slower but more permanent storage. They should have communications capability and power supply. In case of the assembler, we might also develop interchangeable tips that can-be placed at the ends of the assembler's arms to allow for expanded functionality.

It would take a lone assembler an eternity to build anything we might hold in our hands as atoms are so small; and so we must think of a large network of assemblers working together to build our products. Networking machinery is something that we humans have learned how to do, and our understanding of the issues involved is becoming more sophisticated every year. If a computer network is reasonable guide, there is a vast potential for interconnectivity among nanotechnological devices.

THE NEED TO DEVELOP

Ignoring for the moment that scientists are a curious lot, always pushing the envelope of what can and cannot be done, precision has been mentioned as a benefit of molecular machines and is one of the key to understanding why we would want to develop this technology.

In this application, precision means that there is a place for every atom and every atom is in its place. Schematics will be detailed, and there will be no unnecessary parts anywhere in the design. We will use machines of precision to create products of equal precision. With this precision, we should be able to recycle all of the waste products produced by the manufacturing processes and put them to good use elsewhere. Manufacturing will also become less expensive as a result.

Technology has never had this kind of precise control; all of our technologies today are bulk technologies. We take a lump of something and add or remove pieces until we're left with whatever object we were trying to create. We assemble our objects from parts, without regard to .structure at the molecular level. Precise atomic-level fabrication has previously only been seen in the growth of crystals or in living biological organisms like the ribosome, which assembles all the proteins in living creatures, or DNA, which carries the instructions for creating a living being. If we incorporate similar processes during our development of nanotechnology, we will begin to gain a degree of complexity and control over systems that previously only evolution and nature have had.

Additional benefits arise when we consider the size of devices that we will be able to create. Once we are working on the atomic scale, we can create machines that will go places about which we could once only dream. More information will be packed into smaller and smaller spaces, and we will be able to do much more with much less. Nanotechnology promises unprecedented and efficient control over our environment, but taking advantage of anticipated developments requires forethought and planning. This is a primary aspect of Foresight's mission, and we continue to explore the costs and the benefits of developing nanotechnology.

HOW WILL NANOTECHNOLOGY IMPROVE OUR LIVES ?

One of the first obvious benefits is the improvement in manufacturing techniques. We are taking familiar manufacturing systems and expanding them to develop precision on the atomic scale. This will give up greater understanding of building things, and greater flexibility in the types and quantity of things we may build. We will be able to expand our control of systems from the macro to the micro and beyond, while simultaneously reducing the cost associated with manufacturing products.

Nanotechnology is expected to touch almost every aspect of our lives, right down to the water we drink and the air we breathe. Once we have the ability to capture, position, and change the configuration of a molecule, we should be able to create filtration systems that will scrub the toxins from the air or remove hazardous organisms from the water we drink. We should be able to begin the long process of cleaning up our environment.

Space will also open up to us in new ways. With the current cost of transporting payloads into space being so high ($20,000/kg), little is being done to take advantage of space. Nanotechnology will help by allowing us to deliver more machines of smaller size and greater functionality into space, paving the way for solar system expansion. Some have suggested that application of medical nanotechnology might even go so far as to allow us to adapt our bodies for survival in space or on other worlds. While this is certainly a long way off, it provides a glimpse of the thorough control that nanotechnology may provide.

Taking all of this into account, it is clear that nanotechnology should improve our lives in any area that would benefit from the development of better, faster, stronger, smaller, and cheaper systems.

PRECAUTIONS FOR SAFE DEVELOPMENT?

While nanotechnology will facilitate control over the structure of matter, we must ask ourselves who will control nanotechnology. The chief danger may not be a devastating accident, but instead, an abuse of power. We live in a competitive world, and one that is accelerating towards the development of molecular nanotechnology.

This concern about control issues encourages us to argue against secrecy. Combating the dangers will be greatly aided if we all have access to information about progress in the laboratory. If we reduce the number of projects being developed in a military black box, we will probably increase the number of people working on nanotechnology. Having more people involved in the field will mean that we are better able to defend ourselves in an emergency. We might see increase in the number of additional projects working on medicine, manufacturing and the environment. Openly focusing on projects that aid people should go a long way to ensure that information remains available to the public.

We must also remember that there are dangers from both accidents and deliberate misuse. Much can be done to prevent accidents through the promotion of a consistent ethical system and a system of accountability for those who develop and employ new technology. Trust will remain a central issue as nanotechnology research comes closer to deployment in the commercial world.

There are those who propose that trust is in short supply and that development guidelines should take into account that there will always be subversive elements. In this case, steps can be taken to prevent the abuse of nanotechnology through the application of, say, exotic environments, whereby a machine will only operate under specific laboratory conditions; and if applied, a machine released into the "wild" would cease to function.

Irrespective of trust issues, there are also concerns that replication errors may arise. We must work towards the creation of systems that reproduce information with few errors. Some suggest that it is also a good idea to design systems to limit internal evolution.

Computer systems continue to advance as well, with the development of faster smaller, and cheaper systems that have greater capacity. Assuming that security system also see improvement, then these should be applicable to molecular machines, once they are developed. These improvements will also impact our ability to model new molecular devices, and help stabilize design parameters before the machines are actually built.

Development in nanotechnology is expected to continue at an accelerating pace, given that funding for these types of research is increasingly available. While estimates range from 15-30 years, there is no question that nanotechnology will arrive in the not-too-distant future..

Some Issues in Emerging Manufacturing Scene

Prof D P Agrawal

Chairman, UPSC, New Delhi

Introduction

Industry is essential for the development of the standard of living of a country. A country in an early stage of development relies on primary production - agriculture, forestry, fisheries and mining - as its largest source of wealth - usually about one-third to one-half of its national income - and an even larger proportion of its work force is engaged in this sector, much of which very often is mere" subsistence farming". At this stage, manufacturing industry accounts for only a small proportion of the national income - one-tenth to one-seventh. Thus a large percentage rise in manufacturing output produces only a small rise in overall national income, whereas a small percentage improvement in agricultural output will produce the same overall rise. since the agricultural work force is a large proportion of the total in countries at an early stage of development, stagnation in its productivity and standard of living prevents any notable rise in COP. However during the last decade the growth in service sector has enabled over country to have a decent COP growth. Lot is needed to be done for the enhancement of the contribution of the industry towards the COP growth. This shall need considerable inputs in infrastructure sector especially for power.

Manufacturing is the process by which raw materials become a finish product. Manufacturing is a diverse field. Manufacturing took place on a larger and larger scale and was revolutionized during World War II, as machinery was needed on an even larger scale than ever before. The war needed equipment, and manufacturers across the country had to figure out ways to ensure that they could produce equipment quickly and at large volumes, while still maintaining quality. The post-war boom encouraged greater and greater production as people eagerly consumed more and more. Industries moved the manufacturing lessons learned during the war to the products wanted by consumers: televisions, refrigerators, vacuum cleaners, cars, and so on and so forth. The next real revolution in manufacturing happened in Japan, however, as engineers at companies such as Toyota and Motorola developed approaches to manufacturing that strove to reduce waste and increase quality while taking into account customer satisfaction and needs: Six Sigma manufacturing and lean manufacturing are examples of these types of approaches to manufacturing processes. In recent times IT has impacted the manufacturing process and systems. Computers too have been used widely for the same purpose. Further research in electronics and miniaturization for computers hardware and medical equipment has opened a new era of manufacturing.

Micro manufacturing

Emerging miniaturization technologies are perceived as potentially key technologies of the future that will bring about completely different ways people and machines interact with the physical world. Manufacturing at the micro-scale (a few microns to a few millimeters) is taking on increased importance as needs in bridging the nano- and the macro-worlds become more acute. Applications of miniaturization technologies can now be found in many areas including optics, electronics, medicine, bio-technology, communications, and avionics to name a few. These applications involve a wide range of engineering materials, three-dimensional features, and high relative accuracies. As a result, new processes and manufacturing equipment are being developed to meet needs not achievable by more conventional lithography-based, surface micro-machining techniques.

Key issues in micro manufacturing include mechanics and dynamics of process behavior at the microscale; the miniaturization of machines and equipment as well as associated issues such as tooling, fixturing, positioning, motion generation, sensors systems, and control; the microfactory paradigm; new concepts and methods for micro-scale metrology; materials handling, joining, and assembly at the micro-scale; multi-scale modeling and simulation; design for micro-scale manufacturing; and materials-related issues at the micro-scale. A broad range of processes will be considered including machining, forming, EDM and ECM, laser-based processing, and others.

Lean manufacturing

Lean manufacturing concepts were developed over the last five to six decades, primarily in Japan, particularly for the Toyota production system. These manufacturing techniques are conceptually different from the traditional process. For an example, traditional manufacturing works based on inventory. But lean manufacturing questions the role of inventory and defines as a waste it self.

Lean manufacturing is becoming lean enterprise by treating its customers and suppliers as partners. This will make the organization strong in all three conventional competition points. They are Price, Quality and the Delivery and enable them to deliver high quality products quickly, with low price.

Prime objective of waste elimination from the system is achieved with lean manufacturing technique and tools. Based on this requirement, Just In Time (JIT), Total Quality Management (TQM), Total Productive Maintenance (TPM),Flow charts, Workplace Redesigning techniques are used.

Basically, lean manufacturing technique consists of four steps. First step is to realize that there are wastes in the system to be removed. The second step, identify the different forms of waste and the causes for these wastes. In this step tools like Ishikawa diagrams or cause and effect diagrams can be used for good effect.

In the third step, comes the solution finding for the identified root causes. One golden rule to be followed in this step is adhering to the basic lean manufacturing principle of seeing the total picture. For an example if you are trying to reduce the line down time, it is very important to make sure the solution is not going to increase the lot sizes heavily and make the net effect on the organization a negative.

Final step is the implementation process and making sure things are going in the intended way. Here the solutions will be tested and implemented. User training and follow-up are among the most important things in this step of lean manufacturing technique. This step generally takes long time.

Lean manufacturing is based on a management approach that is called Five S. The first S is sorted: you need to prioritize. The second S is straighten up: straighten up your workplace so that time is not wasted in searching for things. The third S is swept: clean up your workplace so that nothing is in the way. The fourth S is sustain: sustain your operations. Maintain them well. The fifth S is standardize: the idea is that standardized operations are more efficient and effective operations. By implementing these 5S's, you can cut down on the time wasted in waiting for the arrival or the availability of different tools and machines, the time wasted in moving equipment around. You can also cut down on time and people wasted on taking care of avoidable processes, like taking care of problems with your inventory, taking care of queue problems, moving people around, or the problems caused by a poor use of space.

There are a number of important benefits that come from implementing a lean manufacturing strategy. You reduce the time of the product cycle, reduce inventory that is taking up space. Furthermore, you can both increase your capacity for production and reduce the amount of work that is in process., you can also improve productivity, efficiency, and quality. ROIC, will increase with the implementation of lean manufacturing.

Ways to improve manufacturing productivity

Analyze causes for downtime and rejects: Record and analyze machine downtime and reject events to minimize interruptions and poor productivity.

Monitor machines in real time: Detect problems before productivity and quality suffers: see real-time displays of efficiency, utilization, OEE, yield, rate, cycle time.

Automate production reporting: Implement automated production data collection and reporting from ALL types of production machines. Print standard and custom reports automatically and export data to Excel,1-2-3or your Enterprise systems.

Automate production scheduling, job tracking: Reduce time-consuming manual production scheduling and job tracking chores to just a few clicks of a mouse.

Schedule P.M. based on actual machine/tool use: Don't wait for your machinery to break or produce scrap before you perform maintenance. Instead, be proactive: schedule Preventive Maintenance based on actual machine / toolf component usage: run hours and cycle count.

Analyze manufacturing process variable performance: Monitor temperature, pressure, cushion, shot size, stroke, shut height, tonnage, inject/fill/hold time, etc. Chart as X bar and R or export it to SQC/SPC applications.

Implement OEF/ISO/Continuous Improvement programs: Develop real-world production standards to make your job costing accurate. Implement activity based costing, Continuous Improvement and OEE programs.

Manufacturing data collection for ERP, MES, CMMS systems: Close the loop with your Enterprise systems: Automatically download production schedules into System's 'Job Queue, then upload production/ performance/ productivity and usage data at Shift and Job end.

Export cycle counts and run time to CMMS systems. Eliminate manual "meter" reading and data collection: Production ACE can export actual runtime and cycle counts to any third-party CMMS/ EAM software during the production shift: cycle counts and runtime" meters" are updated in a real-time file.

Read and Print Bar Code labels at each machine as parts are made: Printed labels can contain your choice of information such as Product Description, Work Order #, Operator Name, Date/Time, Lot Number, etc.

Productivity Enhancement Techniques

Two decades ago JIT,TQM, SPC, and the continuous-improvement philosophy generally represented auto makers' frantic attempt to keep their heads above the flood of Japanese imports by adopting Japanese quality techniques. In the NAM's 1993 plant survey, the most popular technologies were CAD, TQM, JIT, and CNC, in that order. Soft technologies like JIT, TQM, SPC, MRP (Material Requirements Planning) and MRPII (Manufacturing Resource Planning), and manufacturing cells are still key factors in productivity in 1997,though bar codes, concurrent engineering, and simulation and modeling were added.

An interesting development in the 1997survey is that TQM is no longer one of the top four, though JIT remains. The top two technologies are now CAD and CNC, and LAN has pushed JIT out of third place. "Factory networking is taking, off, and because LAN is the key to computerized integration, plants in the' 90s are putting their money there".

Many manufacturers that had created islands of automation within their plants saw ERP as a way to integrate these automated systems and tap the benefits. This make a plant agile, enhancing the speed at which data flows and the ability of manufacturing systems to respond to changes. However, cellular manufacturing requires multi skilled operators.

Skill levels are crucial in getting the payoff from these technologies. Skilled work force reported the highest level of return on investment . Plant managers, especially those in small plants, may find vendor training, the best option. Managers in large plants will save about half that amount, so each plant must weigh the time-money tradeoff.

One of the benefits for having computers aid your quality control process is to eliminate human error. computers are programmed to use specific definitions to measure quality and are fixed for a computer.

Quality

Quality control is generally used in engineering and manufacturing in developing systems to ensure products or services that are offered to customers live up to their expectations. It will also improve the safety, reliability, and maintainability of their products. They will overhaul their products to ensure that their customer's needs are met and that the design, development, and production of the product are successful. Quality control techniques for manufacturing will vary from plant to plant as processes, equipment and human skill will vary from plant to plant.

With manufacturing quality control, companies will regulate their raw materials and assembly of these materials. They will take a look at all services that are related to the production of the product and they will also look at internal operations like management.

Small defects and manufacturing variations can become costly for any company. Several companies have begun implementing different lean manufacturing approaches to reduce manufacturing variations and defects. Some of the common methods include SixSigma, Total Quality Control, and the 5"S" Methodology.

For a manufacturing company, one of the most important things is to make sure that quality assurance process is up to par. The reason for this is because if you're not exceeding in quality assurance you are probably losing a lot of money. Quality assurance is vital to business. Businesses need to make sure their quality control processes are up to par. Losses in quality can cost companies and possibly customers.

Failure testing is an important part of the manufacturing process, no matter what you are manufacturing. Failure testing is a way to ensure that you are producing a product and service that will not fail under different circumstances and situations of stress, weather, temperature, and so on and so forth.

Total Quality management

Although occasional defects are to be expected, all must be done to prevent the same defect from happening twice. Recognizing and learning from points in the production process that consistently yield unsatisfactory results is a good place to start when working Developed in the 1980's, Total Quality Management (TQM) has been established at various companies to help manage quality through various processes. TQM is another approach to improving effectiveness, competitiveness, efficiency, and flexibility in order to best suit the customer's needs.

The purpose of instigating a Total Quality Management (TQM) manufacturing system is to raise awareness and improve the quality of all the organizational processes that the organization is a part of TQM is also aimed at increasing customer satisfaction while lowering the cost of production.

TQM manufacturing consists of planning, organizing, directing, control, and assurance. More specifically, total quality is usually looked at in terms of the quality of the return on the shareholder's investments, the quality of the products and service offered, and the quality of life that exists among the members of the organization.

• The TQM philosophy strive to systematically manage the improvement of the organization through the ongoing participation of all employees in problem solving efforts across functional and hierarchical boundaries.

• In the simplest terms, it is the true commitment in operationalizing the concept of customer focus, establishing service performance standards, measuring performance against benchmarks, recognizing and rewarding exemplary behavior, and maintaining enthusiasm for the customer at all times.

• That certain quality management practices had a significant impact on firm-level performance in terms of quality, profitability and productivity. Like, compensation and performance appraisal linked to quality were found to be motivating to middle managers; leadership from senior management was seen through their interest in linking profitability to quality; the importance of training and quality related meetings is visible; and continuous improvement and benchmarking techniques, are being used as ways of learning to improve quality of services. While some methods used in the developed economies were not found to be used significantly, their study begins to shed light on the quality management methods that seem to be effective in emerging economies like India.

• Apart from enabling organizations to maintain a competitive posture necessary for survival also enables the individuals to select the best alternative after weighing the various options available. It would also provide more opportunities to start-ups.

Dimensions of TQM environment in organizations:

• Top Management Commitment and Visionary Leadership.
• Human Resource Management.
• Technical System.
• Information and Analysis System.
• Benchmarking.
• Continuous Improvement.
• Customer Focus.
• Services Marketing
• Employee Satisfaction.
• Union Intervention.
• Social Responsibility.
• Service scapes.
• Service Culture
• SQI [Service Quality Improvement] Through SQC [Service Quality Credentials].
• Service Contact Type.
• Demographics
• Job Standardization.
• Cell Site Infrastructure.

• Knowledge Ability in Work.

• Place Attachement

• Quality Competitiveness Index (QCI)

Customer Percieved value:

Quality is related to customer perceived value and is a part of the construct of perceived value. It is seen as a 'benefit' for evaluating perceived value by customers.

Customer perceived value is a critical variable influencing customer purchase decision making. Thus, it may be used by firms to get desired responses from the customers such as purchase, repurchase intention or good word of mouth

Value-added work is the work that is actually valuable and results in a finished product. Keep in mind that a customer is only going to want to pay for value; if they feel that their money. Customer perceived value is a critical variable influencing customer purchase decision making. Manufacturer must understand the need for:

• Value Creation

• Value Delivery

• Value Communication

• Serious Shortcomings in understanding Value

• No marketing without Value

• Value to the customer then becomes the pivot around which the whole marketing effort moves

Six sigma

SixSigma is a method or a set of techniques and in the business world, it has become a movement that is focused on business process improvement. It is a quality measurement and improvement program that is designed to focus on improving the quality of a company's business processes. The six sigma method was developed to remove defects and variations in manufacturing. It uses a series of quality management methods to implement the changes. These quality management methods are known as "master black belts, black belts, and green belts." An integral part of a six sigma quality approach to your manufacturing processes is statistical process control.

Six sigma is a method used to provide business with the necessary tools to increase their overall performance and customer satisfaction. This is done by statistically analyzing various forms of data and information, then using it to anticipate the needs of their customers. The overall goal of SixSigma is to increase a company's profits by identifying and then eliminating factors that contribute to waste and customer dissatisfaction. A Pareto chart is a type of bar chart where the values being plotted are arranged in descending order. It is one of the key tools used in total quality control and SixSigma .

Lean six sigma

In Lean manufacturing, the processes are defined to achieve the final goal of adding value to the customer. Optimization is the word used in lean environment, not maximization nor minimization. Quality, delivery, price and other factors are almost equally important in the equation of adding value to the customer.

But six sigma starts with quality and its prime focus is on quality. Variations are identified in relation to quality and hence more importance is on quality of the product or service. Minimizing or controlling the process is the aim of six sigma. In a sense this concept accepts that even the best system can have problems in its process. On the other hand six sigma is more statistical that the tools and techniques used by lean manufacturers.

One major advantage of merging lean manufacturing with six sigma is that lean can deliver results quicker and more efficiently while six sigma can bring the process under statistical control. So the end result would be a controlled and measurable system with quick and efficient ways of process improvements.

Information technology and Manufacturing

Information technology creates new opportunities for manufacturing. Powerful tools assist the manufacturer during the entire design and manufacturing process. Therefore the understanding and the processing methods of data, information and knowledge and systems are of utmost interest. Due to the advance of communications and automation technologies it is now common, that a product is designed in one part of the world, manufactured on an other part of the world (often another continent), assembled again somewhere else and used (with various minor customization changes) everywhere in the world. This is feasible because of the available IT technology, and it is cost effective because of the local logistic supply chains that the factories in question need to operate successfully. The total spending on IT by the Indian manufacturing sector has increased regularly with quantum jump occurring starting 2003-04,.whereit was assessed at Rs 3,252 crore, contributing 10%of the total domestic IT pie.

Key Issues in IT implementation in manufacturing.

Culture and value

Leadership

Structures

Strategies

People

Technologies

Knowledge and insight

Processes

IT in manufacturing Engineering

The use of the computer has had a positive impact on manufacturing engineering in many ways. The first and biggest positive impact on engineering has been the use of Computer Numerical Control machines (CNC);computers were first introduced to these controls in the early 1970's. CNC machines typically replace or work in conjunction with some existing manufacturing process. Some other applications are:

Flexible Manufacturing Systems

A flexible manufacturing system is a totally automated manufacturing system that consists of machining centers with automated loading and unloading of parts, an automated guided vehicle system for moving parts between machines, and other automated elements to allow unattended production of parts. In a flexible manufacturing system a comprehensive computer control system is used to run the entire system. This includes Electronic Data Interchange (EDI) and manufacturing software in order to closely monitor inventories and work in process.

Simulation-based Scheduling and Control in Flexible Manufacturing Environments

A simulation-based control system integrates simulation technology, information system technology, and a manufacturing system's execution level controllers for automated and manual equipment. With on-line simulation the most current system information can be used to predict system performance and to develop short-term planning, scheduling, and control alternatives. Simulation-based scheduling and control is a very promising framework for the study and optimization of the dynamic characteristics of a flexible manufacturing system (FMS).

CAD Modeling

Research on CAD modeling mainly focuses on Reverse Engineering, which creates a CAD model starting from an existing sculptured part, usually in wood or clay, or from a medical image. A fully object-oriented expert software environment has been developed to assist mould designers. Electronic 3-D CAD models have replaced physical models in engineering operations. Companies now test and revise their designs using engineering software programs before building a mockup. They also send and receive CAD models from suppliers to ensure consistency and accuracy. Using CAD saves a lot of money and reduces product development cycles.

Process Planning, Scheduling &Shop Floor Control

Research on computer aided process planning (CAPP) focuses on the integration with CAD and shop floor control, and on the development of more efficient process planning systems. These systems generate branched process plans, which contain alternative machining sequences and hence allow a flexible integration with scheduling and shop floor control.

Production control

A new production control system bridges the gap between short-term planning and on-line manufacturing control. Research focuses on manufacturing control solutions capable of handling operational disturbances and changes, especially solutions that achieve a minimum reduction in production throughput under these circumstances.

Feature based NC-control

A next generation feature-based NC-control system is being developed, whose input consists of machining tasks such as milling of pockets or drilling/ tapping of holes. The controller integrates an on-line CAPP module, an on-line CAM module, a machine monitoring module and a machine driver. The controller behaves holonically because in case of disturbances it adapts the machining operation or co-operates with other NC-machines

Robotics Systems

Robotic systems are perhaps one of the more challenging of the new manufacturing technologies since their use and application requires a broad knowledge base that addresses topics ranging from mechanical drive systems to electronic control theory. Industry has access to a flexible manufacturing system incorporating an articulated robot, a pick and place robot, CNC machines and sensor technologies for evaluation and demonstration purposes. A robotic welding system is also available for prototype development.

Advanced Simulation Software

There are two primary areas for software simulation in manufacturing: process simulation and product simulation. Process simulation software allows manufacturers to complete process layouts of the necessary equipment and personnel, mathematically model the process, and then simulate actual operation of the process. This allows manufacturers to estimate production costs, determine production capacity, and identify bottlenecks, which require correction all on the Pc. Product simulation involves creating realistic representations of products that can be assessed for aesthetics, manufacturability, strength, thermal properties, and mechanical performance. This allows manufacturers to optimize both the product design and the production process to ensure high quality at minimum cost.

IT Application for Organisational Issues

IT has helped companies establish in the global market and take on global challenge. It enables large global groups having multi location in handling raw materials and costumers using ERP and Programmable Logic Control (PLG) had helped the complex process dependent company into an innovation-based global player.

The increasing role and importance in industrial sector of IT tools like Enterprise Resource Planning (ERP),SCM, CRM, Decision support tools, knowledge management etc in recent years for increase efficiency, reduced manufacturing cycle time and compress supply chain is quite evident. Sectors like metals, pharma, pulp and paper and FMCG are underscoring the creation of uniform open IT architectures to help companies grapple with growing complexities of the manufacturing value-chain. Not surprisingly, in many manufacturing organisations, the bridge between customer requirements, plan fulfilment and execution needs to be overcome through an effective utilisation of IT changing the mindset of people involved in the companies and data security based concerns. The Indian manufacturing sector's growing emphasis on improving their IT capabilities will help India reach the Global Factory' position.

For significant results from the IT implementation in the manufacturing sector, I underline the need to make it an organizational goal rather than just an IT goal. It must be stressed that unless an efficient plan exists to meet customer demand, it doesn't count much in being closer to customer and well-made plans not executed with speed and efficiency are ultimately meaningless.

In recent years, automotive companies have used IT to reduce labor, capacity and inventory in the supply chain, making great leaps forward in operational efficiency and responsiveness. They are also profiling the strategies driving the ICT investment of suppliers, vehicle manufacturers and dealerships. Analysis suggests industry restructuring & consolidation, made-to-order vehicles, logistics & parts availability, security, QA and regulatory compliance. Identify solution needs that will have the greatest impact on bottom line efficiencies and costs for users, driving solution re-investment. Understand end-user investment characteristics, coupled with analysis of key trends and industry dynamics. Adapt and tailor your solution portfolios and marketing communications to capitalize on the demands and nuances of each automotive sub-sector.

It is crucial that a manufacturer keeps a track of Customer demand and the demand supply matching involves operations that are within the control of the company. Maintaining an efficient Supply /Demand matching in such environment puts a burden on IT. Indeed, a very close collaboration is required with the outsourcer to ensure production capacity; inventory, availability of appropriate skills etc. are known and can be taken into account when decisions need to be made. It is critical for a successful manufacturing outsourcing that a trustworthy relationship is established between the partners and that information flows easily between them. This is possible if the relationship is seen as a "win-win" one by both parties. Where this is the responsibility of the Supply Chain or Manufacturing team, the IT department needs to be available to integrate the information coming from the outsourcer within its own system.

Such approach requires a fundamental change in the way the company sees its suppliers and approaches collaboration. In the following we shall look at relationship approaches.

Partner Relationship Management

There has been recognition that there are benefits in closer working relationships. This can be seen as a continuum extending from single transactions, with a very minimal requirement of trust between the two parties ,to a long-term supply chain 'partnership' with a very high degree of trust, at the other extreme

A partner relationship management strategy seeks to improve business processes by improving communications between a business and its channel partners. Partner relationship management is also important for a manufacturer and reseller or retailer. PRM software allows the producer to understand when a certain product is in demand and allows that producer to adjust his processes likewise Techniques and technologies

Using software and other communication tools often provided through a partner relationship management strategy, suppliers, shippers and the end users can keep in constant contact with each other. This means the end user will be able to know where each item is each step in the process and when to expect it. Depending on the situation, this may allow a factory to adjust production so that the entire operation does not shut due to supply concerns.

Supplier Relationship Management (SRM) is a comprehensive approach of managing an enterprise's interactions with the organizations that supply the goods and services it uses. It's a subset of supply chain management. Suppliers are as important to a business as customers. The goal of SRM is to streamline and make the process effective between an enterprise and its suppliers in the same way as customer relationship management (CRM) is intended to streamline and make the process more effective between an enterprise and its customers .

SRM includes both business practices and software and is part of the information flow component of supply chain management. As a part of business practices, the responsibility is to select suitable supplier for the organization and maintain strategic relationship with them, maintain information related to acquiring goods and services, manage inventory and processing materials. The role of software is the make those process easy and less cumbersome. SRM software assists in decision making (e.g. supplier selection) and increases the efficiency of the processes associated with acquiring goods and services, managing inventory, and processing materials.

There are three major benefits that can be achieved from a strategic supplier-buyer relationship. These are:

i. cost

ii. quality

iii. Technology

A supplier can make or break a company, in terms of providing products and services that either exceed their customers' expectation, or fail miserably to meet them. A poor quality product can virtually shut down a company's operations. In many cases, companies are seeking to increase the proportion of parts, components and services they outsource, in order to concentrate on their own areas of specialization and competence and better meet their own customers' expectation. Finally, purchasing also can improve product and process designs and help introduce new technology into a company's offerings of products and services.

Other benefits of a strategic relationship with supplier are:

• A joint effort occurs to improve supplier performance in all critical performance areas. This includes cost reduction, quality improvement, delivery improvement, and supplier design and production capabilities.

• Buyer and supplier practice an open exchange of information. This includes information about new products, supplier cost data and production schedules and forecasts for purchased items. Information exchange helps create a mutual interdependence between firms.

• Both parties work together to ensure that the design specifications are can be met and that the suppliers' process is capable of producing defect-free products.

Modules

In a scenario of performing at higher levels with fewer resources, many purchasing departments, the key to improved productivity and quality decision making relies on the expanded use of information systems. Different modules that a SRM package, normally, consists of are:

• Supplier Selection Assistance

• Supplier Contacts

• Part Files

• Forecasted Demand File

• Inventory Management and Control

• Material Requirement Processing

• Material Release

• Purchase Order Issuance

• Supplier Performance Measurement and Control

• Receiving and Inspection

Supplier Selection Assistance

A critical task assigned to the purchasing department is supplier selection. Firms are placing an increasing emphasis on supplier selection because of the contribution the supply base makes to strategic performance objectives. The supplier selection assistance module uses a basic set of mathematical algorithms to assist a buyer when evaluating different supply and cost scenarios.

Supplier Contacts

This module contains the names and addresses of each supplier with which a firm does business. When the system generates a material requirement, the system responsible for printing the material release retrieves the supplier name and address from this database to include on the release.

Part Files

All manufacturing firms rely on part numbers to identify the thousands of unique purchased entities within a system. A part file database captures and stores basic information about each separate part number. Virtually all part databases provide some or all of the following information:

• Part number, part name and part description

• Storage location

• Packaging requirements

• Estimated weekly or monthly demand

• Part supplier

• Pricing information

Forecasted Demand File

This module calculates anticipated demand requirements for each part number on the part file. It relies on the historical usage file to update and calculate projected future requirements. A buyer can use these data to provide projected volume requirements to suppliers or to estimate future prices based on projected usage

Inventory Management and Control

The purpose of this module is to provide control and visibility to the status of individual items maintained in inventory. The main functions of this module are to maintain inventory record accuracy and to generate material requirements for all purchased items. The system should also have the capability to analyze inventory performance of purchased items.

Material Requirement Processing

This module involves the processing of material requirements generated. in the inventory management and control module. This part of the system also allows the manual input of requirements to handle one-time purchase requirements when no established need or requirement exists within the system. The module also generates automatic purchase requisitions and passes that information to the material release system.

Material Releases

This module involves the release of a paper-generated document sent directly through the mail or faxed to suppliers. It basically generates the actual material requirement details.

Purchase Order Issuance

This module supports the generation of purchase orders, which involves the automatic assignment of purchase order numbers for selected items along with the transfer of purchase order information to the proper databases. This module provides purchasing with visibility to current purchase orders on file.

Supplier Performance Measurement and Control

This module provides visibility to open-item status and measures and analyzes supplier performance. The module provides updated information about the progress of a material release as it moves through the ordering cycle. The key features of this module include automatic inquiry of items status, monitoring of order-due dates, and supplier performance analysis.

The system generates summary reports of supplier performance compared against predetermined performance criteria. Criteria can include due-date compliance, quality ratings, price variances, quantity discrepancies and total transportation charges.

Receiving and Inspection

This module updates system records upon receipt of an item. Most systems hold a received item in a protected state until all inbound processing is complete. This processing includes tasks such as inspection, material transfer or stock keeping.

Technology. Hence, the application of information technology and the formation of electronic networks have become an important part of corporate strategy. This statement is especially true in the management of company's relationship with their suppliers.

E-Sourcing

The main goal of these systems is to support buyers to find the most appropriate supplier for a good, and the foreground is the negotiation phase of the purchase process in which professional buyers search for the most appropriate product source for a company based on price or any other established criterion.

Electronic auctions and electronic request for quotation (RFQ) are the two most known negotiation form applied in e-Sourcing and are often used in the practices as a synonym of these terms. At the beginning, e-auction systems had their focus exclusively on price negotiation, leaving out of their scope all other relevant negotiation factors e.g. quantity, quality, delivery time. Nowadays, a new generation of auctions systems based on business intelligence technology allows the negotiation of multi-attribute criteria during the online auction and the continuous control of supplier performance. The RFQ process is in some extend similar to the auction process. Thus, what is true for e-auctions can be applied also for e-RFQ. The main difference between RFQs and auctions is the lack of standardization in terms of explicit, formal rules and regulations in

E-Procurement

The general view of e-procurement is software that enables organizations to purchase indirect and MRO (Maintenance, Repair and Operations) goods online, automates the buying processes and centralizes all spending data. The technology has progressed from enabling simple transactions to cover broader categories such as services procurement, as well as the post-procurement stages, such as invoicing, reconciliation and settlement [8]. This solution has its focus on the reduction of the purchase department's administrative costs, by the electronic support and automation of the operative purchasing processes. e-Procurement solutions are adequate to support the purchase of indirect, low value and standard products. These products represent around 5% of the purchasing volume, but generate up to 80%of the total purchasing process costs of a company, 60%of the orders and 70%of the suppliers [9].

Supplier Enablement

Supplier enablement is the channel that enterprises use to integrate with their trade partners and realize their e-sourcing and e-procurement activities. The two main forms in that supplier enablement takes place in companies are through the application of supplier portals and/ or e-marketplaces.

On the other side, e-marketplace is described as a virtual online market where buyers, suppliers, distributors and sellers find and exchange information, conduct trade, and collaborate with each other via an aggregation of information portals, trading exchanges and collaboration tools. It is crucial for an efficient procurement strategy that these channels are not isolated in the enterprise's intranet, but rather they should be integrated with companies' front-end and backend systems in order to integrate their inter-processes and automate the data exchange. At the same time, it is recommend that their users have the possibility to access them anywhere, at any time, regardless of the distance and the sort of device there are using e.g. computer, laptop, Personal Digital Assistant (PDA).

Benefits of SRM

• Increases productivity and profits.

• Improves operational efficiency and quality.

• Increases supplier visibility.

• Responds faster to change and opportunity.

• Enables innovation,

• Profits from a strong, flexible, lean supply chain

One of the biggest advantages of using SRM Software to help boost the supplier/buyer relationship is that it costs less than not using it. Far fewer employees are needed to manage the tasks related to supplier relationship management since most of them are automated or simplified by the software. Businesses also save on the costs of forms, printing. and storage due to automation.

Conclusion

I close by saying that there are Exciting Opportunities in the manufacturing area.The major aspects that machines, cells and manufacturing systems in general have to address in the future are:

• Greater level of flexibility with an optimal degree of modular automation through the development of new machine tools, cells and systems in which a variety of manually operated and automated devices can collaborate,

• Increasingly faster setup and processing times not just for parts, but for entire cells and systems too,

• Application of new materials, such as composites in machine and machine component design,

• Introduction of fundamentally new motion control systems, such as linear drives, that provide fast and accurate positioning,

• Sensors that actively support the increasingly "knowledgeable" and networked machine and/ or cell controller in its efforts to produce the desired quality parts without costly interrupts, and to integrate with the appropriate ERM (Enterprise Resource Management) or CIM (Computer Integrated Manufacturing) systems,

• Application of user friendly, open system architecture based, interactive, networked multimedia at all levels, including machine programming, setup, production control and maintenance/ support systems, even from remote locations.

Energy for Rural Masses: Role of Non-Commercial (Biomass) Fuels

Prof (Dr) M L Mathur

Former Vice Chancellor, University of Jodhpur

Introduction

India the second most populous country in the world has a population of about 121 crores (nearly 17% of world population) on 2.4% land area of the world about 68% of Indian population lives in more than six lakhs village. India has made significant progress since independence in 1947, but the progress is very uneven, much more in urban areas and much less in rural areas. The main reasons for this is less use of energy per capita in rural areas about 25% of that used in urban areas. In modern society energy is the key input for economic growth and there is a linear relationship between per capita gross domestic product (GDP) and energy consumption.

Commercial and Non commercial Energy Sources

A classification of energy is commercial energy (Coal, oil, natural gas, electricity) and noncommercial energy (wood, cow dung, agriculture waste). The developed countries almost exclusively use commercial fuels for their energy needs. The developing countries, however use fair amount of non commercial fuels also. Non commercial energy is often ignored in accounting, which is rather unfortunate because it not only gives a distorted picture of energy scenario but also result in neglect of systematic planning of efficient use of non commercial fuels, which are also vital for rural economy and development. The percentage of non commercial energy consumption in India, mostly in rural areas is about 255 of the total whereas in developed countries it is less than 5%

The non-commercial fuels come under the category of biomass. Bioinass includes all the organic matter produced by photosynthesis that exists on the earth's surface. Biomass is the main source of energy for more than half the world's population in developing countries for domestic energy needs. Biomass accounts for about 14% of the total world energy use. In Indian Villages 80 to 85% of energy used is derived from biomass.

The biomass energy is classified in three categories: solid biomass, the use of trees, crop residues, animal and human waste (although not strictly a biomass source, it is often included in this category for the sake of convenience) , (b) liquid biofuels. ethanol, vegetable oils, bio diesel, and (c) biogas, obtained by anaerobically (in an air-free environment) digesting organic matter to produce methane gas.

Total Energy Consumption in India

As per Planning Commission of India Document Integrated Energy Policy[1] the total energy consumption in India is given in Table 1

Table 1: Annual energy consumption in India

Type of energy	*Example*	*Annual consumption Million Tons of Oil Equivalent (MTOE)*
1. Commercial	Coal, Petroleum, electric power	340 (75.56%)
2. Non- commercial	Wood, Biomass, Cow Dung Cakes	110 (24.44%)
Total		450 (100%)

Domestic Fuel Use in India

The domestic fuel use in India is about 135 MTOE, which is about 30010 of the total energy use. Table 2 gives the share of various fuels in domestic energy use.

Table 2: Domestic fuel use in India (2007-08)

S. No.	*Type of energy*	*Approximate Quantity, MTOE*	*Percentage*
1	Wood	80	60.0
2	Cow dung cake	30	20.0
3	Kerosene	10	7.5
4	Coal	10	7.5
5	LPG	7	5.0
6	Electricity	Very little	
Total		137	100

It is rather surprising that about 80010domestic fuel usage is non- commercial energy. The only clean energy, LPG, is only 5%. Therefore from energy security point of view wood and cow dung must be used most efficiently in villages.

Efficient Use of Cow Dung and Wood in Improved Chulhas (Cook Stove)

In India the use of cow dung is about 133 million tones in rural areas and 8 million tones in urban areas totaling 141 million tones (which is equivalent to 30) million tones of oil (4.7 kg of cow dung = I kg of oil). The cow dung is made into cakes and used in the chulhas (stove) which have very low efficiency of about 8 to 10010.This results in colossal waste of the fuel. Further, it causes smoke pollution. Improved chulhas can give efficiency up to 22%. However converting cow dung into gobar gas can increase fuel efficiency up to 50%. This underlines the importance of gobar gas plants.

The conventional wood chulah has also low efficiency, about 8 to 10%, and pollution level of CO is 30 ppm whereas permissible level is only 0.1 ppm. The estimate of wood being burnt for domestic fuel is about 180 million tones. The increase in efficiency of wood chulahs would save large quantity of wood and reduce deforestation. It would also reduce the time women and children spend in collecting wood. The improved chulhas also reduced kitchen pollution. Thus the function of improved chulhas is not merely to save fuel but improve health and quality of life of women.

Maharana Pratap Agriculture University, Udaipur developed an improved chulha named Udairaj, which gives thermal efficiency of 25-30% at the fuel burning rate of 1.0 kg/hr. it is estimated that on average 950 kg of fuel wood per domestic chulha per year has been saved by the introduction of improved chulha.

For reference, the efficiency of kerosene pressure stove is about 53% arid LPG gas stove 57%.

Biogas Plants

Biogas technology provides an alternative source of energy in rural India. Biogas is produced by anaerobic digestion or fermentation of biodegradable material such as biomass, manure or sewage, municipal waste, green waste and energy crops. The biogas produced by cattle dung is also called gobar gas. Biogas is a clean and efficient fuel. The composition of biogas varies depending upon the origin of the anaerobic digestion process. Table 3 given the typical composition of biogas.

Table 3: Typical composition of biogas[2]

S. No.	*Matter*	*Percentage*
1.	Methane , CH4	50-75
2.	Carbon dioxide, CO2	25-50
3.	Nitrogen, N2	0-10
4.	Hydrogen, H2	0-1
5.	Hydrogen Sulphide, H2S	0-3
6.	Oxygen O2	0-2

The typical composition of gobar gas is about 65% methane, 34% carbon dioxide plus trace gases, hydrogen sulphide and ammonia. The combination of biogas has very little odour or smoke. Owing to simplicity in implementation and use of cheap raw materials in villages, it is one of the most environmentally sound energy source for rural needs.

Biogas is used extensively throughout rural china which has more than 70 lakhs biogas plants. Nepal has installed over 1.5 lakhs biogas plants in rural areas. Vietnam has installed 20,000 biogas plants.

India's National Project on Biogas Development (NPBD)[3]

India has great-potential in development of biogas plants as it has largest cattle population in the world. It has world's 15% cattle (20.2 crore), 54% buffalo (8.4 crore), 200logoatand 4% sheep.

The national project on biogas development was started in 1981-82 for promotion of family type biogas plant of $2m^3$ to $3m^3$ size. For $2m^3$ plant cattle dung required is about 50 kg per day, number of cattles 4 to 6. A $2m^3$ capacity biogas plant is sufficient for providing cooking fuel for a family of 6-8 persons (per capita per day consumption of biogas 0.238 m^3 against 1.06 kg fuel wood). Gas lamps can be fueled by biogas. A 100 candle lamp (60 W) requires 0.13m3 of gas per hour.

The objectives of the biogas projects were as follows: -

I. To provide fuel for cooking purpose, reducing the use of non renewable fuels.

2. To supply enriched biomass for agriculture, saving in the cost of chemical fertilizers.

3. To mitigate the drudgery of rural women and improve their quality of life, cleanliness in kitchen, saving in cooking time.

4. Reduce pressure on forests.

5. Increase employment opportunities in villages. About 30 mandays are required in construction of $2m^3$ plant. Jobs are also created for repair and regular maintenance of the biogas plant. The number of jobs created for repair and regular maintenance of the biogas plant. The number of jobs created per unit and twenty times more than in any other energy system. According to ne estimate about 9 lakhs jobs would be created in India in biogas programme.

The potential of the family biogas plants was estimated to be 1.2 crore. However up to 2006-07 a cumulative total of only about 40 lakhs family type biogas plant were set up. Evaluation of biogas project : The government conducted an evaluation study in 2001-02 and found that only 45% plants were working fully a later survey by Tata Energy Research Institute (TERI) showed that about 80% biogas plants were into disorder and disuse resulting in huge loss of government and public money. This failure of a very promising and useful project for rural masses forces us to reassess the strategy of executing the biogas project.

According to the survey conducted the main reasons for biogas plants becoming nonfunctional were as follows:-

1. Structural and operational problems like chocking of inlet/outlet, corrosion/leakage in pipe line, scum formation in digester slurry, water accumulation in gas pipe, lower gas generation in winter, etc.

2. Poor and unsatisfactory repair and maintenance services available.

3. Lack of training for beneficiaries.

4. Insufficient availability of cattle dung ..

5. Easy availability of alternate convenient fuels.

Strategy to Realize Biogas Potential

(i) Input of advanced technology: One reason of the failure of biogas plants is the general perception that it is a simple system which an untrained common man can handle. Biogas system cannot survive as low technology system. The system will develop and be successful only with input of latest advanced technology. For this purpose the Ministry of Non-Conventional Energy Sources(MNES) should establish a permanent high level National Biogas Commission(NBC) who should organize a research and training institute for advanced biogas technology. It should also develop more efficient new designs.

(ii) Create trained personnel for repair and preventive maintenance: A major reasons of large number of biogas plants becoming non functional is lack of repair and regular preventive maintenance facility. Though there are ten biogas training centers in India attached to agriculture universities, who are supposed to conduct training programmes for masons, turnkey workers, staff engaged in biogas development and users, they have failed in their assignment.

Trained technicians in large number are needed for maintenance of biogas plants. Regular certificate courses should be introduced in Industrial Training Institutes (ITIs) for this purpose. The proposed National Biogas Commission should organize training programmes in various regions of the country.

(iii) Give more emphasis on large biogas plants: The government biogas project is centered around family type biogas plants of 2 to 3 m^3. The full potential of biogas plants can only be realized by large community/ institutional biogas plants of the size 30 to 50 m^3. These may be run by panchayats, non- government organizations (NGOs) and entrepreneurs on scientific and commercial basis. Qualified agencies should be developed who can be given contract for running large biogas plants.

Baba Amte's Leprosy Centre had given 3 gobar gas plants of 35 m^3 each running on cow dung and night soil for supplying to a kitchen of 500 inmates.

Large scale biogas plants would require development of dung collection centres and market for selling biogas and enriched slurry. They can also develop non domestic use of biogas. Biogas can be used in dual-fuel engines which run on 80% biogas and 20% diesel oil. In the case of non availability of biogas these engines can run on 100% diesel oil. The transport of biogas is possible through ballons. Biogas can also be compressed and supplied in cylinders, after removal of carbon dioxide, for use in industry and automobiles.

(iv) Give emphasis on night soil-linked biogas plants: A very sad and shameful aspect of Indian village life is about 75% houses do not have toilets. Therefore in biogas development project maximum emphasis should be given on toilet linked biogas plants for which extra subsidy should be given. The excreta of 6 to 8 persons is required to provide for one person's daily requirement of gas. Hence biogas plants linked to community latrines, used by a large number of people, would be viable supplying gas to a limited number of households.

The design aspects of toilet linked biogas plants need special consideration. Sulabh International has done good work in this field and is running over 140 such plants all over the country. Toilet- linked biogas plants are a boon for the villagers as they serve the dual purpose of neat sanitation and providing gas fuel.

(v) Develop designs of biogas plants to use different types of waste: The conventional designs of biogas plants are based on using cattle dung and night soil. New designs should be developed which can use different wastes-agriculture waste, municipal waste, domestic waste, vegetable market waste, etc.

In India annual vegetable waste is about 50,000 tons. One to vegetable waste yields 80 m3 of biogas, sufficient for cooking demand of 50 families. Specific designs could also be developed to suit local conditions of the area.

(vi) Modify pattern of subsidy for biogas plants: In the past people installed biogas plant to make advantage of government subsidy. The pattern of subsidy should be changed. Instead of giving subsidy on installation of plant, it should be given on quantity of gas generated and used by customers.

The subsidy is justified because of the socio-economic-environmental benefits of biogas plants to the society.

(vii) Avoid easy availability of alternate fuels: A reason for abandonment of biogas plants is easy availability of alternate fossil fuels like subsidized kerosene. For success of the biogas project the subsidy given to non renewable energy sources like kerosene, LPG, diesel oil and electricity should be abolished.

(viii) Make conversion of waste to energy mandatory: Disposing of solid waste, coming from domestic, municipal, vegetable market and industrial sources, is a very big problem, particularly in urban areas. Improper and non-disposal of solid waste is responsible for many diseases and environment pollution.

The government should enact laws for making biogas plants mandatory for converting solid waste to energy.

Some examples of Novel Biogas Plants:

(i) Compact biogas plant of Dr. Anand Karve[4]: A conventional biogas plant working on cow dung requires 40kg input to produce 250gm of methane taking 40 days to decompose. Karve's innovative biogas technology requires only I kg of vegetable and kitchen waste and just 24 hours to produce 250 gm of methane in a small plant. About 800 homes in Maharastra have installed Karve's plant. The plant provides cooking gas and simultaneously solve waste disposal problem. It is suitable for kitchens of hotels, hostels and housing clusters.

(ii) Kitchen waste based biogas plant, Bhabha Atomic Research Centre[5]: The waste generated in kitchen in the form of vegetable refuse, stale cooked and uncooked food, extracted tea powder, waste milk and milk products can be processed in this plant The plant produces biogas by using thermophilic microorganisms that flourish in extreme environment. The main digester tank is $35m^3$ in size.

Success of this biogas plant depends a great deal on proper segregation of the kitchen waste.

(iii) Biogas plant using cake of Jatropha seed[6]: Disposal of cake of Jatropha seed is one of the major problems being faced by biodiesel producers. The seed cake is unsuitable as feed for livestock due to its toxicity. A one ton per day biodiesel plant produces 2.5 to 3 ton of seed cake. It can be used in biogas plant to produce gas. The production of gas is about 0.25 to 0.35 Ml per kg of cake. The composition of gas produced can be used as a high quality manure.

A biogas plant of a capacity of 1 ton/day of oil cake would require area 300 M^2. manpower two unskilled persons, power supply l kW, water supply 1200 litre, cost about Rs. 5 lakhs.

Epilogue:

In India the great problem we face is not only poverty but the great disparity in the income of rural and urban people. The supply of adequate energy to rural masses will increase their income and also generate greater employment, reducing the flow of population of villagers to cities.

Non- commercial energy (wood, cow dung, agriculture waste) plays as important role in the economy of villages. These sources of energy must be used most efficiently in improved chulhas and in generation of biogas.

The energy requirements of rural masses can be served by integrating non-commercial energy in the overall energy policy making and planning.

References:

1. Leena Mehendale. "Energy Security and Efficiency : Role of Bio-Gas" ACT(PCRA) , July- September, 2008

2. Wikipedia, the free encyclopedia.

3. Evaluation Study on Natural Project on Biogas Development. "Planning Commission, Government of India. May 2002.

4. Vinita Deshmukh Compact Biogas Plant Making Waves. Appropriate Rural Technology Institute (ARTI), Pune-EMail: artipune@snl.net.

5. Kale S.P. and Mehetre. Kitchen Waste Based Biogas Plant Bhabha Atomic Research Centre.

6. Stalish Lele 'Biogas Plant', Indian Biofuels Awareness Centre, www.svlele.com

Investigation and Control of High Speed End-Milling of Hardened EN 24 Steel

Dr M S Shunmugam

Professor, Manufacturing Engineering Section
Department of Mechanical Engineering, Indian Institute of Technology Madras, Chennai

PREAMBLE:

I feel privileged to deliver this lecture in memory of Dr. S. C. Bhattacharya for his dedicated service to the development of human resources in mechanical engineering. In spite of having his entire engineering education abroad, he had devoted his entire active service to the advancement of mechanical engineering education in India. I am happy that Institution of Engineers (India) instituted has been arranging an Annual Memorial Lecture in his name during the National Convention of Mechanical Engineers. I am thankful to the organizers for giving me an opportunity to deliver a memorial lecture during this convention being held in Coimbatore.

1. INTRODUCTION

High Speed Milling (HSM) has emerged as the most efficient machining process to provide solutions not only for mass production but also for prototype (Schmitz et al., 2001). It can be used for both rough and finish machining operations and has specific advantages like, high productivity without sacrificing the accuracies, less tool wear, low distortion and deflection, reliable and repeatable accuracies, good surface finish and burr-free edges. High speed endmilling is used for production of variety of parts, dies and moulds made of hardened EN24 steel which are widely used in power and transport industries.

Surface finish is directly influenced by cutting parameters and these parameters have been optimized for surface finish by integrating RSM with evolutionary algorithms for end milling (Prakasvudhisarn et al., 2009). Cutting force is a key response and prediction of cutting forces is important in end milling. Among different approaches for modeling of high speed end-milling processes, AI techniques are very useful (Torabi et al., 2009). Tool wear is also an important aspectto be studied in machining operations, as the cutting performance is affected with the progress of tool wear. Haber et al. (2004) has carried out monitoring of tool wear in high speed machining process. It is possible to carry out on-line tool wear monitoring indirectly by cutting force measurement, as cutting force values are most sensitive to tool wear than other measurements such as vibration or acoustic emission (Jemielniak, 1999). With proper integration of monitoring and control of the high-speed end-milling, many industries stand to gain in terms of productivity and quality (Jawahiretal., 2003).

2. NEED FOR THE PRESENT WORK

Literature shows that HSM is capable of producing the surface finish of the order of N4- N6 (0.2- 0.8 μm), which may overlap with the finishing process like grinding (Dewes and Aspinwall, 1997). It has been pointed out that a 50 % increase in tool life would lead to a 1.5 % reduction in production cost, whereas 20 % increase in productivity would lead to a 15 % reduction in production cost (Werthiem, 2002). Greater gains are definitely possible by increasing metal removal. Hence there is a necessity to develop adequate models for end milling process to achieve the benefits like productivity and quality.

An extensive study and a thorough understanding of the process are necessary to make HSM highly efficient, productive and economical. The objectives for roughing and finishing are quite different; volume of material to be removed is the output target in rough end-milling and the good surface finish and dimensional accuracy are the vital factors in finish end-milling. HSM is a highly complex process and hence it is difficult to model the process. As the response surface has hills and valleys, a suitable optimization method is necessary to select optimal machining from the multiple solutions. The literature shows that a limited work has been carried out in HSM of hardened steel considering specific aspects like surface finish, tool wear and selection of cutting parameters. Many times, a single set of experiments is carried out to come up with recommendations for higher metal removal and better surface finish. An integrated approach is required to study and implement control strategies for high speed rough and finish end-milling operations.

In the present work, the high speed end-milling has been analyzed with a view to model the metal removal and surface roughness in roughing and finishing operations respectively along with tool wear using Response Surface Methodology (RSM). Appropriate cutting conditions are selected for rough and finish end-milling operations using Differential Evolution (DE). Relevant force signals or their components which correlate with tool wear have been identified and reference parameters for rough and finish end-milling operations are predicted using Artificial Neural Network (ANN) models (Saikumar and Shunmugam, 2012). Finally suitable control strategies are arrived at for high-speed rough and finish end-milling operations and implement on available high-speed milling machine (Saikumar and Shunmugam, 2012).

3. EXPERIMENTAL WORK

Fig.1 shows a framework of the proposed work, giving the cutting parameters and the responses measured along with their notations for the rough and finish end-milling experiments. The experiments have been conducted on a vertical 3-axis CNC Mikron high- speed milling machine, model VCP71 0 for rough and finish end-milling operations as shown schematically in Fig. 2.

The machine is equipped with 15 kW spindle power and maximum speed and feed rate of the machine are 12,000 rpm and 20 m/min respectively. The work material is EN24 (AISI4340) steel. The test specimens of size 155 × 185 × 35 mm are hardened in vacuum furnace and tempered to achieve uniform hardness of 43-45 HRc. End-mill holder of Φ10 mm (HM90 E90A-10) and TiAIN coated P30 grade inserts (HM90 APKT 1003 PDR) of ISCAR make are used. The details of the insert are included in Fig. 3. The endmill holder with a single insert is used and a tool overhang of 40 mm is maintained for all the experiments to minimize the effect of setting error and run out. The experiments are planned according to central composites design with three levels as low-medium-high (code: -1, 0, +1) for each cutting parameter namely as spindle speed (n), feed (s) and depth of cut (a). To account for the possible non-linearity and interaction effects, two augments are added at lowest and highest levels (code: -1.682, +1.682). Center 3 experiments are repeated to distinguish between lack-of-fit and experimental error (Montgomery, 1976).

A set of 16 experiments have been designed based on DOE for rough and finish end milling respectively. In each experiment, a new insert is used for machining 10 mm slot width. The cutting forces are measured using 3-component Kistler dynamometer. Data Acquisition is performed with a personal computer and a multi channel data acquisition board, at a sampling frequency of 30 kHz. Forflank wear measurement, a special fixture is developed to position the insert. The flank wear is measured at 20-magnification with 1 μn least count as per the recommendations of ISO 8688-2 using an optical measuring machine, Flash make Model 200, Switzerland. In rough end-milling, slots of 185 mm length are machined and several cuts are needed to observe the progression of flank wear (VB) up to 0.5 mm. For example, 12 slots are cut for Exp. 11, while 33 slots are cut for Exp. 13. Cutting forces are measured sufficiently before the completion of every 3rd slot, while cutting time and flank wear (VB) are recorded after completion of every 3rd slots. With faster progression of flank wear towards the end, measurements are done for alternate or very next slot. In the present work, a total of 136 slots have been cut and 64 data sets (maximum flank wear of about 0.4 mm) are used for the analysis of the rough end-milling. However, only partial result for each set of experiments is presented in Table 1.

For finish end-milling experiments also, 185 mm long slot of 10 mm width are cut and fresh inserts are used for each set of experiments. Since the surface finish is affected by the tool-wear, tool wear is also taken to be an influencing factor and the end-milling is continued till a maximum of 0.3 mm VB is reached. Measurement of flank wear is done before cutting a particular slot and the cutting forces are recorded shortly after the start of end-milling. The surface roughness Ra is measured using Mitutoyo roughness measuring instrument in the initial portion of the slot. A cut-off of 0.8 mm and a tracing length of 2.5 mm are used and an average of nine readings is taken to represent the surface roughness. Table 2 presents the partial result of finish end-milling experiments.

4. INVESTIGATIONS INTO HIGH-SPEED END-MILLING

4.1 Analysis and Parameter Selection in Rough End-milling

In rough end-milling operation, the given tool is expected to remove as much as material as possible. Apart from the machining parameters such as spindle speed, feed and depth of cut which are independent/controllable factors, the progression of flank wear on the insert also influences the volume of material removed. Faster wear out of the insert can adversely affect the volume of material removed. With the experimental data (as in Table 1), the response surface for volume of material removed is obtained by fitting a second order polynomial using Statistica 6.0 as:

$$MR = 454.180 - 0.11252n - 0.247s - 158.096a + 234.857VB$$
$$+ 1.168(10^{-5})n^2 - 3.0(10^{-4})s^2 + 43.211\,a^2 - 231.052VB^2$$

$$+ 1.336(10^{-5})ns - 7.6(10^{-3})na - 1.973(10^{-2})nVB + 0.19146sa + 0.169sVB + 46.162aVB \quad (1)$$

where spindle speed (n) is in rpm, feed (s) is in mm/min, depth of cut (a) is in mm and flank wear (VB) is in mm. Statistical tests are carried out using Statistica 6.0 to check the adequacy of 4 the model and the regression coefficient (R2 value) is obtained as 0.8905 for the above model expressed by Eqn. 1.

As MR is in the form of polynomial equation of 2nd degree, the Differential Evolution (DE) algorithm is used (Storn and Price 1997) in the present work for arriving at the machining parameters to achieve material removal within a specified range of values. There are four variables such as spindle speed, feed, depth of cut and flank wear used to predict the volume of material removal. A new objective function is defined so as to predict the cutting parameters for a given range of flank wear, when volume of material removed would lie in a specified range.

$$Obj = |Y - Ymin| + |Ymax - Y| \quad (2)$$

where Ymin and Ymax are the minimum and maximum material removal values specified and Y is given by Eqn.1. It can be seen that minimum value of objective function will be the range itself, i.e. $|Ymax - Ymin|$. DE code available in Matlab 7.1 is used with following parameters, No. of populations: 15; Strategy: DE/rand/1/bin; DE-step size (F): 0.8 and Crossover factor: 0.8. The algorithm is run several times, and results obtained for one typical range of volume of material values are recorded. For a given range of 80 -100 cm^3 values, and VB in the range of 0.38 - 0.4 mm, Table 3 gives material removal for typical combinations of spindle speed, feed, depth of cut, and flank wear. The machining parameters thus obtained are used in the CNC program.

4.2 Analysis and Parameter Selection in Finish End-milling

In finish milling, the cutting insert is replaced when it fails to produce the required surface finish. As the surface finish is affected by the tool-wear, tool wear is also taken to be an influencing factor. Using the experimental results of finish end milling (as in Table 2), 2nd order polynomial equation for surface roughness has been developed. The best fit equation with a regression coefficient (R2 Value) of 0.8028 for surface roughness (Ra) is given below:

$$Ra = 1.279 - 2.66(10^{-4})n + 3.42(10^{-3})s - 0.912a + 0.961\ VB + 1.858(10^{-8})n2 + 2.27(10^{-6})s2 + 0.408a^2 + 1.194VB^2 - 4.945(10^{-7})ns + 2.5(10^{-5})na - 1\ (10^{-4})nVB + 7.63(10^{-4})sa + 4.6(10^{-4})sVB - 0.15aVB \quad (3)$$

where spindle speed (n) is in rpm, feed (s) is in mm/min, depth of cut (a) is in mm and flank wear (VB) is in mm.

The methodology applied for selection of cutting parameters for rough end milling process has been implemented for finish end milling also. In this problem, three factors Such as cutting speed, feed and depth of cut, are used to predict surface roughness for finish end milling process with flank wear lying between the specified values. Since flank wear for rough end-milling is taken to lie between 0.38 and 0.4 mm, the corresponding values for finish end-milling are taken as 0.28 and 0.30 mm. For a given range of 0.15 - 0.20 m Ra values, the results of DE are shown in Fig.5. Typical combinations of parameters identified by DE are given in Table. 4.

4.3 ANN Model of Rough End-milling

Cutting force being the most sensitive to tool wear, the first task is to determine the cutting force component which correlates well with the progression of flank wear. A part of signal data consisting of 3 cycles is considered for the processing of cutting force signals in X, Yand Z directions, namely lateral (FJ, longitudinal (Fy)and axial (Fz)forces. The tooth passing frequency for the maximum cutting speed of 11,681 rpm with a single insert is found to be around 200 Hz. Therefore, cutting force signals are filtered using a low pass filter having a frequency cut-off of 200 Hz. Gaussian filter is selected in the present work, as it is an averaging filter, which has zero phase-shift and distortions. It removes high frequency components and provides smoother signals for further interpretation. Matlab code is developed for Gaussian filtering (Matlab, 2005) and the filtered signal is designated as F_{xg},F_{yg} and F_{zg}. The filtered signal is subtracted from the original signal and they are designated as F_x-F_{xg}, F_y-F_{yg} and F_z-F_{zg}. Fig. 4 shows amplitudes of the signals taking F_y, F_{yg} and F_y-F_{yg} as examples. In order to identify the cutting force component among F_x, F_y, F_z, F_{xg}, F_{yg}, F_{zg}, F_x-F_{xg}, F_y-F_{yg} and F_z-F_{zg} which correlates well with the tool wear, 2"" order polynomial function is fitted taking cutting parameters and the tool wear as input parameters and each component of cutting force as output parameter. It is seen that F_x, F_y and F_z are having R^2 value of 0.8974, 0.9368 and 0.6669 respectively. F_{yg} yields the highest R^2 value of 0.9484, followed by F_{xg} and F_{zg} having R^2 value of 0.9136 and 0.6990 respectively. Therefore, the values of F_{yg} are included in Table 2 for further processing.

For on-line control of rough end milling operation, it becomes necessary to monitor the cutting force and cutting time. Whenever the actual cutting force or the cutting time exceeds the reference values, appropriate control must be brought in. In the present work, ANN is developed to predict the cutting force and cutting time, given the input variables such as cutting speed, feed, depth and flank wear. A single ANN model with Bayesian regularization is used to predict reference cutting force and cutting time simultaneously (MacKay, 1992). Matlab's neural network toolbox (Matlab 2005) is used to train neural networks taking the experimental values of cutting force component F_{yg} and cutting time Ct (as in Table 1). The parameters are normalized to lie between 0 and 1, by fixing the minimum and maximum values. Final network having a structure of 4-9-10-2 yields average errors of -0.08% and -0.13% with standard deviations of 2.89% and 3.09% for cutting force and cutting time respectively. The weights and biases are stored for further use. The network, when tested using additional data set (not given here), gives average errors of 0.51 % and -2.50% for cutting force and cutting time respectively, while the standard deviations are 8.93% and 12.78% respectively. For the set of cutting parameters identified by DE, the reference cutting force and cutting time obtained using the developed ANN are included in Table 3 itself.

4.4 ANN Model of Finish End-milling

In case of finish end-milling, the cutting force component more sensitive to flank wear is identified from the correlation coefficients between flank wear and various components of cutting forces. In the present case, F_{xg}, F_{yg} and F_{zg} show R^2 values of 0.8603, 0.8731 and 0.8760 respectively. It is seen that F_x-F_{xg} shows a better correlation (R^2 value) of 0.8961 where F_x is the maximum cutting force in X-axis before filtering and F_{xg} is the ,maximum cutting force component after Gaussian filtering. This is closely followed by 0.8959 for F_y-F_{yg} and 0.8834 for F_z-F_{zg}. Hence cutting force component F_x-F_{xg} is considered for high speed finish end milling process as given in Table 4. A final network of 4-4-7-1 for prediction of cutting force component F_x-F_{xg} yields an average error of -0.19% with a standard deviation of 4.31 %for cutting force component taken up in the present work. The weights and biases are stored for further use. The network, when tested using additional data set (not given here), gives an average error of -2.01 % for cutting force component, while the standard deviation is 4.55%. For the set of cutting parameters identified by DE, the reference cutting force component F_x-F_{xg} obtained using the developed ANN are included in Table 4.

5. IMPLEMENTATION OF CONTROL STRATEGIES

A PC based control system has been configured using NI hardware and LabVIEW software as shown in Fig. 5. A test part as shown in Fig. 6(a) has been prepared. When the end-milling proceeds from left to right, the cutter encounters a hard portion followed by air and a soft portion followed by again a hard portion. Hence this test part is referred to as H-A-S-H part. Two strategies shown in Fig. 6(b) and 6(c) have been selected for rough end-milling and finish endmilling operations. Taking the parameters predicted by ANN for rough end milling, feed of 230 mm/min is taken to be 100% for a spindle speed of 4707 rpm and a depth of cut of 2.49 mm. The reference FY9 is 962 N and the value of 512 N for VB = 0.1 mm is taken to be lower limit. In case of finish end milling, feed of 370 mm/min is taken to be 100% for a spindle speed of 11655 rpm and a depth of cut of 0.43 mm and reference F_x-F_{xg} is 272 N. During initial trials, a lower limit of 25% (68 N) is found to give the desired surface finish results. The feed variations as shown in Fig. 6(b) and (c) are programmed using LabVIEW for control purposes. Fig.7 brings out the variations of relevant force components and feed during the test cutting.

The trials on H-A-S-H test parts show nearly 14% reduction in cutting time, as the cutter moves faster during air-cuts. In addition, long run tests (155×185×35 mm hardened EN24) were also conducted in CNC mode using the cutting parameters predicted by ANN as well as using PC based control system. The control strategies implemented have led to improved performance in both roughing and finishing operations.

6. CONCLUSIONS

In the present study, an integrated frame work has been followed for the investigation of high speed rough and finish end-milling operations carried out on EN24 (AISI 4340) steel of 43-45 HRc using TiAIN coated insert.

- Using experimental results, quadratic models with the highest R^2 values have been developed by the application of Response Surface Methodology (RSM) taking flank wear as additional parameter along with the cutting parameters for rough (R^2 = 0.8905) and finish (R^2 = 0.8028) end-milling operations.
- Differential Evolution (DE) algorithm has been successfully employed to identify cutting parameters for rough and finish end-milling operations with different objectives. In case of rough end-milling, desired material removal (MR) is taken as the objective, while desired surface roughness (Ra) forms the objective in case of finish end-milling. As tool wear plays a very important role in both cases, appropriate limiting flank wear has to be specified. In the present study, the best combinations of cutting parameters have been found to provide

the required responses for rough and finish end-milling operations. These parameters will be used in development of CNC programs to run the machine .

- Extensive analysis of cutting force components shows that the filtered cutting force component in V-direction (F_{Yg}) is the best indicator (R^2 = 0.9484) in rough end-milling and it is highly sensitive to the changes in flank wear. In case of finish end-milling, the high frequency (dynamic) component of the signal F_X given by the difference between the maximum force along X-axis and the maximum of its filtered component (F_X-F_{Xg}) is found to be the best indicator (R^2 value 0.8961) .
- ANN models based on the Bayesian generalization have been developed in the present work. The model with a structure 4-9-10-2 is used to predict the reference cutting force component (F_{Yg}) and cutting time (Ct) in rough endmilling. The maximum of absolute average errors is 0.13% and maximum of the standard deviations is 3.09% for training data set and these values are 2.50% and 12.8% for test data respectively. The model with 4-4-7-1 structure is able to predict the reference cutting force component (F_X-F_{Xg}) in finish end-milling. For this model, absolute average error and standard deviations are 0.19% and 4.31% respectively with training data and the corresponding values are 2.01% and 4.55% with test data .
- The reference parameters from ANN models are used in developing real time control strategy for high speed end-milling to achieve high productivity and quality. The hardware and control architecture selected for the implementation are successfully tested by end-milling trials on specially prepared H-A-S-H test parts as well as by long run tests.

REFERENCES

Oewes, R.C., O.K. Aspinwall (1997) A review of ultra high speed milling of hardened steels, J. Mat. Process. Technol., 69,1-17.

Haber, R.E., J.E. Jimenez, C.R. Peres and J.R. Alique (2004) An investigation of tool-wear monitoring in a high speed machining process, Sensors and Actuators, 116, 539-545.

Jawahir, I.S., A.K. Balaji, K.E. Rouch and J.R. Baker (2003) Towards integration of hybrid models for optimized machining performance in intelligent manufacturing systems, J. Mat. Process. Technol., 139 (1-3),488-498.

Jemielniak, K. (1999) Commercial tool condition monitoring systems, Int. J. Adv. Manuf. Technol., 15, 711-721.

MacKay, O.J.C. (1992) A Practical Bayesian Framework for Back-Propagation Networks, Neural Computation, 4, 448-472.

Matlab user manual, Version 7.1, R14, The Math Works Incorporation Natick, U.S.A., 2005.

Montgomery, D.C., Design and Analysis of Experiments, John Willey and Sons, New York,1976.

Prakasvudhisarn, C., S. Kunnapapdeelert and P.Yenradee (2009) Optimal cutting condition determination for desired surface roughness in end milling, Int. J. Adv. Manuf. Technol.,41 (5-6),440-451.

Saikumar S. and M.S. Shunmugam (Accepted) Investigations into high speed rough and finish end-milling of hardened EN24 steel for implementation of control strategies, Int. J. Adv. Manuf. Technol. (00110.1007 /s00170-012-3915-8)

Saikumar S. and M.S. Shunmugam (2012) Development of a feed rate adaption control system for high speed rough and finish end-milling of hardened EN24 steel, Int. J. Adv. Manuf. Iechnol., 59(9-12), 869-884.

Schmitz, 1, M. Davies, B. Dutterer and J. Ziegert (2001) The application of high-speed CNC machining to prototype production, Int. J. Mach. Tools & Manufact., 41 (8),1209-1228.

Storn, R. and K. Price (1997) Differential Evolution - a Simple and Efficient Heuristic for Global Optimization over Continuous Spaces, J. Global Optimization, 11,341 - 359.

Werthiem, R (2002) Future direction for R&D in manufacturing engineering in Ireland and UK, CIRP Workshop, Dublin.

Torabi, A.J., M.J. Er, l. Xiang, B.S. Um, Z. Uanyin, S.J. Phua, Z. Junhong, S. Un, H. Sheng and J.lT. Tijo (2009) A survey on artificial intelligence technologies in modeling of high speed end-milling processes, Proc. IEEE/ASME Int. Conf. Adv. Intelligent Mechatronics, AIM, Singapore, 320-325.

ACKNOWLEDGEMENT

The details reported in this lecture notes are based on the research work carried out by Dr. S. Saikumar during his doctoral programme under my guidance.

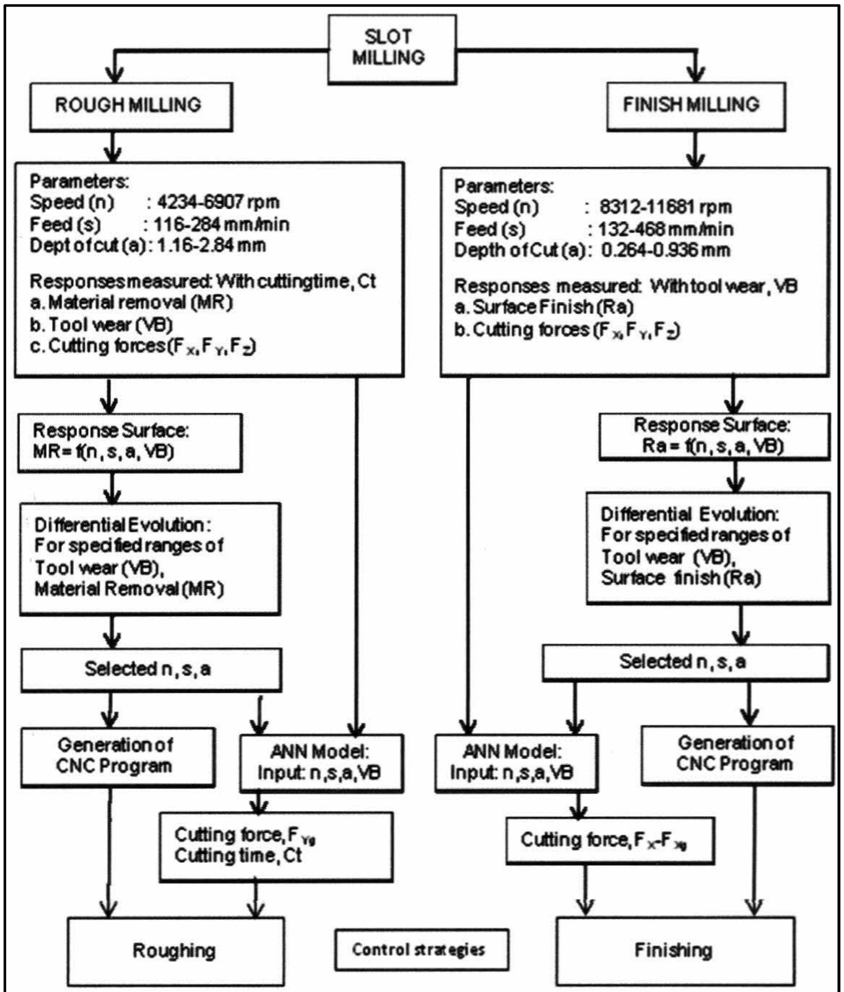


Fig. 1 Framework for Proposed Approach

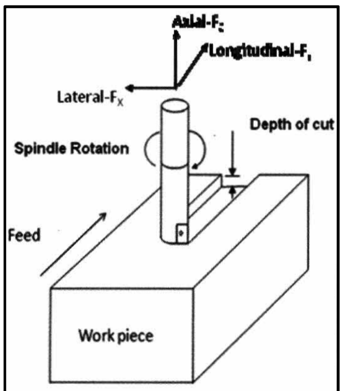
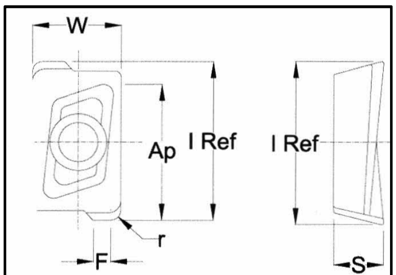
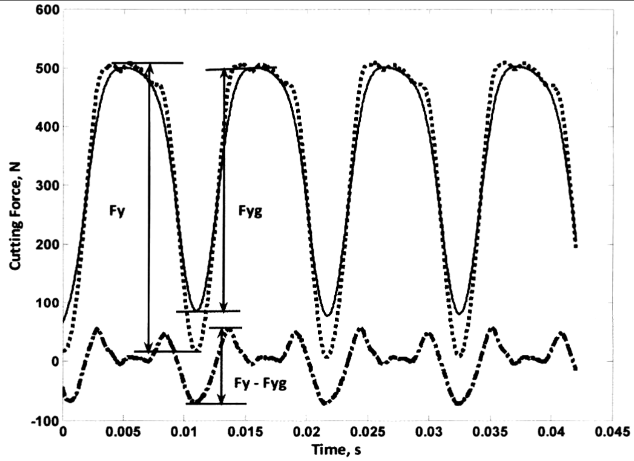


Fig. 2 Scheme of Slot-milling



Designation	W, mm	Ap, mm	1 Ref, mm	F, mm	S, mm	r, mm	Grade
Hm90 APKT 1003 PDR	6.76	10.26	11.45	1.4	3.53	0.8	IC 908

Fig. 3 Details of the Insert



.... Orginal signal Filtered signal -.-. Resultant signal

Fig.4 Longitudinal (Fy) force signal in rough end-milling, Exp:15, Slot: (machining parameters: speed = 5570 rpm, feed = 200 mm/min, depth of cut = 2 mm)

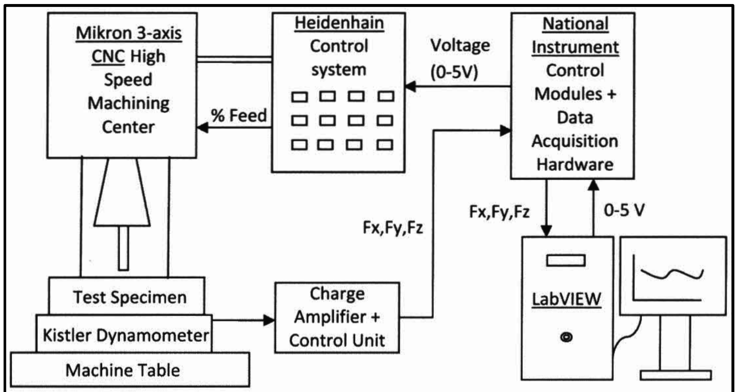


Fig. 5 Proposed PC based control system

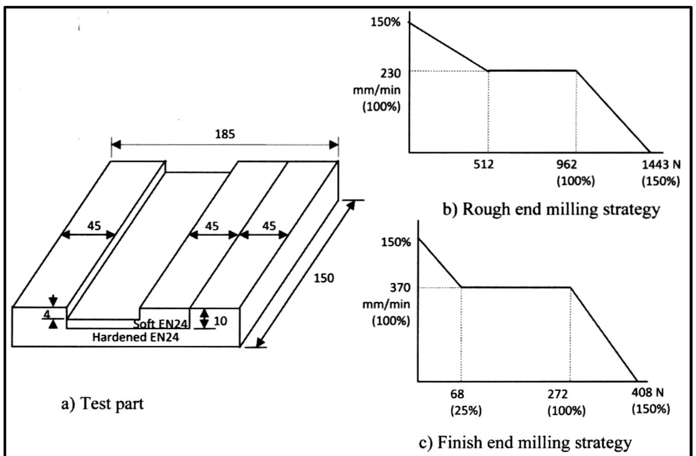
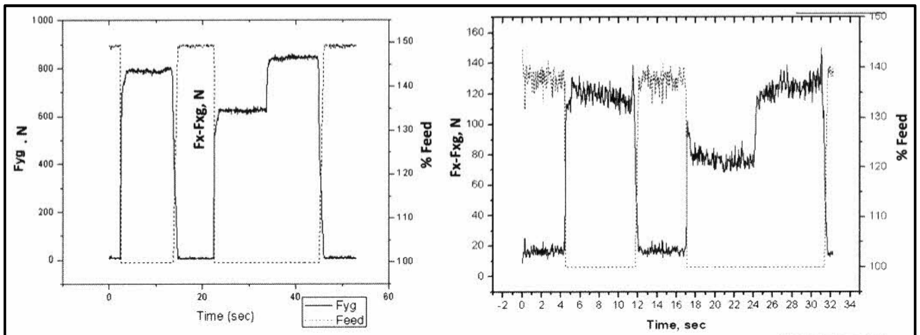


Fig.6 H-A-S-H Test part for control strategies



a) Rough end milling   b) Finish end milling

Fig. 7 Force and feed variations for H-A-S-H Test part

Table 1 Partial result for rough end-milling (Sets 3 & 4 not included)

Sl. No.	Speed *n* rpm	Feed *s* mm/min	Depth of cut *a* mm	Intermediate results									
				Set 1					Set 2				
				Slot No.	*Ct* min	*MR* cm^3	*VB* mm	F_{yg} *N*	Slot No.	*Ct* min	*MR* cm^3	*VB* mm	F_{yg} *N*
1	4775	150	1.5	6	7.60	16.65	0.102	454.4	12	15.20	33.30	0.188	485.7
2	4775	150	2.5	6	7.60	27.75	0.137	903.2	9	11.40	41.63	0.235	1003.7
3	4775	250	1.5	6	4.56	16.65	0.101	546.1	12	9.12	33.30	0.225	687.7
-													
14	5570	200	2.84	12	11.4	63.05	0.133	602.8	15	14.25	78.81	0.152	704.3
15	5570	200	2	6	5.70	22.20	0.128	512.8	9	8.55	33.30	0.254	557.4
16	5570	200	2	6	5.70	22.20	0.124	474.0	9	8.55	33.30	0.250	566.6

Table 2 Partial result for finish end milling (Sets 3 & 4 not included)

Sl. No.	Speed *n* rpm	Feed *s* mm/min	Depth of cut *a* mm	Intermediate results					
				Set 1			Set 2		
				VB mm	*Ra* µm	F_x-F_{xg} *N*	*VB* mm	*Ra* µm	F_x-F_{xg} *N*
1	9000	200	0.4	0.0	0.162	110.5	0.093	0.202	122.0
2	9000	200	0.8	0.0	0.141	195.6	0.113	0.161	259.7
3	9000	400	0.4	0.0	0.206	117.0	0.101	0.219	146.5
-									
14	10000	300	0.936	0.0	0.153	276.4	0.153	0.160	277.7
15	10000	300	0.6	0.0	0.125	190.1	0.138	0.132	194.3
16	10000	300	0.6	0.0	0.142	225.3	0.178	0.148	206.3

Table 3 Reference parameters for rough end milling predicted by ANN for a typical combination of parameters selected by DE

Sl. No.	*MR* = 80 - 100 cm^3 and *VB* = 0.38-0.4 mm							*VB* = 0.1 mm		
	DE					ANN		DE	ANN	
	Spindle speed *n* rpm	Feed *s* mm/min	Depth of cut *a* mm	Tool wear *VB* mm	Material Removal MR cm^3	Cutting Force F_{yg} N	Cutting Time *Ct* min	Matterial Removal MR cm^3	Cutting Force F_{yg} N	Cutting Time *Ct* min
1	5634	236	2.617	0.384	97.191	799.013	17.739	48.279	601.724	9.104
2	5634	237	2.616	0.384	97.238	799.895	17.695	48.408	605.513	9.086
3	4769	193	2.420	0.385	84.159	943.877	21.302	35.056	753.293	6.720
-										
10	**4707**	**230**	**2.490**	**0.388**	**99.664**	**962.363**	**19.265**	**51.012**	**512.300**	**5.942**
11	6572	236	2.564	0.398	99.525	566.057	14.359	55.463	515.837	6.578
12	4480	176	2.548	0.395	99.098	978.995	21.843	46.184	940.232	5.491

Table 4 Reference parameter for finish end milling predicted by ANN for a typical combination of parameters selected by DE

Sl. No.	*Ra* = 0.15 - 0.20 μm and *VB* = 0.28-0.3 mm						*VB* = 0.1 mm	
	DE					ANN	DE	ANN
	Spindle speed *n* rpm	Feed *s* mm/min	Depth of cut *a* mm	Tool wear *VB* mm	Surface roughness Ra μm	Cutting Force F_x-F_{xg} N	Surface roughness Ra μm	Cutting Force F_x-F_{xg} N
1	11398	316	0.441	0.299	0.190	243.462	0.096	183.440
2	11398	316	0.337	0.290	0.196	236.718	0.103	154.986
3	11659	346	0.604	0.286	0.175	336.282	0.097	234.750
-								
8	**11655**	**370**	**0.430**	**0.281**	**0.163**	**272.352**	**0.076**	**184.092**
9	11637	412	0.431	0.285	0.164	288.540	0.066	179.424
10	11675	380	0.444	0.288	0.165	283.920	0.073	187.740

Challenges in Supercritical Technology- NIT Tiruchirappalli Initiatives

Dr Srinivasan Sundarrajan

Director, NIT Trichy

Friends,

I am happy and feel highly honoured to deliver Dr. S.C. Bhattacharya Memorial Lecture. As a student, I had the opportunity to learn subjects through the books authored by Dr. Bhattacharya

The 29th National Convention of Mechanical Engineers has taken up Super Critical Technology as the theme subject. Through this lecture, I am attempting to outline some of the Research and Development issues which are emerging to the forefront. I am also conveying our commitment from NIT Tiruchirappalli for providing the necessary technological research input to the major national programme which is already on.

India is currently going through crisis in terms of energy and power. The Government of India through various departments and planning commission has identified super critical technology as one of the major power source in the country to be looked into. While we are proceeding on usage of nuclear power with no emission, there is a parallel need for developing efficiently the power generation with minimum carbon-di-oxide emission. This has led to the development of clean coal technology with low carbon energy. While this programme throws major challenges, this also provides multiple opportunities to meet these challenges.

When we discuss the issues on Super Critical Technology, three major areas are emerging:

1. Design & Development of components.

2. Optimization to maximize operational efficiency.

3. Environmental factors.

All the above areas are specially significant requiring focused attention. Dealing with higher pressure and temperature requirements call for use of recently developed materials which may pose special design requirements. Manufacturing methods especially welding and forming require experimental investigations. The overall system requires optimization to improve the performance efficiency. Environmental factors do play a major role.

Technology Benchmarkin

For improving the efficiency of power systems, there is a requirement of collection and consolidation of data on combustion based supercritical power generation status. Along with this, environment and pollution control data are to be compiled based on global operations of existing boilers. This will enable us to bench mark the design and performance characteristic of supercritical boilers. This exercise will provide detailed thrust areas for R & D in coal, materials and processing.

Coal Based Research

Coal is a dominant energy source for India. 80% of coal produced in the country is being used for coal based power production. Pulverized coal technology needs to be improved when we switch over to combustion for Super Critical application. After assessing the availability and quality of domestic coal, the specification requirements of pulverized coal are to be arrived at. When we increase the pressure and temperature of steam, the ash content of coal is a serious concern where research is to be oriented towards clean coal technology. During the next phase of operation with the available coal, optimization studies may have to be carried out for efficient conversion of water into steam. Along with this, the studies on emissions on the environment are to be carried out with the different characteristics of pulverized coal from subcritical to ultra super critical application.

Material Research

When we move from conventional to ultra super critical conditions, improvements are needed in terms of design, development and system integration. The behavior of gases with high pressure drop, flow stability and the effect of flow of gases on heat transfer characteristics of materials will be significantly different from conventional boilers.

Also, there is a primary requirement for development of materials to sustain and withstand higher levels of temperature and pressure. The corrosion and erosion characteristics have to be studied in detail for steam generator tubes, steam piping and high pressure turbine. The conventional systems use steels with 12% chromium content for achieving 30 MPa pressure for a temperature of 620°C. Nickel based alloys like inconel are used for pressure of 35 MPa and temperature of 720°C expecting an overall plant efficiency of about 48%.

Ultra supercritical conditions require materials that withstand high temperature and pressure. Since most of the materials are used in the form of pipes and tubes, ability to manufacture becomes a major area of study.

Role of NIT Tiruchirappalli

A major national programme is on to set up 800 MW ultra super critical power plant with steam pressure of 300 bar with operating temperature of 700'C/750'C . BHEL, Indira Gandhi Center for Atomic Research (IGCAR) and NTPC are core partners along with a number of educational institutions. The areas of activities include development of alloys and process equipment design and setting up of testing facilities.

National Institute of Technology, Tiruchirappalli has BHEL in neighborhood as a strategic partner. Supercritical Technology has been identified as thrust area for NITT. Around 20 faculty members have been trained on the current status of technology. The institution has very good materials and manufacturing specialists and is in a position to provide applied research support for all aspects of the technology. The areas of research include material characterization and property upgradation, corrosion an erosion studies, applied research on metal forming, joining and casting areas and on simulation. As a first step in this direction, a research project is on studying the hot corrosion behaviour of supercritical boiler materials. Corrosion proceeds in accelerated mode in the presence of salt contaminants like sulfides and chlorides of Sodium. They damage the protective oxide surface at high temperature. Burning of high ash coal, residual fuel oil and condensed molten salts cause these contaminants. In order to counter this, the material for the boilers should have resistance to service environment to withstand corrosion along with good thermal conductivity and low thermal expansion.

Similar studies on stainless steel are already available in the literature. NIT Tiruchirappalli is proposing to carry out corrosion, erosion, oxidation and coating studies on the materials which are proposed to be used for super critical boiler development programme. Inconel 740, 617, Haynes 230, Super 304H will be studied in detail. Coating methods proposed to be carried out are Ni-Cr-Al coating, Ni-Al/Ti/Ta coating (Specially for Corrosion/Erosion & Oxidation), Cr-V coating and Alumina Coating.

Mathematical models using factorial design and optimization techniques like Genetic Algorithm, Particle Swarm Optimization, Neural Network and Hybrid Algorithm are going to be used to optimize the parameters of corrosion behavior.

Focused research is required in the area of water for long term operation of the plant. Feed Water Treatment, HO Treatment, Oxi-generated Treatment are some of the major areas in controlling the chemistry of water. NIT Tiruchirappalli has an excellent group working on water treatment. We have the expertise to study the parameters and cycle option for the turbine and Electrical Power Plant. We have a group to study the Material Inventory and Process Flow Optimization. The faculty members and students will be taking up projects in the areas to be identified in the super critical technology. We are offering ourselves to join the national integrated group for development of super critical technology in India.

To sum up

Super Critical Technology is an important step for the country to counter the power issues. Extensive base work II has already been carried out by BHEL, NTPC & IGCAR. The technology has crucial research areas which are to be identified. In this integrated approach, NIT Tiruchirappalli will be able to play a role as a team member of the national mission.

Let me thank the organizers for giving me the opportunity to deliver Dr.S.C. Bhattacharya Memorial Lecture.

From Horse Power to Horse Power

Dr V Ganesan

Professor Emeritus
Department of Mechanical Engineering, Indian Institute of Technology Madras

INTRODUCTION

It is believed that man got his mobility when he invented wheels. But I beg to differ. God has given mobility to all the living beings including human beings right from the birth. The first form of mobile transport for the man was of course shanks pony. What is Shanks poney? It is nothing but the human foot. Before going into the details of horse power, let us briefly go through the brief history of ancient transport.

ANCIENT TRANSPORT

Even thought the first form of transport was, of course, Shanks pony (the human foot!). People eventually learned to use animals for transport. Donkeys and horses were probably domesticated between 4,000 and 3,000 BC (obviously the exact date is not known). Camels were domesticated slightly later between 3,000 and 2,000 BC.

Meanwhile about 3,500 BC the wheel was invented in what is now Iraq. At first wheels were made of solid pieces of wood lashed together to form a circle but after 2,000 BC they were made with spokes. This invention gave man greater mobility.

The earliest boats were dug out canoes. People lit a fire on a big log then put it out and dug out the burned wood.

Egyptians Transport

About 3,100 BC the Egyptians invented the sailing boat. They were made of bundles of papyrus reeds tied together. They had simple square sails made of sheets of papyrus or later of linen.

However the sail could only be used when sailing in one direction. When traveling against the wind the boat had to be rowed. About 2,700 BC the Egyptians began using wooden ships for trade by sea. Early ships were steered by along oar.

Roman Transport

The Romans are famous for the network of roads they built across the Empire. Roman legionaries built them so the Roman army could march from one part of the empire to another quickly. Rich people traveled by horse or on long journeys by covered wagon. Sometimes they were carried in litters (seats between two long poles).

Travel by water was also important to the Romans. They built large merchant ships called cortia, which could carry up to 1,000 tons of cargo. Roman ships had a single main mast, which carried a rectangular sail, although some ships also had small sails at the bow and stern. Roman ships did not have rudders. Instead they were steered by oars. The Romans also built lighthouses to aid shipping.

Transport in the Middle Ages

After the fall of Rome, roads in Europe returned to being simple dirt tracks, which turned to mud in the winter. In the Middle Ages rich people sometimes traveled in covered wagons. They must have been very uncomfortable as they did not have suspension and roads were bumpy and rutted.

Others travelled on a box between two poles. Two horses, one in front and one behind carried it. They were trained to walk at the same pace. However, at sea a number of useful inventions were made. The Chinese invented the compass centuries before it was used in Europe.

Nevertheless by the 12th century Europeans had learned to use it. Also in the 12th century Europeans invented the rudder. Rudders made ships much easier to steer. Furthermore shipbuilding became far more advanced and by the 15th century ships were made with 3 masts.

Tudor Transport

In Tudor times roads were still just dirt tracks. Men were supposed, by law, to spend a number of days repairing the local roads but it is unlikely they did much good! People travelled by horse. You could either ride your own or you could hire a horse.

In Tudor times you would be lucky if you could travel 50 or 60 kilometers a day. It normally took a week to travel from London to Plymouth. However rich people deliberately travelled slowly. They felt it was undignified to hurry and they took their time.

Goods were sometimes transported by pack horse (horses with bags on their sides). Also carriers with covered wagons carried goods and sometimes passengers. However, when possible people preferred to transport goods by water. All around England there was a 'coastal trade'. Goods from one part of the country, such as coal, were taken by sea to other parts.

TRANSPORT IN THE 17TH CENTURY

Transport and communications improved in the 17th century. In 1600 the royal posts were exclusively used to carry the kings correspondence. However in 1635, to raise money, Charles I allowed members of the public to pay his messengers to carry letters. This was the start of the royal mail. From the middle of the 17th century stagecoaches ran regularly between the major towns. However they were very expensive and they must have been very uncomfortable without springs on rough roads. There was also the danger of highwaymen.

In 1663 the first Turnpike roads opened. You had to pay to use them. The money was used to maintain the roads. In towns wealthy people were carried in sedan chairs.

TRANSPORT IN THE 18TH CENTURY

Transport was greatly improved during the 18th century. Groups of rich men formed turnpike trusts. Acts of Parliament gave them the right to improve and maintain certain roads. Travelers had to pay tolls to use them. The first turnpikes were created as early as 1663 but they became far more common in the 18th century.

Transporting goods was also made much easier by digging canals. In the early 18th century goods were often transported by packhorse. Moving heavy goods was very expensive. However in 1759 the Duke of Bridgewater decided to build a canal to bring coal from his estate at Worsley to Manchester. He employed an engineer called James Brindley. When it was completed the Bridgewater canal halved the price of coal in Manchester. Many more canals were dug in the late 18th century and the early 19th century. They played a major role in the industrial revolution by making it cheaper to transport goods.

Travel in the 18th century was made dangerous by highwaymen. The most famous is Dick Turpin (1705-1739).

Originally a butcher Turpin does not deserve his romantic reputation. In reality he was a cruel and brutal man. Like many of his fellow highwaymen he was hanged.

Smuggling was also very common in the 18th century. It could be very profitable as import duties on goods like rum and tobacco were very high. There were also wreckers. On stormy nights they deliberately lured ships onto rocks with lights. When the ship was wrecked they stole anything they could.

TRANSPORT IN THE 19TH CENTURY

In the mid 19th century travel was revolutionized by railways. They made travel much faster. (They also removed the danger of highwaymen). The Stockton and Darlington railway opened in 1825. However the first major railway was from Liverpool to Manchester. It opened in 1830. In the 1840s there was a huge boom in building railways and most towns in Britain were connected. In the late 19th century many branch lines were built connecting many villages.

The first underground railway in Britain was built in London in 1863. Steam locomotives pulled the carriages. The first electric underground trains began running in London in 1890. From 1829 horse drawn omnibuses began running in London. They soon followed in other towns.

In the 1860s and 1870s horse drawn trams began running in many towns. Karl Benz and Gottlieb Daimler made the first cars in 1885 and 1886. Meanwhile at sea travel was revolutionized by the steam ship. By 1815 steamships were crossing the English Channel.

Furthermore it used to take several weeks to cross the Atlantic. Then in 1838 a steam ship called the Sirius made the journey in 19 days. However steam did not completely replace sail until 1897 when Charles Parsons invented the steam turbine.

Horse Power Transportation in 19" Century

In the beginning of the 19th century, the main mode of transportation was the horse and carriage. But, the horse power gave lot of problem. It is worthwhile to dwell on this problem, which caused a lot of pollution and accident. The world's first international conference on urban planning was held in New York City in 1898. The discussion was not about urban planning and not even about housing or land use or economic development or infrastructure. The delegates were discussing the strange problem of horse manure.

Horses were used for transportation for thousands of years. The horse was the only source of mobility in the urban area. But by the late 1800s, the problem of horse pollution had reached unprecedented heights. The growth in the horse population was outstripping the population of the city dwellers. It may not be an overstatement if we say American cities were drowning in horse manure as well as other unpleasant byproducts. It was due to man's dependence on horses for his predominant mode of transportation. Urine, flies, congestion, carcasses, and traffic accidents were the order of the day. Widespread cruelty to horses was a form of environmental degradation as well.

The situation seemed to be quite daunting. In 1894, the Times of London estimated that by 1950 every street in the city would be buried ten feet deep in horse manure.

One of the New York reporters of the 1890s wrote that by 1930 the horse droppings would rise to Manhattan's third-story windows. A public health and sanitation crisis of almost unimaginable dimensions loomed large.

And no alternative solution could be thought of. It is because the horse had been the dominant mode of transportation for thousands of years. Horses were absolutely essential for the functioning of the nineteenth century city for personal transportation, freight haulage and mechanical power. People could not think of living without horses. Horses have become part and parcel of daily life. All efforts to mitigate the problem were proving woefully inadequate. The delegates of the urban planning conference declared their work fruitless. The conference was closed in three days instead of the scheduled ten.

It wasn't until the latter part of the century that railways changed people's lives and habits. But even after the advent of the railway, remote areas still relied on the horse for local transport. Following is a brief summary of the types of vehicles used to get around. Carts, drays, vans and wagons were generally used for carrying goods in England. They could also be used to carry people, but generally people of the lower orders. Carriages carried people in England. Barouches, landaus, victorias, curricles and broughams were all carriages. They varied in body shape and number of horses pulling them.

Open Carriages

Barouche--a four-wheel fancy carriage with a fold-up hood at the back and with two inside seats facing each other. It was the fancy carriage of the first half of the 19th century.

Berlin--A big four-wheel carriage with a hood.

Curricle--A two-wheel carriage that was fashionable in the early 1800s. It was pulled by two horses and deemed sporty by the younger set.

Gig--A two-wheel vehicle intended for single-horse driving by an owner.

Landau--Open, fancy carriage with four wheels with a hood at each end and two seats opposite each other. It was popular in the first half of the 19th century. Two horses pulled the landau.

Phaeton--A light four-wheel carriage with open sides and drawn by one or two horses.

Victoria--A low, open carriage with four wheels, which sat only one or two people. It was in use from about mid-century and very popular with ladies' driving.

Closed Carriages:

Brougham - All-purpose everyday vehicle for the quality in the latter part of the century. Originally a two-wheel vehicle, by the latter part of the 19^{th} century, they were most often four-wheel carriages.

For Hire Vehicles:

Hackney--For hire, hackneys were often discarded carriages of the wealthy, They served as taxis in the 19" century.

Cabriolet--(cab)--These were introduced into England in the 1820s from France. They quickly replaced hackney coaches.

Hansom--Invented in the 1830s, it had two wheels and the driver sat in back, so the passengers could get a clear view of where they were going. They eventually replaced the cabs. It was introduced into the United States later in the century. By the 1890s, tires were rubber, making the ride smoother.

Omnibus--The first one appeared in London in 1829 and carried about 22 passengers. By the 1880s, a circular staircase leading to the roof added more seating on top. They carried 12 passengers inside and 14 on top. They ran fixed routes and were pulled by horses.

Country Vehicles

Wagon--long, heavy vehicle used in the English countryside for carrying heavy goods and people who didn't have the money to travel fast.

Dray--a cart with no sides used for hauling heavy loads.

Van--A covered-over, lightweight version of the wagons used for hauling goods, and sometimes for people.

Coaches

Coaches were enclosed, four-wheel vehicles used for long-distance travel.

Stagecoach--coaches which stopped at various pre-appointed stages in order to pick up and drop off passengers. They were the only way to visit people not on the mail coach routes. They were built to carry the same passengers as the mail coaches.

Mail coaches--subsidized or owned by the post office and painted uniformly. They carried four inside passengers and up to eight outside passengers. Mailbags were piled on the roof and luggage was carried in receptacles called boots.

Carriages of American Origin

Road Wagon, Dog-cart, and Surrey--Were most useful for country work and for fast trotting.

Rockaway--Usually relegated to country use, as it was difficult for the coachman to drive in crowded streets on a low seat. They were either closed or open.

Runabout--The most generally used light wagon for two passengers.

Wagonette--lightweight and led by two horses, it was useful in the country because it carried a large number of passengers with the least effort to the horses.

TRANSPORT IN THE 20TH CENTURY

Although the first cars appeared at the end of the 19th century, only after the First World War they became cheaper and more common. However in 1940 only about one in 10 families owned a car. They increased in number after World War II. By 1959 32% of households owned a car. Yet cars only became really common in the 1960s. By the 1970s the majority of families owned one.

In 1903 a speed limit of 20 MPH was introduced. It was abolished in 1930. However in 1934 a speed limit of 30 MPH in built-up areas was introduced, Meanwhile in 1926 the first traffic lights were installed in London. A driving test was introduced in 1934. Also in 1934 Percy Shaw invented the cat's eye.

The parking meter was invented by Carlton Magee. The first one was installed in the USA in 1935. In 1983 wearing a seat belt was made compulsory. Meanwhile in 1936 Belisha Beacons were introduced to make road crossing safer. The first zebra crossing was introduced in 1951.

The modern pelican crossing gates from 1969 and lollipop men and women were first introduced in 1969.

In 1931 an American called Rolla N. Harger invented the first breathalyser. It was first used in Indianapolis USA in 1939.

A Swede named Nils Bohlin developed the three-point seat belt in 1959.

Meanwhile in the late 19th century horse drawn trams ran in many towns. At the beginning of the 20th century they were electrified. However in most towns trams were phased out in the 1930s. They gave way to buses, either motorbuses or trolley buses, which ran on overhead wires. The trolleybuses, in turn were phased out in the 1950s.

Ironically at the end of the 20th century some cities re-introduced light railways.

In the mid-20th century there was a large network of branch railways. However in 1963 a minister called Dr. Beeching closed many of them.

The first hovercraft was launched in 1959. The first hovercraft passenger service began in 1962.

In 1919 aeroplanes began carrying passengers between London and Paris. Jet passenger aircraft were introduced in 1949.

However in the early 20th century flight was a luxury few people could afford. Furthermore only a small minority could afford foreign travel. Foreign holidays only became common in the 1960s.

The Boeing 747, the first ‘Jumbo jet' was introduced in 1970.

The Channel Tunnel opened in 1994.

MODERN AUTOMOBILES TRENDS

Modern Global Automobile Industry

Today, the modern global automotive industry encompasses the principal manufacturers, General Motors, Ford, Toyota, Honda, Volkswagen, and Daimler Chrylser, all of which operate in a global competitive marketplace. It is suggested that the globalization of the automotive industry, has greatly accelerated during the last half of the 1990's due to the construction of important overseas facilities and establishment of mergers between giant multinational automakers.

Industry specialists indicate that the origins in the expansion of foreign commerce in the automobile industry, date back to the technology transfer of Ford Motor Company's mass-production model from the U.S. to Western Europe and Japan following both World Wars I and II.

The advancements in industrialization led to significant increases in the growth and production of the Japanese and German markets, in particular. The second important trend in industrial globalization was the export of fuel efficient cars from Japan to the U.S. as a result of the oil embargo from 1973 to 1974.

Increasing global trade has enabled the growth in world commercial distribution systems, which has also expanded global competition amongst the automobile manufacturers. Japanese automakers in particular, have instituted innovative production methods by modifying the U.S. manufacturing model, as well as adapting and utilizing technology to enhance production and increase product competition.

There are a number of trends that can be identified by examining the global automotive market, which can be divided into the following factors:

Global Market Dynamics — The world's largest automobile manufacturers continue to invest into production facilities in emerging markets in order to reduce production costs. These emerging markets include Latin America, China, Malaysia and other markets in Southeast Asia.

Establishment of Global Alliances — U.S. automakers: “The Big Three” (GM, Ford and Chrysler) have merged with, and in some cases established commercial strategic partnerships with other European and Japanese automobile manufacturers. Some mergers, such as the Chrysler Daimler-Benz merger, were initiated by the European automaker in a strategy to strengthen its position in the U.S. market. Overall, there has been a trend by the world automakers to expand in overseas markets.

Industry Consolidation — Increasing global competition amongst the global manufacturers and positioning within foreign markets has divided the world's automakers into three tiers, the first tier being GM, Ford, Toyota, Honda and Volkswagen, and the two remaining tier manufacturers attempting to consolidate or merge with other lower tier automakers to compete with the first tier companies.

1st Tier Company Mergers — Volkswagen-Lamborgini; BMW-Rolls Royce; 2nd Tier Company Mergers — Chrysler-Mercedes Benz; Renault- Nissan-Fiat; 3rd Tier Company Mergers - Mazda-Mitsubishi; Kia-Volvo.

The Hottest Trends in Automation & Technology — Automation and technology systems are exerting more influence on the way businesses run. And as automated systems and technologies get more ubiquitous and powerful, they are also becoming more invisible, with many imbedded intelligent devices undetectable to passersby. CAD/CAM software is improving its process planning capabilities, which involves finding the right tool to do the right job.

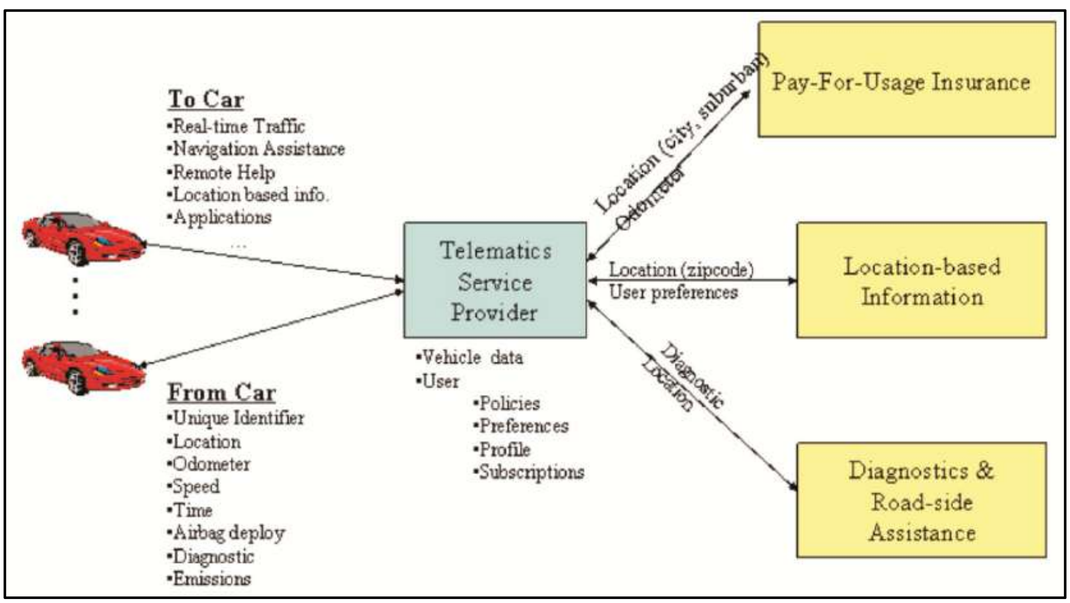
AUTOMOTIVE TELEMATICS

Automotive Telematics combines the power of computers and computer systems with remote communications technologies (such as GPS, wireless, cellular, etc.) to obtain information about remote automotive vehicles. Today, telematics applications now range from tracking rental cars to lost pets or persons. Of course, there have been well-known retail applications of telematics in the automotive industry for several years.

To understand telematics, we begin with a description of the global positioning system (GPS) because without GPS, there would be no telematics. GPS is a technology that is ideally suited to both navigation and positioning. The GPS was developed to fulfill this important military need and included a satellite network, ground communications stations and receivers. It is the only fully functional satellite navigation system. Currently, more than two dozen GPS satellites orbit the Earth, transmitting radio signals that allow GPS receivers to determine their location, speed and direction.

The telematics system within the car is comprised of a telematics communications unit (TCU) that is connected wirelessly to a central service center. The TCU serves as the central platform of a telematics system, where all telematics-related technologies are deeply integrated.

It communicates location-specific information to a central service center, and in turn, the center helps deliver telematics services to a driver via cellular phone. The TCU is also connected to the engine control unit (or the on-board computer), which enables enhanced services such as remote engine diagnostics and automatic airbag notification.



Telematics is an emerging market of automotive communications technology that combines wireless audio and visual data to provide location-specific security, information, productivity and in-vehicle entertainment services to drivers and their passengers. Telematics can be divided into two groups:

1. Features related directly to operating, locating or maintaining the vehicle.

2. Features enabling the use of certain applications that were once used outside the vehicle, i.e. in the home and office.

Telematics has three basic principles:

1. two-way communication capabilities (wireless);

2. location technology (geographic position); and

3. computing platform for system control and interface to automotive electronics system(s).

Brief History of Telematics

For vehicle technology, all the pieces came together in the 1990s: GPS, cell phone technology and the Internet. Telematics emerged as the means to link the automobile to satellite-based positioning technologies via wireless connectivity, enabling audio or visual data and drivers to connect.

A telematics system offers drivers emergency and roadside assistance, airbag deployment notification, navigation, remote door unlock, vehicle security notification and stolen vehicle tracking services. Drivers activate telematics systems via buttons located on the dashboard or an overhead console of the car.

With the explosion of cell phone, computer and electronic entertainment use, there was a growing interest among motorists to extend these capabilities into their automobiles.

Some telematics service providers (TSPs) wanted to provide more than just a help line by offering a variety of services, incorporating in-car DVD players, GPS, hands-free cell phones and other telematics into vehicles. Telematics could feasibly provide automobile monitoring and, at the same time, a safe communications link.

Telematics systems have evolved from the concept of one company putting the whole system together to the realization that specific areas of expertise in hardware, software or other vital services can be provided by individual companies.

Practical Applications of Automotive Telematics

There are numerous applications, services, software packages and hardware under the telematics banner. Currently there is no “all-in-onesolution.” Today's driver may have multiple independent systems all wirelessly connected to his or her vehicle: cell phone, On Star emergency service, Blackberry and a tag for automated highway toll collection. Some current or future applications of automotive telematics include:

Vehicle tracking that monitors the location, movement, status and behavior of a vehicle or fleet. This is achieved through a combination of a GPS/Global Navigation Satellite System (GNSS) receiver and an electronic device [usually comprising a Global System for Mobile Communications (GSM) and General Packet Radio Service (GPRS) modem] installed in each vehicle. These components communicate with the user (dispatching, emergency or coordinating unit) and computer- or Web-based software. The data is turned into information management reporting tools in conjunction with a visual display on computerized mapping software. Advanced vehicle localization systems for public transport may employ odometry instead of GPS/GNSS.

Trailer tracking follows the movement and position of an articulated vehicle's trailer unit. It uses a location unit fitted to the trailer and a method of returning the position data via mobile communication network or geostationary satellite communication for use through either computer- or Web-based software.

Satellite navigation technology uses GPS and an electronic mapping tool to enable the driver of a vehicle to locate a position, then route and navigate a journey.

Mobile data employs wireless data communications by using radio waves to send and receive real-time computer data to, from and between devices used by field-based personnel. These devices can be fitted solely for use while in the vehicle (fixed data terminal) or for use in and out of the vehicle (mobile data terminal).

The introduction of real-time traffic data to the in-vehicle navigation systems occurred in 2005. The driver is provided alternative routes when commuting to/from work or when traveling. The application has been impressive but has presented some problems with the accuracy and timeliness of the traffic data itself.

Intelligent Transportation Systems include automated highway and traffic control systems, the integration of private and public transport and tolling technology for bridges, highways and urban areas.

Dedicated Short-Range Communications (DSRC) are wireless systems used to communicate over distances of less than 1,000 feet (300 meters). They can be used for vehicle-to-roadside (VtR) or vehicle-to-vehicle (VtV) applications. The systems are primarily deployed using radio frequencies; other options include infrared (IR), or low-power laser. DSRC systems consist of roadside units (RSUs) and the on-board units (OBUs) with transceivers and transponders. This technology is currently being tested but could be seen in vehicles as early as 2009.

Widespread acceptance of telematics will be advanced by commercial fleets, which use GPS to track vehicles and cargo. Telematics provides the means for a company to know the location of every vehicle or how the vehicle is driven. Netistix, a Canadian company started in 2002, services customers all over North America. Its technology, known as Fleet Pulse, can collect a wide range of data that the fleet manager can decide what is or is not relevant. Each vehicle is equipped with a device ($400/vehicle) that plugs into the diagnostic port of the vehicle - OBD-II or J1708 on heavy duty vehicles. The device comes with Wi-Fi and Bluetooth wireless communication ability. Once installed, this system will report what's happening with the vehicle — emissions control data, oxygen sensor performance, fuel consumption, diagnostic trouble codes, whether or not the check engine light is on, etc.

Another company, Networkcar, offers an integrated GPS tracking and diagnostic monitoring system for wireless vehicle management. Currently, it is primarily aimed at fleets. The system plugs into an on-board diagnostic port to send wireless information to a secure Web site.

Radio frequency identification (RFID) is an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags or transponders. An RFID tag is an object that can be applied to or incorporated into a product, animal or person for the purpose of identification using radio waves. Some tags can be read from several meters away and beyond the line of sight of the reader.

This technology has been employed by major aftermarket suppliers and retailers to improve the efficiency of inventory tracking and management. Other current uses include passports, transportation payments, product tracking, car keys and animal identification.

THE CAR OF THE FUTURE

Future Outlook

The future of the automobile may move from a basic form of transportation to include all things home, office and in between. Cars may become a future hub ofinformation—handling everything from important e-mail and news, to making reservations and obtaining directions. Everything that can be done at home or office could now be done in your vehicle.

Automotive telematics systems are used for a number of purposes, including collecting highway tolls, managing road usage through the U.S. Department of transportation, Intelligent Transportation System, tracking fleet vehicle locations, recovering stolen vehicles, providing automatic collision notification, and providing location-based driver information services.

In addition, a telematics system could have the capability to provide remote diagnostics, whereby the vehicle's built-in systems would identify a mechanical or electronic problem and that information would be relayed to the vehicle manufacturer. As an added bonus for consumers, audio and audio-visual entertainment packages could be added to the system. There is also the option of integrating GPS functionality into mobile devices — PNDs, PDAs and cell phones — instead of embedded in the vehicle itself.

The major obstacle to this is the ability of the GPS to operate inside the automobile without an external GPS or cellular antenna. GPS antennas must have an unrestricted view of the sky to track satellites. This would be attractive from a cost and convenience perspective, but it would not support the stolen vehicle alarm, door lock/unlock and other features that require the device to remain in the vehicle when the occupants have left.

Telematics systems once relied only on satellites to communicate, but now providers are piggybacking on digital cellular signals through agreements with providers such as Sprint and Verizon, making communicating more cost-effective. This will help the telematics market to reach the “critical mass,” which will make a major difference in the automotive aftermarket.

The Car of the Future — Tomorrow's vehicles will be different. Very different. Take the higher voltage electrical and electronics systems for example. A 36 volt battery in place of today's 12v system is one change that is coming. Digital wiring harnesses is another. Be amongst the few who know what's around the corner as Automotive Telematics reveals the secrets of the future car and also provides you with answers to key questions like: What is this all likely to mean to auto makers and component manufacturers? How will these changes benefit drivers? And how will they effect you?

Human Machine Interface — Which is the best way of getting information to the driver, screen or voice? Or a combination of both? Find out what you can expect to see implemented as Automotive Telematics explores the options available. You'll also learn about some of the alternatives that are already being developed, including voice-activated control systems and heads-up display technology.

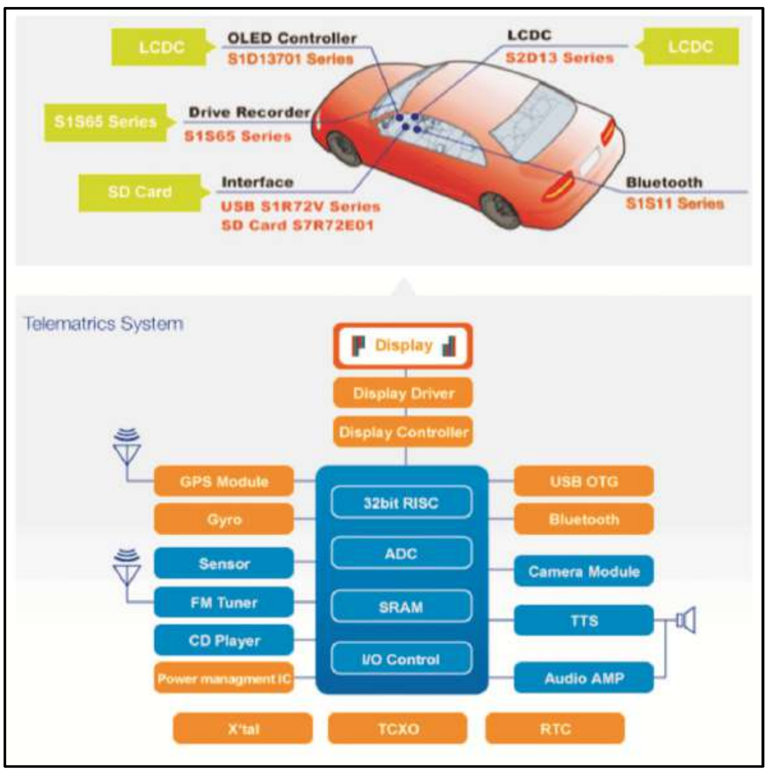
Navigation — Accurate route guidance is integral to the success of telematics platforms. How has it been developed? And even more importantly — do you know what is about to be unleashed? Automotive Telematics shows you the route forward and answers burning questions like, "Is it true that every time I use route guidance, somebody can check on my movements?"

Mapping — The days of the paper map are numbered. But what are the digital cartographers to provide accurate and up-to-date information to telematics service providers? How can digital mapping be used to increase road safety? How do providers overlay vital information like speed limits, real-time traffic information codes and height restriction data? Automotive Telematics has the answers.

Traffic Information — Live, valid and accurate traffic information is considered a must-have application by many end users. It brings navigation to new heights and makes child's play out of avoiding congestion hotspots. Time and money savings are tremendous, especially for fleet operators. But what about the data gatherers? What do they get out of all this? Does a business case exist for them?

Automotive Telematics uncovers the answers to these questions and more. Discover how traffic jams can be made to pay!

Telematics as a Security Aid — Being able to track the whereabouts of vehicles and personnel is one of the many major benefits that telematics can provide. But how do you decide the best option for your company? What are the most reliable tracking and communications systems? Automotive Telematics provides you with key pointers to assist you in the decision making process and helps ensure you avoid costly mistakes.



Telematics as a Safety Aid — Duty of Care requirements are an increasing burden on employers. Automotive Telematics investigates the ways in which telematic technology can be used to ease the load, providing you with rapid response options to staff-in-danger calls. Telematics can even come to the aid of stricken sailors, automatically notifying the coastguard —and giving a precise set of location coordinates.

The Mobile Internet — What exactly is meant by mobile Internet? How do drivers interface with their offices? Will cars have computer-style keyboards, or will there be a more driver-friendly way of accessing webbased information on the move? Automotive Telematics tells you what you can expect and why?

Remote Diagnostics — Discover the fascinating truths about the vehicle that can heal itself, the workshop that can automate its diagnostics, and the car that calls in sick all by itself. Find out what these amazing technologies will mean to you and how they can save youmoney!

Remote Vehicle Control — There are hundreds of horror stories about control of vehicles being taken over by a computer someplace. What substance is there to these tales? Is it really possible? And will you ever get into your car, punch in a destination and then sit back and relax for the entire journey? Or is this just the work of an overwrought imagination? Discover the facts in Automotive Telematics and be prepared for some surprises!

Lone Worker Protection — What can you do to ensure that your service engineers, your paramedics, your security officers are safe in their work? Telematics offers a range of solutions, but which is right for you? Automotive telematics evaluates these technologies and the hardware required to make your people feel safe as they work.

Wouldn't you like to have all the facts to hand before you make such an important decision?

Telematics and Human Rights — Yes, Big Brother can watch over you if the potential of telematics technology is abused. Automotive Telematics investigates this controversial aspect of the industry so you can fully appreciate the human rights issues involved and their implications. But Automotive Telematics doesn't stop there, and goes on to offer ways of balancing the rights of your employees with your rights as a business operator.

Remote Fixed Asset Management — What is happening to your piece of plant when you aren't watching it? How will you know if it breaks down, or is attacked by vandals? Telematics is the answer to your problems, and provides remote monitoring even from as far as a thousand miles away. But take note — great care needs to be taken when deciding on the best choice of equipment for your particular requirements and situation. Mistakes are expensive! Thankfully Automotive Telematics empowers you with the facts you need. With Automotive Telematics you'll be able to make informed choices and ensure you don't get burned.

Automated Highway Technology & Public Transport Systems — How do local authorities achieve their holy grail of reducing the ecological impact of transportation systems? How do you link up trains, buses, cars and trucks to integrate with each other's functions? Automotive Telematics delves deep into the world of automated highway systems and integrated transport to provide answers to these questions. You'll also discover how these ideas are likely to effect you, no matter which part of the chain you are in.

CONCLUSION

Industry experts see a definite need and a place for the aftermarket in the telematics segments, especially as hardware and services become more cost-effective and new products demand quicker product development cycles, something the OEMs often can't accommodate.

The independent repair sector is keenly aware that remote diagnostic capabilities may keep motorist captive to the automaker for maintenance and repair. It appears that telematics will have an impact on the independent automotive service and repair industry. However, it's hard to predict how large an impact. Currently, enough data exists to support the fact that the dealerships will not be able to service every vehicle on the toad. But, a reality is that OEMs will continue to produce vehicles with telematics capabilities.

The popularity of telematics will continue to depend on the consumer. The OEMs will have to find the right fit at the right price to increase the demand.

To ensure that an OEM gets a return on its investment, it appears that telematics must become standard equipment on all vehicles.

Independent repairers have faced many challenges over the years and have survived. Telematics is another hurdle that the independent repairer will have to address. Just like computers, cell phones and the Internet — which were once new technologies — telematics will also become integrated into our daily lives. Some independent repairers may fear telematics and envision it as a dark cloud over the industry. Others will see it as a light leading to new business opportunities. Every problem has a solution. There will be a solution to telematics that will benefit the independent automotive service and repair professional, as well as the manufacturers and service providers. Facing the challenge, accepting it and educating yourself about telematics will move the independent automotive repairer forward. The automotive service and repair industry can adapt to this technology.

BIBLIOGRAPHY

1. Clay McShane and Joel A. Tarr. “The Centrality of the Horse in the Nineteenth Century American City,” in The Making of Urban America.

2. Clay McShane. Down the Asphalt Path: The Automobile and the American City. (New York: Columbia University Press, 1994),

3. Francis Michael Longstreth Thompson, ed. Horses in European Economic History: A Preliminary Canter (Great Britain: British Agricultural History Society, 1983).

4. Francis T. Underhill, Driving Horse-Drawn Carriages for Pleasure by (Dover Publications) What Jane Austen Ate and Charles Dickens Knew by Daniel Pool (Simon & Schuster).

5. G.&D.Cook & Co.'s Illustrated Catalogue of Carriages and Special Business Advertiser foreword by Paul H. Downing (Dover Publications).

6. http://www.asashop.org/news/asaresources/ASAtelematics_0508.pdf.

7. http://www. localhistories.org.

8. Joel A. Tarr (Akron, Ohio: University of Akron Press, 1996).

9. Joel A. Tarr, “The Horse: Polluter of the City,” in The Search for the Ultimate Sink: Urban Pollution in Historical Perspective, ed.

10. Kristine Hughes, The Writer's Guide to Everyday Life in Regency and Victorian England by (Writer's Digest Books).

11. Lawrence H. Larsen, “Nineteenth-Century Street Sanitation: A Study of Filth and Frustration,” Wisconsin Magazine of History, vol. 52, no. 3, Spring 1969.

12. Raymond A. Mohl (Wilmington DE: Scholarly Resources, 1997). Nigel Morgan, “Infant Mortality, Flies and Horses in Later-Nineteenth-Century Towns: A Case Study of Preston,” Continuity and Change, vol. 17, no. 1, 2002.

Prospects and Challenges of Manufacturing Sector within Ethical Framework

Shri Subir Chattopadhyay

Director (Project)
MECON Limited, Ranchi, India

I deem it a privilege to deliver the Dr S. C. Bhattacharyya Memorial Lecture before this august gathering. Dr Bhattacharyya's accomplishments in several disciplines such as production engineering, metal cutting and machine tools are not only invaluable but also serve as models to emulate. His multi sided capabilities as an outstanding engineer as well as an educationist are exemplary. But what are even more significant are the spirit and the commitment he displayed for developments in indigenous technology for welfare of society, which is the key issue that is now triggering new waves in academics, social actions, business enterprises and even polity. In the contemporary world, the spirit to innovate on technologies had been the central force that transforms emerging economies as their expanding market potentials provide enormously challenging environment which breeds innovations.

Ever since the Industrial Revolution in the 18th century, the manufacturing activity has been considered-to be the main engine of economic growth. India's manufacturing sector was very good in pre-historic period. We have the examples of Qutub Minar, Taj Mahal, Dhakai Moslin etc. Although manufacturing activity started with iron works in 1800 BCE, however, after independence, the second Five Year Plan, designed by Dr P. C. Mahalanobis, put stress on development of heavy industries. Public Sector Units (PSU) were at commanding heights. That period was dominated by metal-based and machine building activities and the eighties when chemical and allied industries were the prime movers of industrial growth, the nineties was marked by a different trend when beverage recorded a I significant improvement by achieving the highest growth followed by non-metallic minerals. Thereafter, a sharp decline in manufacturing sector was observed.

Poor implementation is a root cause for India's poor performance in Manufacturing. In China, Japan and Germany-countries that have developed very competitive manufacturing sectors, implementations have been very effective. In contrast, the same is not true for India. Policies, even well conceived ones, are often not implemented. Projects, albeit well intended, do not get completed on time. Only if solutions address these root causes will the plan produce its intended results.

Two root causes for poor implementation are: inadequate consensus amongst stakeholders for policy changes, and very poor coordination amongst agencies in execution. Going deeper, there are two root causes for poor coordination. One is poor planning and the other is lack of alignment amongst agencies regarding the purpose of policies and objectives of projects-which cycles back to inadequate consensus. However, National Manufacturing Policy, has set a target of achieving the share of manufacturing sector as 25% of GDP in 2022 from the current level of around 18%.

Indian manufacturing sector - present status

In India, contribution of manufacturing to GDP is only 18% which is low compared to many countries. In Thailand, China and Poland the share is as high as 40%, 34% and 30% respectively. The growth rate of manufacturing is less than the growth of GDP. In order to achieve a share of 25% of GDP, manufacturing GDP should grow at 2-4% higher than GDP. Moreover, employment generated by Indian manufacturing sector is quite less compared to many countries. In India, only 12% of the employment is generated by the manufacturing sector. Unless manufacturing becomes an engine of growth, providing at least 100 million additional decent jobs, it will be difficult for India's growth to be inclusive.

A strong focus on improving the "depth" in Indian manufacturing is essential. "Depth" can be defined as the capability and expertise in all aspects of a product value chain. Achieving a greater depth in manufacturing entails ensuring a higher level of value addition within the country. This requires focus on a few key areas like the heavily import-skewed capital goods sector, technological advancements in nearly all manufacturing sectors, and a focus on improved domestic research and development.

"Make in India"

On September 2014, Hon'ble Prime Minister Sri Narendra Modi Ji announced the "Make in India" campaign to promote the manufacturing sector and spur job creation. The Prime Minister invites foreign companies to invest in India and promises that his government will provide effective and easy governance to help India become a global manufacturing hub.

Challenges and opportunities of Indian manufacturing sector

Indian manufacturing sector is beset with several challenges like infrastructure bottlenecks, unreliable power supply - poor quality and high tariffs, transport infrastructure sector which suffers from long delays, land constraint, lack of skilled human capital, delay in environmental clearances, high cost of finance, etc. Along with the challenges there are some opportunities too such as growing market prospects, large pool of engineers, good export potential etc. Although, lot of challenges and opportunities exist for development of manufacturing sector in India, the ethical dimension of the same needs to be deliberated further.

Business & Society

Business is something which provides goods and services that society needs. It is not separate from the society or imposed upon the society, rather it is an integral part of the society and its activities. Manufacturing sector is not an exception. As an integral part of the society, it has certain duties, responsibilities and obligations toward the society, which provides opportunity to conduct business. Of course, it is necessary to make profit or get return on investment in order to take the business forward and meet the aspirations of the shareholders, but it is not sufficient for flourishing in business. It has been observed that many profit making organizations vanished from the market not because of market failure but because they failed to address certain macro and micro level issues such as dealing with customers, suppliers, employees, community, natural environment, transparency in transactions, integrity and accountability. In order to achieve excellence, stability and sustainability, it has to be ethical and has to take into account the needs of the stakeholders at large.

Conflicts of interest and business dilemma

For some 200 years, conventional wisdom argued that what's good for business is good for everyone. Adam Smith, the father of economics, wrote in 1776 that a businessman who works to maximize his own profits is led by an "invisible hand" to promote the general welfare - even though he has no real intention or motivation to improve society as a whole.

Business guru Peter Drucker said that the purpose of a business is to create and keep a customer and generate a surplus. Milton Friedman, one of the most prominent economists of the 20th century, said that the purpose of a public company is to create as much wealth as possible for its stockholders by maximizing profit following the rule of the game that ensure open & free competition without deception or fraud. So where does ethics fit in?

Granting that a business person's ultimate objective is to make the world better, how is this best achieved? Conflicts of interest and ethical dilemma abound in the business world.

The conflict over marketing: A famous case study describes how the Nestle Corporation marketed its infant formula in parts of Africa by hiring nurses in local clinics to recommend formula over breast feeding. The nurses convinced mothers that using formula was sophisticated and Western, while breast feeding was primitive and third-worldish. Unfortunately clean water was often unavailable to mix with the powdered formula, and babies often became ill. The company continued its marketing efforts despite worldwide protests and relented only after years of massive consumer boycotts of its products. Similar examples abound, such as pollution in Nigerian oil fields, worker exploitation in Southeast Asia sweat shops, and bribery around the world.

The conflict over outsourcing: In early 2010, headlines around the world blared that some Chinese factories that supplied Apple used underage workers, forced employees to work excessive hours, and These above incidents clearly counter the assumption that, given the choice between profits and ethics, companies will always choose the former. However, profits and ethics are not mutually exclusive. In many cases, ethical decision leads to long run profitability of the company.

Ethical issues for multinational companies

Few years back, Thomas Friedman wrote his bestselling book "The World is Flat". Friedman writes in the context of globalization - global economy and global business. There are various flatteners like demolition of Berlin wall in

1989 which have made the world a leveled playground for companies of various counties of the world to play fair game. It foresees that the world will be border less - border less economy, border less business; So globalization of business is inevitable. With globalization the multinational companies may face various ethical issues.

One of the toughest ethical questions for multinational businesses is whether they should follow the adage "When in Rome, do as the Romans." Different cultures have different moral norms and practices. When multinational companies assume that their moral values depend on the culture in which they operate, they apply different ethical and moral standards according to the physical locations of their operations.

The first obligation of any multi-national company is to follow universal moral standards – the standards that societies develop in order to survive. Although cultures differ in many of their traditions of what constitutes right and wrong, all societies share some universal moral views. In addition they have to honour human rights, political rights, civil rights, economic rights, environmental rights, workers right, etc. - whatever may be the country of operation.

The most notorious case of environmental discrimination is the 1984 explosion at a Union Carbide plant in Bhopal, India. The explosion sent clouds of toxic gases over Bhopal and the surrounding countryside, killing thousands immediately and killing or sickening thousands more in the weeks and months following the disaster. A quarter of a century later, the water and soil around Bhopal remain contaminated from the explosion.

The Union Carbide plant was built in old Bhopal, an economically and socially disadvantaged community made up mainly of poor farm workers and other nonunionized laborers. Internal company documents showed that Union Carbide was aware of "technology risks" at the plant. In fact, for several years before the explosion, factory workers and residents complained about contaminated water, cattle deaths, and health problems associated with the factory. In spite of that Union Carbide did not take any corrective measure.

Stock Holders Vs Stake Holders

For generations, the traditional view of the purpose of business has been to generate profits for stockholders - the owners of the company. In fact, many business experts still subscribe to this view. However, in the last 20 years or so, economists and business ethicists have broadened the definition of the purpose of business to include its impact on a variety of different constituencies. Managers and executives still have a responsibility to stockholders, of course, and sometimes that responsibility trumps all other concerns. But more and more often, the concerns and welfare of other groups like employees, lenders, customers, suppliers, regulators, local community etc. (called stakeholders) that are affected by or that affect a company's operations carry greater weight in decision making and strategic planning.

Considering stakeholder interests - as opposed to simply stockholder concerns - in business planning and operations is a fundamental part of corporate social responsibility (CSR). Socially responsible companies recognize that the impacts of their activities and decisions can reach far beyond their own facilities. Identifying stakeholders and their concerns helps companies make responsible, ethical decisions.

Relationship between Ethics and Profits

At one point, many business experts thought ethical standards and programs were unaffordable luxuries - expensive to implement and unlikely to improve revenues or profits. The truth is that sometimes making the ethical choice can be expensive in the short run. After all, a commitment to ethics may mean that we miss out on a partnership opportunity with another business that doesn't share our values, or that our production costs are higher because we refuse to use overseas sweatshop labor.

Over the past 20 years or so, economists and others have been studying the relationship between business ethics and profits: Do companies that adhere to moral codes do better or worse in the marketplace than companies that view ethics as irrelevant to their business plan? The evidence is far from conclusive, but several studies show that ethical companies tend to do better over the long term than apathetic or unethical companies. A growing body of research indicates that companies with a good reputation for ethical behavior can charge a premium in retail transactions and can lower their operating costs by streamlining arrangements with suppliers, vendors, and retailers. Ethical companies also enjoy greater customer retention and loyalty, which translate into more repeat sales over a longer period.

The incidence of non-tariff measures across the world

According to the newly collected data, Technical barriers to Trade (TBT) refer measures such as labelling and other measures protecting the environment, standards on technical specifications and quality requirements are by far the most commonly used regulatory measures, with the average country imposing them on about 30% of products and trade. Countries impose Sanitary and phytosanitary (SPS) measures, refers to measures affecting areas such as restriction for substances and measures for preventing dissemination of disease, on average on about 15% of trade. The high incidence of SPS measures and TBTs raises concerns for the exports of developing countries. These measures impose quality and safety standards which often exceed multilaterally accepted norms. Although these measures are not protectionist in nature, they often result in diverting trade from developing countries, where the production process and certification bodies are frequently inadequate. Moreover, the cost of compliance is often higher in low- income countries as infrastructure and export services are more expensive or need to be outsourced abroad. In practice, SPS measures and TBTs may erode the competitive advantage that developing countries have in terms of labour costs and preferential access.

Among non-technical measures, pre-shipment inspections affect, on average, almost 20% of trade and products. Although pre-shipment inspections (PSIs) are often necessary to provide some assurance on the quality/quantity of the shipment and thus may promote international trade, they add to the cost of trading. These additional costs may reduce the competitiveness of countries, thus distorting trade. Price control measures (8% of trade and only 5% of products) constitute one of the least used forms of NTMs. They affect only a small share of goods and are largely related to anti-dumping and countervailing duties, as well as some form of administrative pricing for staple foods, energy and other sensitive sectors.

Finally, on an average, countries impose quantity controls on about 18% of products and 23% of trade. Only a small percentage of these measures still take the form of quotas and export restrictions, since most of these quantitative restrictions are illegal under World Trade Organization (WTO) rules. Some of them, such as quotas, prohibitions and export restraints are in place, but are largely limited to a number of sensitive products; in other cases, they take the form of non-automatic licensing used as a tool to administer the importation of goods where SPS- and TBT-related issues are of particular importance.

The incidence of different forms of NTMs varies across geographic areas. Although SPS measures and TBTs are the most used forms of NTMs regardless of the region, many countries especially in Asia and Latin America still implement a large number of quantitative restrictions (largely in the form of licensing). African countries appear to regulate their imports relatively more than many other developing countries, especially in relation to PSIs. The reason behind this relatively large number of PSIs is that they are often implemented to fight corruption, to facilitate and accelerate custom procedures and ultimately to help in the correct evaluation of imports and their proper taxation. The heavy use of SPS measures and TBTs by African countries may result from an effort to harmonize regulations with their main trading partner, the European Union. Majority of the NTMs are related to ethical issues such as use of child labour in production.

Conclusion

In spite of the arguments in favour of Adam Smith's "Invisible Hand", Milton Friedman's support for "Stock Holder Theory" against "Stakeholder Theory", it is observed by the researchers that there is growing trend of implementation of ethical practice in various organizations. The mission and vision of various companies give more focus on society, customer satisfaction, trustworthiness, etc. rather than only profit. The social mission drives the companies business strategy and success is measured both by the traditional revenues and profits and by how effective the strategy is in resolving the targeted social issue. Though on some occasions it may be expensive to follow ethical practices in short run, research shows that business ethics ultimately leads to corporate excellence in long run and makes the business responsible, sustainable and inclusive.

As discussed, Indian manufacturing base was strong in ancient times and share of manufacturing in GDP growth increased steadily. But it is not enough to provide the required employment and sustainable growth of the economy. With the new manufacturing policy, Make in India and other initiatives, it is expected that manufacturing sector will grow in leaps and bounds in the years to come. To have sustainable growth and to be responsible corporate citizen, manufacturing sector must work within the framework of ethics and social responsibilities.

Thank You!

Textured Surfaces for MEMS Applications

Dr Suhas S Joshi

'Rahul Bajaj' Chair Professor,
Department of Mechanical Engineering, Indian Institute of Technology Bombay, Powai, Mumbai
Email: ssjoshi@iitb.ac.in

1. Introduction

Nature often efficiently nurtures numerous processes, designs and materials for its functioning over a period of time. Consequently, engineers gain inspiration from the nature for designing products that can be used in applications ranging from micro- to macro-scale domains. Many organisms in nature have specific textures on their body surfaces that evolved over a time to adapt to harsh environments. For example, a lotus leaf repels water from its surface. When a water droplet is placed on a lotus leaf, it simply rolls away carrying dirt particles with it. This act of self-cleaning is carried out without any external support, but due to its clever combination with surface textures and low energy wax coating. Ever since the biologists Neinhuis and Barthlott[I] explained this mechanism, it became a subject of extensive research in energy saving applications. Another example is the property of Clanger cicada wings in resisting bacteria from being attached to its surface. It is observed that nano-scale features on its wings could mechanically rupture the cells by stretching the cell membrane that gets suspended between successive nano-pillars, causing the cell death [2]. Interestingly, the bactericidal nature of these surfaces is solely attributed to physical structure rather than chemical nature of the surface. Therefore, surface texturing has found many engineering applications such as surface wettability (de-icing of aircrafts), friction reduction (bearings), drag reduction (microfluidics and underwater vehicles), anti-biofouling (ship hulls) and single cell biology (protein screening). The main emphasis of this talk is on surface texturing for drag reduction in microfluidics and on the fabrication of such textured surfaces.

Transportation and handling of liquids at micro scale have led to the development of innovative products and solutions in the application areas such as chemical, biotechnology, and medical diagnostics. Despite its success, liquid handling in miniaturized systems faces a fundamental challenge as the pumping power required to transport liquids across microchannels rapidly increases with a decrease in the characteristic length scale of the system: $\Delta P \sim 1/l^4$, where ΔP is the pressure drop across the micro channel and l is the characteristic length scale of the system[3]. This severe resistance to the liquid flow at the micro scale is promoted by large surface area to volume ratio. Therefore, it is essential to reduce pressure drop across microchannels.

Surface texturing allows liquid to exist in two states: Cassie-Baxter state and Wenzel state as shown in Fig. 1. In the former, the liquid flows over entrapped gas in cavities. In this state, a reduction in the pressure drop is possible due to velocity slip at liquid-gas interface. In the latter, the liquid fills the cavities and a reduction in pressure drop in this state is ascribed to an increase in effective flow area. Under the influence of flow and geometric parameters, these two wetting states compete in minimizing the hydrodynamic drag. In addition, the Cassie-Baxter state likely to breakdown towards the Wenzel state with aid of external stimuli such as pressure [4], vibration [5] and gas dissolution into liquid [6], etc. in practical operating conditions. Therefore, we aim to explore various aspects related to the wetting transition under flow conditions. The focus is laid on understanding dynamics of the liquid-gas interface and demarcating wetting regimes for a range of flow and geometric parameters in textured microchannels.

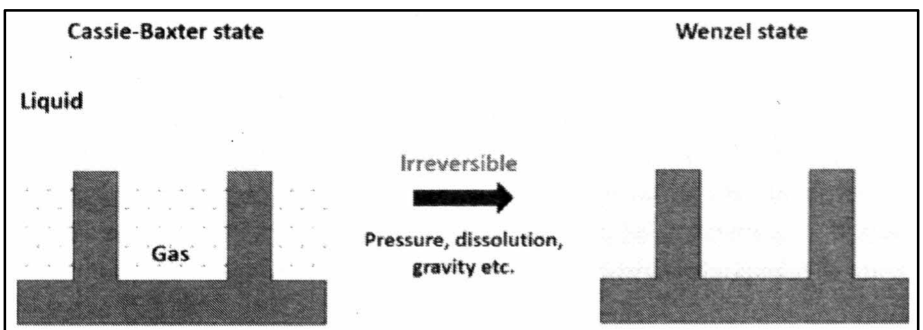


Figure 1: Different wetting states on a textured surface are shown.

In addition, it is customary to assume the liquid-gas interface as shear-free in analytical and numerical works in predicting the pressure drop (or slip length as used as a common metric in literature) [7-10]. The shear stress experienced by the liquid at the liquid-gas interface scales with the viscosity ratio between gas and liquid as $\tau_{l\text{-}g} \sim \mu_g/\mu_l$; For an air-water system, the magnitude of shear stress at the liquid-gas interface reads as $\tau_{w\text{-}a} \sim 0.01$. Therefore, the shear-free boundary condition is a reasonable approximation at the liquid-gas interface, thus, adopted in most of the analytical and numerical works. However, the liquid-gas interface exerts a finite resistance in reality and its deformation depends on pressure difference between the liquid and the gas phases. Therefore, the assumption of shear-free boundary condition and flat interface over estimates the slip length. In this regard, slipping behavior of the liquid-gas interface is also investigated.

2. Slippage at the liquid-gas interface

We begin with investigation of slippage at the liquid-gas interface under flow conditions. We. addressed this problem by two-phase numerical simulations. Instead of considering the liquid gas interface as a rigid boundary, in the present work the liquid-gas interface was tracked using volume of fluid (VOF) method to replicate real flow situations. The slip velocity, slip length and deformation was measured over the liquid-gas interface and compared with the previous works. The gas fraction (6, area covered by the liquid-gas interface to the total area) is varied between 0- 1and the flow rate was maintained corresponding to the Reynolds number (Re) = 1.

A flat and shear-free interface indicates that the slip length is constant over the liquid-gas interface. However, distribution of the slip length is not constant over the liquid-gas interface as shown by the VOF results as shown in Fig. 2a. Here, the local slip length is normalized by half channel height and its variation is shown along the length of the cavity (E) at different gas fractions (20%, 50% & 80%). At low gas fraction the liquid-gas interface is flat, signifying the validity of the assumption of flat liquid-gas interface. But the liquid-gas interface tends to deform as the gas fraction increases. As the liquid passes over the cavity, momentum is transferred to the gas through viscous diffusion; hence a curvature is produced. The interface tracking clearly shows the curvature at the liquid-gas meniscus. For low gas fractions (< 40%), the pressure difference is slightly negative indicating flatness of liquid gas interface. However, at higher gas fractions (> 40%), the curvature is manifested by increase in pressure difference across the liquid-gas interface. Fig. 2b shows the deformation profiles for $\delta = 0.2, 0.4, 0.6$ and 0.7 along the length of the cavity. Here, the magnitude of the deformation (Δ) is normalized with the height of the cavity (H) while the x-coordinate is normalized by the length of the cavity (L_s) It is observed that the amount of overhang of the interface increases with gas fraction. Fig. 2b inset shows the maximum deformation (calculated at the center of the cavity) of the meniscus versus gas fraction. It can be observed that almost no deformation occurs till $\delta = 0.2$, which indicates that the meniscus is flat at low gas fractions. The maximum magnitude of deformation is observed for $\delta = 0.9$.

A combination of these two effects (local slip length on the liquid-gas interface and deformation) resulted in a decrease in overall slip length when compared to earlier models in the Fig. 3a. That is, earlier models apparently overestimated the slip length due to the conditions imposed on the liquid-gas interface such as flat and shear-free.

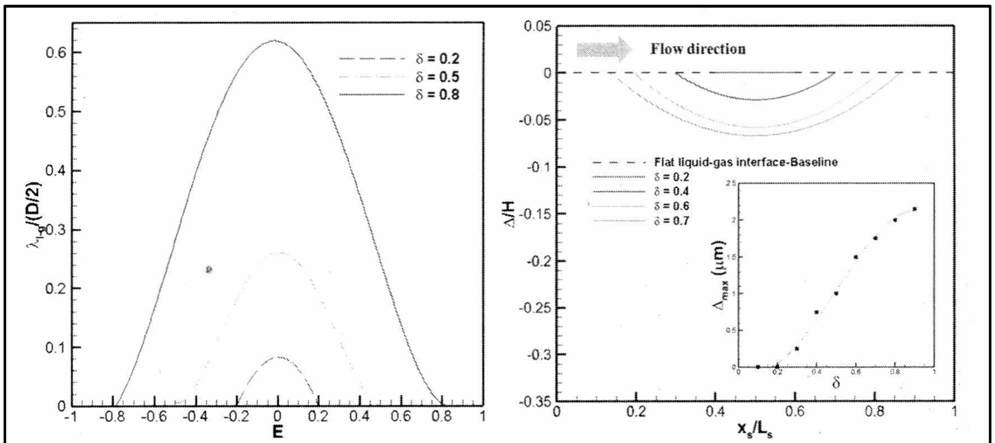


Figure 2 (a-b): a. Variation of local slip along the gas cavity for $\delta = 0.2$, 0.5 and 0.8 **b.** Liquid-gas interface deformation along the length of the cavity for $\delta = 0.2$, 0.4, 0.6 and 0.7 with a maximum deformation shown in inset [12].

To validate these observations, VOF results were compared with existing experimental results [11] as shown in Fig. 3b. It is observed that, the overall slip length calculated by the VOF model is in excellent agreement with experiments, whereas the earlier numerical models could not capture the additional dissipation effects such as interface deformation at large gas fractions. Therefore, it is concluded that the slipping behavior of the liquid-gas interface is affected by the dissipation in the underlying gas phase.

3. Wetting transition in textured microchannels

In general, the hydraulic pressure is equally distributed on flat surfaces in a static fluid. If the surface is decorated with cavities with the same gas fraction, the liquid-gas interface should ideally have the same curvature over every gas cavity under static conditions, as shown in Fig. 4a. The local liquid pressure above the gas cavity drives the liquid-gas interface into the cavity, while surface tension (γ) of the interface and gas pressure (P) resist this action. The critical pressure required to prevent the collapse of the liquid-gas meniscus is given by the Young- Laplace equation. If the pressure difference across the liquid-gas interface (P_{water} - P_{air}) exceeds the critical pressure ($P_{Laplace}$), the surface tension can no longer sustain the weight of liquid column, leading to a collapse. The CBS-WS transition occurs through three stages under static conditions.

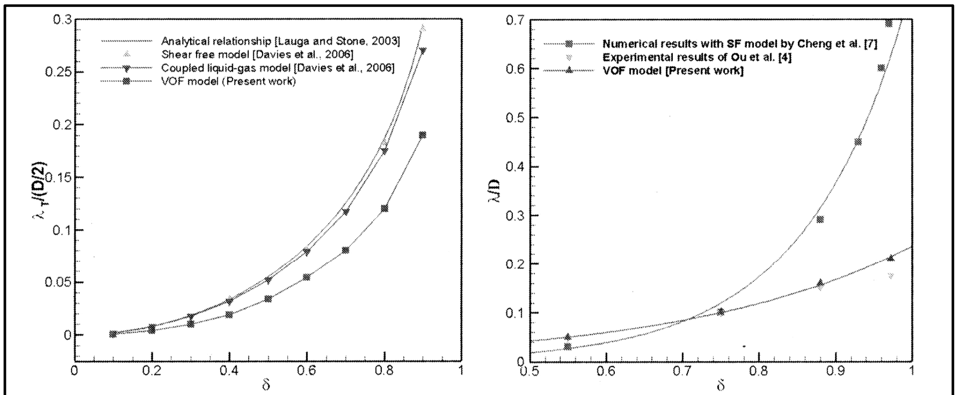


Figure 3 (a-b): a. Comparison of normalized slip length for obtained from VOF model and previous models **b.** Comparison of numerical results (by VOF model and shear-free interface model) with experimental results [12].

In the first stage, an increase in hydraulic pressure of the liquid causes the liquid-gas interface to deform into the gas cavities with the interface remaining pinned at the edges of the cavity. This in turn reduces the gas cavity volume and thereby increases the cavity gas pressure. The pressure difference across the liquid-gas interface gradually reduces due to the increase in gas pressure in the cavity.

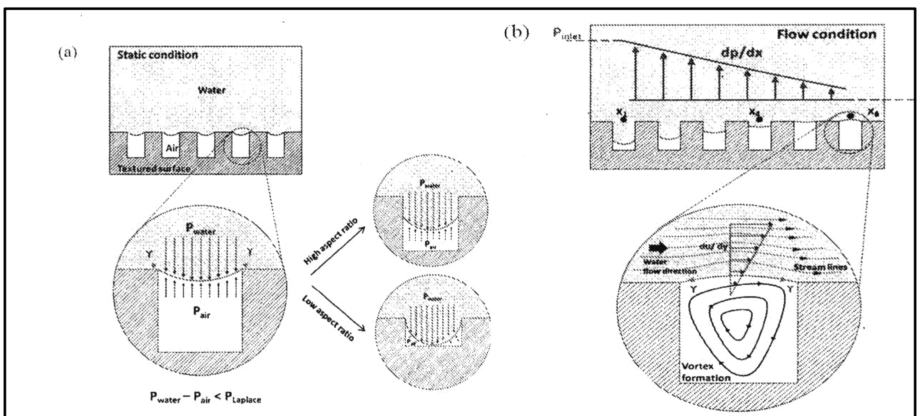


Figure 4 (a-b): (a) Wetting transition at static conditions **(b)** Dynamics of liquid-gas interface during flow condition [13].

In the second stage, with an increase in pressure above the gas cavity, the interface depins and slides along the walls of the cavity for high-aspect- ratio structures. In the final stage, the sagged liquid-gas interface touches the bottom of the gas cavity, thus completing the transition to WS.

In confined flows, a pressure gradient (dp/dx) is required to drive the liquid through the passage. Since the local pressure in the microchannel decreases monotonically with streamwise location, the force driving the liquid-gas interface also changes with streamwise position as shown in Fig.4b. A larger penetration of liquid-gas interface into the cavity is expected at the inlet cavity due to a relatively larger local pressure difference ($P_{[x1]} - P_{air}$). Since the local pressure difference at a cavity situated at the midsection (P[x4] - pair) is less than that at the inlet ($P_{[x1]} - P_{air}$),only minor penetration is expected at the middle location. Note that in certain cases ($P_{air} > P_{[X6]}$); the liquid-gas interface may become convex. This convex interface may in turn displace the streamlines in the core liquid flow region as shown in Fig. 4b inset. The movement of streamlines toward/away from the wall of the microchannel implies that the flow experiences local deceleration/acceleration. Unlike static conditions, liquid sliding across the gas column generates a circulation cell inside the cavity. This situation is analogous to a lid-driven cavity flow. The vortex generated inside the cavity carries circulation, which depends on the flow velocity, cavity shape and size, and fluid properties. The circulating vortex leads to dissipation of energy and can therefore be considered as an additional resistive force on the liquid-gas interface. The transfer of momentum across the interface therefore serves as an additional factor affecting the CBS-WS transition.

3.1 Methodology

Photolithography was used to fabricate a mold of microchannels with side cavities on silicon wafers. An oxidized silicon wafer was spin coated with SU8-2100 negative photoresist to achieve the required height of the microchannel. Then standard photolithography was carried out to process the final mold. A PDMS base and curing agent (Sylgard 184, Dow Coming, USA) was mixed in the ratio of 10: 1 and poured in the mold. Simultaneously, the PDMS base and curing agent were mixed in 20: 1 ratio, and poured on a flat glass plate. Both the slabs are baked for 30 min at 65°C. After becoming sufficiently hard, the patterned PDMS slab was peeled off from the mold, and 2 mm holes were punched for accommodating inlet and outlet ports on the slab. Then, the uncured plain PDMS slab and patterned PDMS slab were bonded to each other and baked overnight at 95 'c for cross-linking of the polymer to take place.

A flow rate of de- ionized water 0.06 and 0.3 ml/min was fed through the inlet of the microchannel using a syringe pump (Cole-Parmer), while the outlet was kept open to the atmosphere. A pressure transducer (Keller, UK) was connected between the syringe pump and inlet of the microchannel to record the pressure drop across the micro channel and the external tubing. Losses from external tubing were deducted from final pressure drop readings. Each measurement was carried out for ten minutes to visualize the air-water interface dynamics. The total pressure drop is averaged over a ten-minute period to quantify frictional effects due to wetting of the cavities. A constant temperature was maintained ensuring that there was no variation in viscosity during the measurements. An upright microscope was used to visualize the air-water interface. The dynamics of the air-water interface was recorded using a CCD camera attached to the microscope at an interval of one minute between measurements. Movement of the air-water interface inside the cavities was measured with the aid of image-processing software (ImageJ). All the pressure drop measurements were converted into a non-dimensional parameter (Poiseuille number, Po) and plotted with non-dimensional flow rate (Reynolds number).

3.2 Results and Discussion

As discussed earlier, water flowing over cavities generates bulk vortical flow inside the air cavity, analogous to lid-driven cavity flow. The formation of vortices can result in a finite force on the air-water interface, and can therefore affect the movement of the interface. To test the above hypothesis, numerical simulations were first carried out to visualize and quantify the vortex dynamics inside air cavities. All the simulations are carried out at Re = 1. Fig. 5 depicts streamlines highlighting the vortical flow in an air cavity for the different shapes (square, V, trapezoidal, triangular) considered in the study. It is observed that the location of the vortex and its shape changes with the geometry of the cavity. It is evident that the center of the vortex for both triangular and trapezoidal cavities is closer to the air-water interface as compared to that for square and If-shaped cavities. That is, the inclination of the sidewalls seems to squeeze the vortex pushing it towards the air-water interface. Figure also shows the variation of the flow velocity with the depth of the cavity, for all considered geometries. Here, the location of the center of a vortex corresponds to kink in the velocity profile.

The above numerical results were verified experimentally by fabricating microchannels with different cavity geometries. Fig. 6 presents images taken at the inlet, mid, and outlet of microchannels with square, If-shaped and trapezoidal cavities, at two different time instances. The interface position is markedly different for the three cavity shapes at the inlet location, at both the time instances considered. The difference persists at the mid location but vanishes at the outlet location. The interface position for the three cavity shapes is approximately the same at t = 0 as shown in figure. However, at t = 10 min, the interface has moved almost fully inside the square cavity; while the movement into the cavity is incomplete for the V-shaped cavity. In contrast, the interface position does not change significantly over the 10 min experiment duration for the trapezoidal cavity. At the mid location, square and If-shaped cavities exhibit a concave interface, whereas a clear convex interface is observed for trapezoidal cavities. As explained above, the convex interface generated by a trapezoidal cavity is due to a force exerted by the vortex, being closer to the liquid-gas interface.

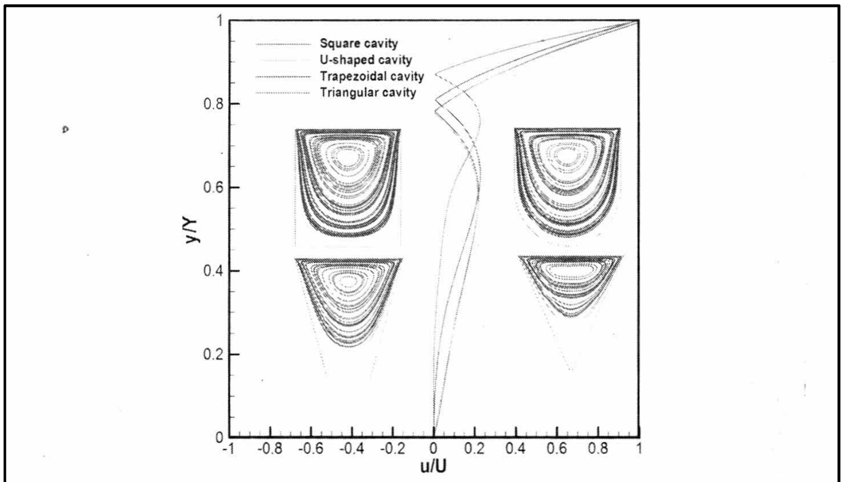


Figure 5: Horizontal velocity variation versus height along the centerline of different cavities for *Re* =1. The streamline patterns for the various cavity shapes are shown in the insets [13].

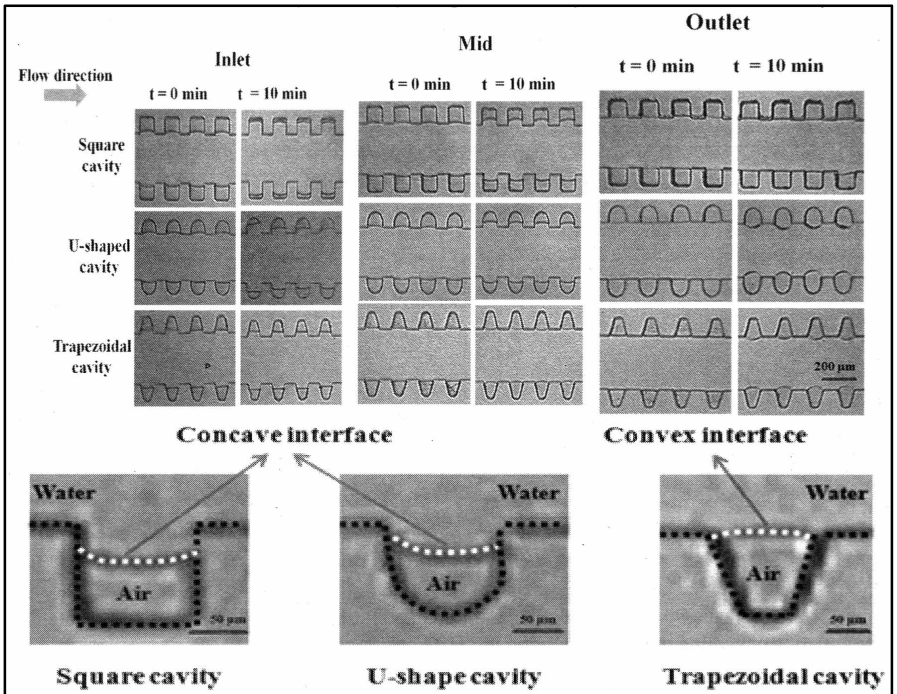


Figure 6(a-d): Visualization of air-water interface for square, U-shaped and trapezoidal cavities: **(a)** at inlet; **(b)** mid section; and **(c)** outlet positions of the microchannel. The results are presented at two different time instances for *Re* = 10. **(d)** Enlarged view of the interface shape (concave and convex) at the channel middle section for square, U-shaped and trapezoidal cavities. The air-water interface is marked by yellow dotted line [13].

As it was observed that the variation of the Poiseuille number is a function of wetting state, we asked whether we can correlate wetting transition with the Poiseuille number under flow conditions. In this regard experiments were conducted in textured microchannels containing micro-pillars on the bottom wall. Different wetting states were demarcated by qualitatively assessing the behaviour of Poiseuille number, which are further corroborated by confocal microscopy-based measurements and numerical simulations. The wetting transition ensued smoothly with an increase in Re, independent of the gas fraction, for moderate gas fractions, whereas an early breakdown of the Cassie-Baxter state occurred irrespective of Re at high gas fractions as shown in Fig. 7.

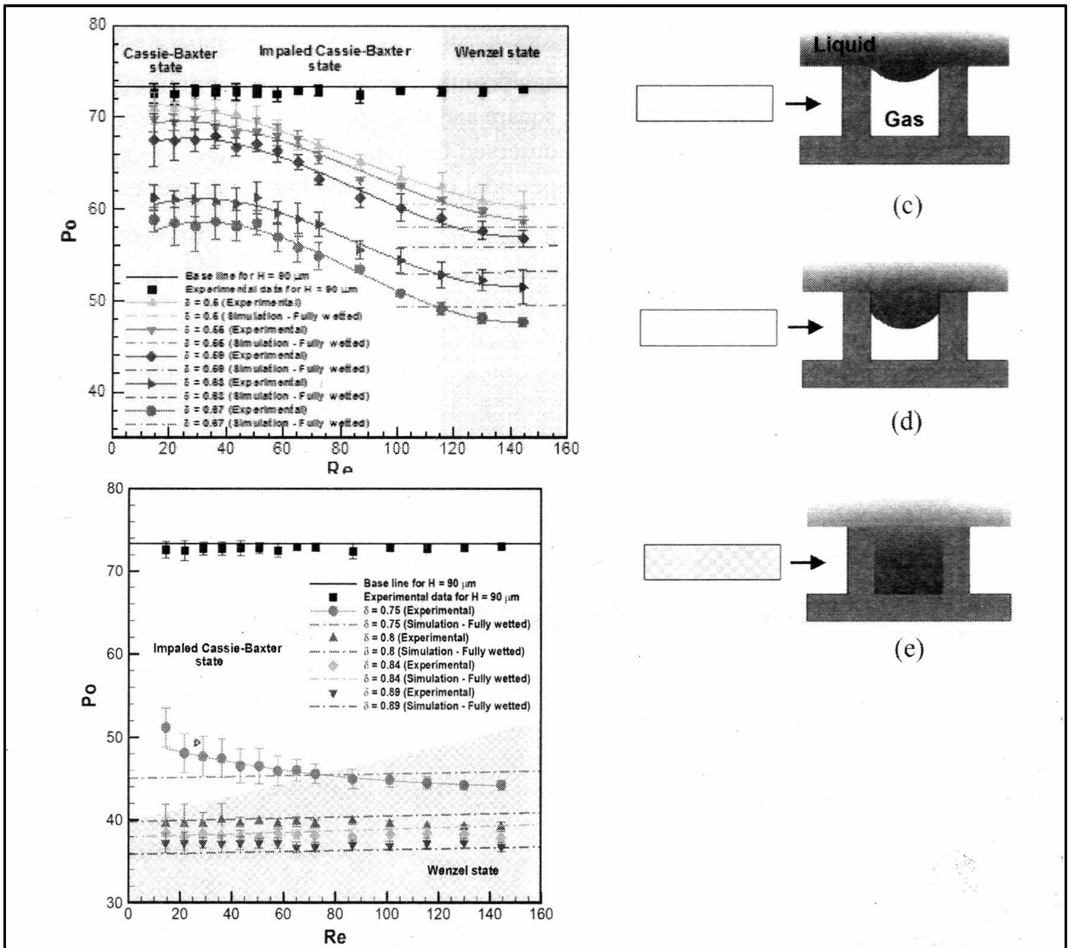


Figure 7 (a-e): Variation of *Po* with *Re* for **a.** moderate gas fractions (δ = 0.5-0.67) and **b.** high gas fractions (δ = 0.75-0.89). **(c-e)** Wetting transition corresponding to *Po* variation. Legend indicates the wetting state **c.** Three-phase contact line pinned at edges with curved liquid-gas interface (LGI) showing CBS. **d.** Depinning and sliding of LGI showing ICB state. **e.** Completion of wetting transition showing WS [14].

4. Other Applications of Texturing

The textured surfaces were also fabricated by using photo-lithography on silicon wafers and other indigenously developed methods. In the following paragraphs, details of these are described.

4.1 Photo-lithography: In this method using photo-lithography four different textures were fabricated over a silicon wafer of 2.5 inch diameter. The surfaces thus fabricated were used as bottom surfaces of microchannels. Another mask made of SU-8 was superimposed on the Si wafer. The three channels placed at the diameter of the wafer were having smooth bottoms, whereas the others were micro-channels with different textures. The surface of the microchannels were sealed. See Fig. 8 (a-d). The microchannels were fitted with inlet and outlet tubes to measure pressure drop. across them, Fig. 8 (e). Based on the experiments, new correlations were obtained between the pressure drop and texture profiles for micro-domain.

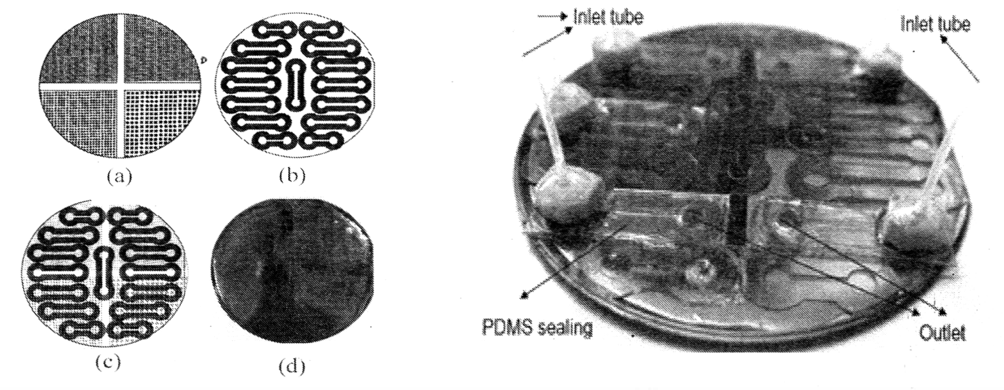


Figure 8 (a-e): a. Mask used in first step lithography. **b.** mask used in second step lithography. **c.** alignment of the second mask with is surface fabricated in the first step. **d.** surface fabricated with the two step lithography. **e.** Microchannels with sealing and inlet tubes [15].

4.2 Reverse Micro-EDM for Texturing: In this method, electric discharge machining was used wherein a perforated electrode is sunk on the work surfaces. The empty spaces on the electrode, where machining does not happen, give rise to projection as the material at the remaining places is eroded due to EDM. When the process was incorporated with ultrasonic vibrations, (see Fig. 10(a-b)), it was used to develop textured surfaces on biological implants where resistance to the flow of body fluid (blood) is minimal and the damage to the blood cells is also minimal.

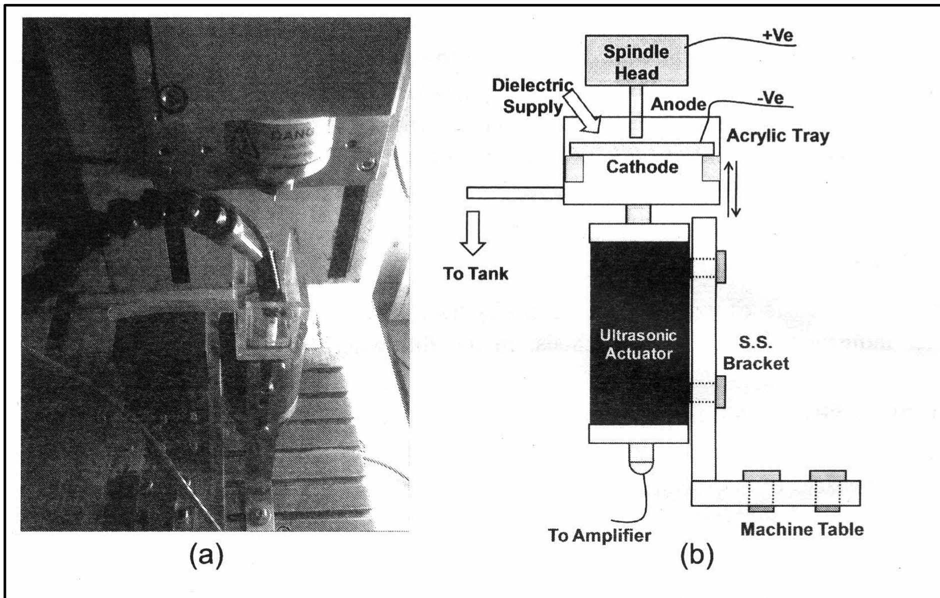


Figure 10(a-b): Experimental set-up for reverse micro-EDM using ultrasonic vibration assistance. **a.** Photograph of the set-up. **b.** Schematic of the set-up [16].

The textures produced using reverse micro-EDM on a titanium (Ti6AI4V) rods is shown in Fig. 11 (a-d). The textures were also tested for hydrophobicity using water droplet test. They were found to offer a wetting angle of ~ 114°, which is far more than the smooth surfaces (52°). Large number of work samples of size 10 mm × 10 mm were fabricated using the process. They were also tested by :flowing blood over them. The textures were not found to damage the blood cells during 10 minutes flowover them. Thus, the textures produced were biocompatible.

4.3 Texturing of cutting tool surfaces using laser machining: It was evident that during machining when chip flows over the face of the cutting tool, it encounters two different frictional conditions. One, heavily loaded slider in the sticking zone and lightly loaded slider in the sliding zone. In a work done by the authors' group, cutting tools were textured differently to take care of the different frictional conditions on the sticking and sliding zones. On the sticking zone, the tools were textured with grooves and on the sliding region, the tools were textured with dimples.

See Fig. 12 (a-c). The figure shows schematic of the design and a photograph of a textured cutting tool. These textures were performed using lasers. A large number of texture variations were inscribed on the tool inserts and extensive experimentation was done to find out the effect of texturing on the performance of cutting tools by measuring cutting forces and chip forms. The, results are presented in Fig. 13 (a-c).

The texturing of tool surfaces helps in a number of ways. Firstly, it reduces the cutting forces as a result of 14% reduction in the coefficient of friction (Fig. 13 a). The chip formation also undergoes a significant change due to texturing. The chips produced with non textured tools show heavy segmentation, which is an indication of a large fluctuation in cutting forces during machining. (Fig. 13 b) The chips produced using the textured tools on the other hand show a lot of contunity indicating that the cutting forces are more stable (Fig. 13 c). A stable machining operation is likely to generate a good surface finish on the machined components.

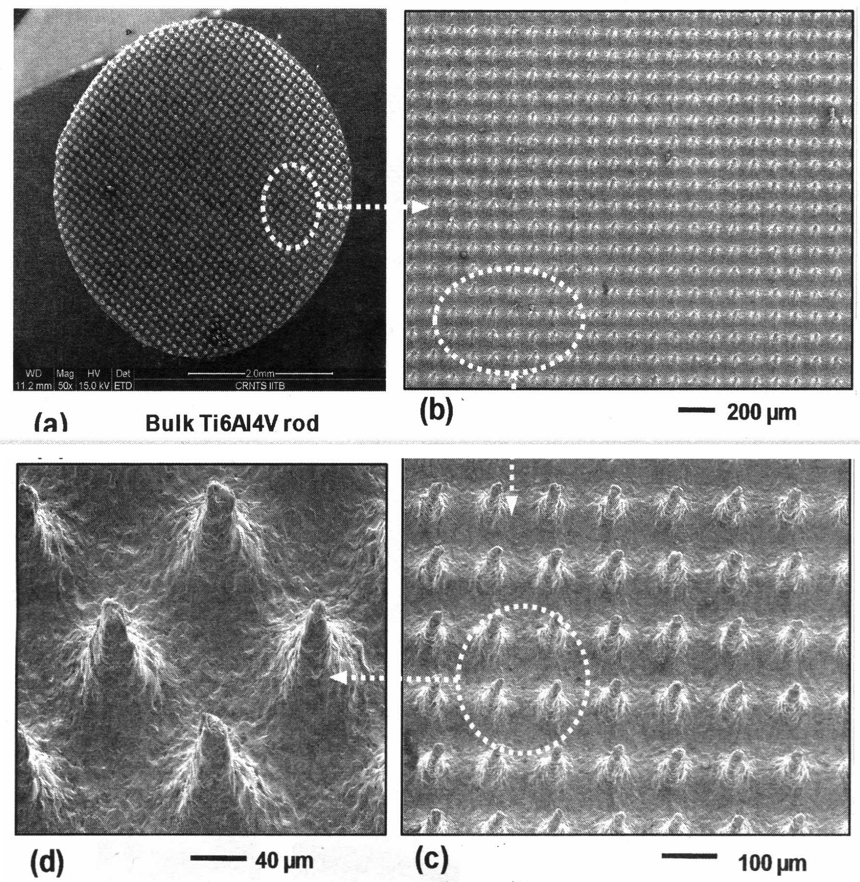


Figure 11(a-d): a. Titanium rod textured using reverse micro-EDM (Pillar height: ~170μm; Pillar width: ~25 μm; pillar gap: ~75 μm). **(b-d)** Progressively enlarged views of the pillars. [16].

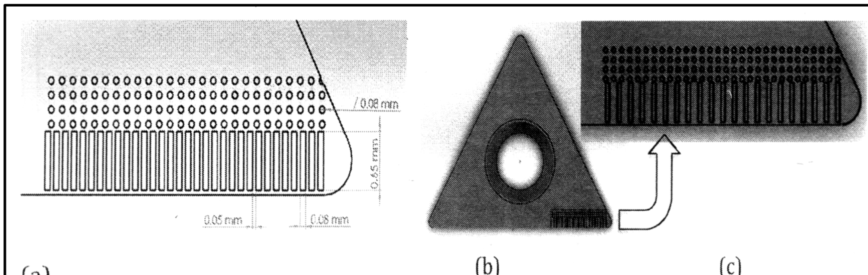
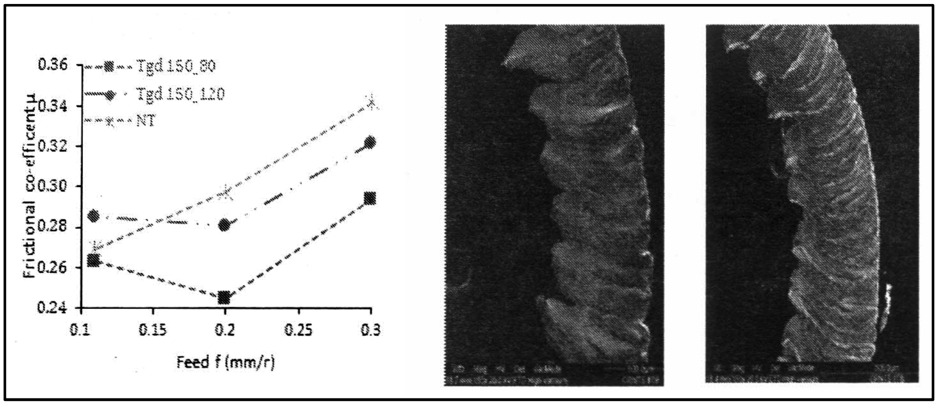


Figure 12 (a-c): a. Schematic of tool face texturing. **b.** Carbide inserts textured using lasers. **c.** An enlarged view of the textures [17].



5. Conclusions

Texturing of has several applications in the development of hydrophobic, ice phobic or dust phobic surfaces besides changing frictional conditions at the moving interfaces. This work presents theoretical as well as numerical modeling of interaction of textures with the fluids .under static as well as dynamic flow conditions. The following conclusions can be drawn based on this work:

• The liquid-gas interface exhibits a finite resistance due to the dissipation in the underlying gas phase. This result in non-monotonic variation of slip length along the liquid-gas interface. The deformation of the liquid-gas interface has a significant effect on the behavior of the local slip length at higher gas fractions. A good agreement between VOF results and experimental results shows an importance of these parameters in capturing flow physics at the interface.

• It was proposed and demonstrated that liquid-driven vortices stabilize the liquid-gas interface and delay the CBS-WS transition in textured microchannels.

• The Poiseuille number (Po) was shown to be a robust parameter to predict the wetting transition under flow conditions, irrespective of optical and surface properties of the textured microchannel.

• The textured surfaces were also fabricated using indigenously developed process named as reverse-micro- EDM and laser micromachining.

• The reverse micro-EDM was used to fabricated textured surfaces on the titanium biomedical implants and tested for the flow of blood over them. The surfaces were found to cause no harm to the blood cells flowing over them.

• The textured surfaces were also fabricated using lasers on the cutting tools and were found to improve frictional conditions favourably during machining operations.

References

1. C. Neinhuis, and W. Barthlott, "Characterization and distribution of water repellent, selfc1eaning plant surfaces," Ann. Bot., 79, 667-677 (1997).

2. S. Pogodin, J. Hasan, V. A. Baulin, H. K. Webb, V. K. Truong, T. H. P. Nguyen, V. Boshkovikj, C. J. Fluke, G. S. Watson, J.A. Watson, R. 1. Crawford, and E. P. Ivanova, "Biophysical Model of Bacterial Cell Interactions with Nanopattemed Cicada Wing Surfaces", BiophysicalJoumal, 104,835-840 (2013).

3. E. Lauga, H. A. Stone, "Effective slip in pressure-driven stokes flow," J. Fluid Mech., 489,55-77 (2003).

4. P. Forsberg, F. Nikolajeff, M. Karlsson, "Cassie-Wenzel and Wenzel-Cassie transitions on immersed superhydrophobic surfaces under hydrostatic pressure," Soft Matter, 7, 104 (2011).

5. J. B. Boreyko, C. H. Chen, "Restoring superhydrophobicity of lotus leaves with vibrationinduced dewetting," Phys. Rev. Lett., 103, 174502 (2009).

6. R. Poetes, K. Holtzmann, K. Franze, and U. Steiner, "Metastable underwater superhydrophobicity," Phys. Rev. Lett., 105, 166104 (2010).

7. J. R. Philip, "Flows Satisfying Mixed No-Slip and No-Shear Conditions," Angew Math Phys, 23, 353-372 (1972)

8. C. J. Teo, and B. C. Khoo "Analysis of Stokes flow in microchannels with superhydrophobicsurfaces containing a periodic array of micro-grooves", Microfluid Nanofluid 7,353-382 (2009).

9. C. o. Ng, and C. Y. Wang, "Apparent slip arising from Stokes shear flow over a bidimensional patterned surface," Microfluid Nanofluid, 8, 361-371 (201 0).

10. 1.Davies, D. Maynes, B. W. Webb, and B. Woolford, "Laminar flow in a microchannel with superhydrophobic walls exhibiting transverse ridges," Phys. Fluids, 18, 087110 (2006).

11. J. Ou, B. Perot, and J. P. Rothstein, "Laminar drag reduction in microchannels using ultrahydrophobic surfaces," Phys. Fluids, 16,4635 (2004).

12. A. Gaddam, M. Garg, A. Agrawal, and S.S. Joshi, "Modeling ofliquid-gas meniscus for textured surfaces: Effect of curvature and local slip length," J. Micromech. Microeng., 25,125002 (2015).0

13. A. Gaddam, A. Agrawal, S. S. Joshi and M. C. Thompson, "Utilization of Cavity Vortex To Delay the Wetting Transition in One-Dimensional Structured Microchannels", Langmuir, 31,13373-13384 (2015).0

14. A. Gaddam, K.S. Bharath, A. Agrawal and S. S. Joshi "Demarcating wetting states in textured micro channels under flow conditions by Poiseuille number," Microfluid. Nanofluid., 21,137 (2017).0

15. A. Mall, A. Agrawal, R. K. Singh and S. S. Joshi, "Numerical Characterization of Laminar Bulk Flow over Textured Surfaces," Journal of MicrolNano Lithography, MEMS and MOEMS, 10, 1-11 (2011).

16. S. Mastud, N. Kothari, R. K. Singh and S. S. Joshi, "Modeling. Debris Motion in Vibration Assisted Reverse Micro Electrical Discharge Machining Process (RMEDM)," J. Microelectromech. Syst., 24, 661-676 (2014).

17. S. Amal, "Development of cutting tools with micro scale textures on rake face to improve frictional Behaviour," M.Tech. Dissertation, Indian Institute of Technology Bombay (2015).

Challenges in Manufacturing

Mr Keshav Chandra

Former Member (Mechanical), Railway Board &
Ex-officio Secretary to the Government of India

I will start with a real life illustration from Indian Railways

Classic Example of a Stupenduous Challenge Faced by Mechanical Engineers in Indian Railways

The Indian Railways came into being in 1853. In over 100 years plus of its operations, steam locomotives remained the main work-horse, its prime motive-power. Diesel locomotives began to enter the system in 1960s-1970s. At its peak, the number of steam locomotives hauling both the passenger and freight services was about 7000 plus.

By mid 20th century, steam locomotive repair, maintenance and operational practices were well entrenched in the railway system. The matrix of men, machines and materials for running and maintaining steam locomotives was an amazing tri-contraption. By 1970s,the technical skills had already come down over four generations and had been almost perfected, the machines available in steam locomotive maintenance depots ('sheds' as they were called) though robust were conventional and materials-the childparts, sub-assemblies and assemblies of steam locomotives (Figure 1) were wholly and solely mechanical in nature with Indian Railways being the biggest supplier, with some minor ancillary suppliers from trade and industry.

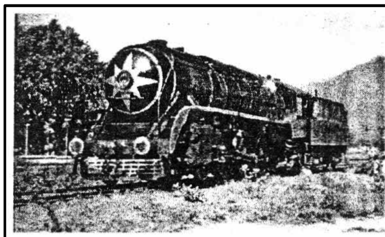


Figure 1: A Steam Locomotive Plying On Indian Railways (Circa 1970s)

With the advent of diesel locomotives, the change was overwhelming and clearly a break from the past with the old matrix reversed and the new one vastly different. The technical skills required were totally at variance with the past, requiring more specialized knowledge on the part of the workers, the machines available in diesel maintenance depots and workshops were far more sophisticated and of multiple variety and inventory stocking of materials, had hues of all engineering colours in them, ranging from purely mechanical to electrical to electronics to chemical to metallurgical. The diesel locomotive (Figure 2) was an aggregation of multiple engineering disciplines.

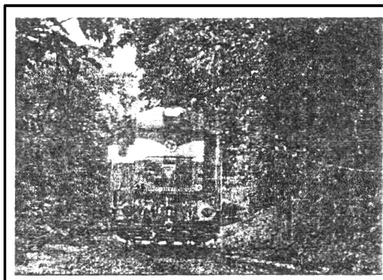


Figure 2: A Diesel Locomotive Of Indian Railways (Circa 1980s)

So the initial phase of switching over from steam locomotives to diesel locomotives on Indian Railways was difficult on all the three fronts, men, machines and materials. And when the final guillotine fell with rigid cut-off dates being set by Railway Board for switching over completely and fully from steam to diesel locomotives, there was a period of great stress and anxiety, huge adjustment maneuvers and a mild upheaval in terms of re-training and redeployment of staff and the arduous fask of setting up of new diesel maintenance depots with newer set of machines and procuring of and stocking of thousands of a fresh lot of materials from absolutely new sources, with vendors themselves struggling to find their own feet. This was a major experience of many dimensions for Indian Railways-the enormity of the problem and facing a challenge of such gargantuan proportions, required the best in

Railway men to make sure that the transition was smooth, with maximum optimization of resources and speedy results. It was to use the common management expression-hit the ground running and we did well.

Luckily I happened to be a part of that era, right in the epicenter.

Main Challenges are being Faced by Mechanical Engineers

Introduction

As of now, one of the main contributors to India's GDP is the Industrial Sector, after that of 'Service' Sector. The graph (Figure 3) shows the growth in the industrial sector as a percentage of the GDP at the beginning of each decade, viz, 1950,60,70 ...2010, with 2020 still to come.

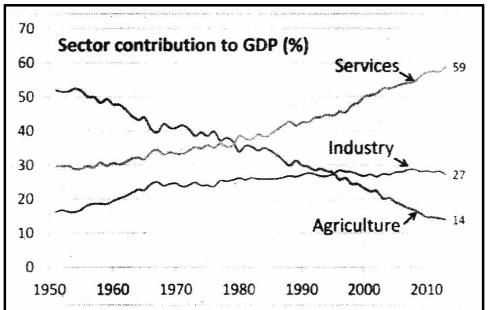


Figure 3: Sector-wise Contribution to GDP (%)

The Industrial Sector includes Manufacturing (Registered & Unregistered), Mining & quarrying, Gas, Electricity, Construction and Water supply/These are also known as secondary sectors of the economy. Currently it is contributing well above 30% to the Indian GDP.

So the contribution of the Industrial Sector to GDP has to go still higher, for India to be amongst the top nations in the industrial world. And within that space, the manufacturing sector's contribution has to increase to still higher levels.

The Reasons Behind the Challenges to Accelerate Industrial Growth

Poor Infrastructure

Poor infrastructure leading to high logistics cost. Efforts being made by the government are laudable, such as those by National Highway Authorjty of India, Indian Railways, Dedicated Freight Corridor Corporation of India Limited, National Rail High Speed Corporation, Ministry of Urban Development (Metros and Smart cities), Ministry of Civil Aviation, other ministries and corporations. But all said and done, the gaps in infrastructure on date are far too many for effecting accelerated growth.

Lack of Skilled Manpower

There is another front, which is a major cause of worry-poor skilled manpower. The so-called demographic dividend in the country is truly speaking a liability. Off course, the governments efforts in promoting skill development are praiseworthy. such as the PMKVY (Figure 4) (Pradhan Mantri Kaushal Vikas Yojana). PMKVY is a skill development initiative of Government of India for recognition and standardization of skills. Cabinet approved an outlay of USD 1.7 billion for the project, The scheme has a target to train 1 crore Indian youth over the period 2016-20.

Figure 4: Pradhan Mantri Kaushal Vikas Yojana

The Manufacturer's Crucial Role, Often on the Back-burner

It must be admitted that such amazing efforts like PMKVY on the part of the Government are best limited to proficiency in a particular trade, such as carpentry, electronics, electrical, smithy, masonry etc. But further specialization and deeper skills in the work-force require a different set of training tools and aids, taught and honed in different factories or laboratories (and not pure learning institutes) which is . another major challenge. In this regard, the manufacturers have an important and a major role to play and their responsibility is considerably heavy. With increasingly complex machining and manufacturing operations becoming the norm, the traditional broad skills help an artisan to reach a particular level, but to take them beyond those levels, the manufacturers have to step in and take the lead and organize training at their premises to train artisans in the very sophisticated manufacturing skills. Now this is broadly missing in the industry and is a major challenge.

The Bold Zero Defect, Zero Effect, Scheme of Government of India

In order to make the Indian MSMEs at par with the best in the world, the concept of Zero Defect, Zero Effect (ZED) (Figure 5) basically producing a world-class product with no or little impact on environment has been initiated, ensuring enrollment of some 10 lakh MSMEs. On the ground a lot of effort is afoot, but we still have miles to go, as in spite of the best efforts, only a few hundred MSMEs have been covered with respect to Field Assessments.

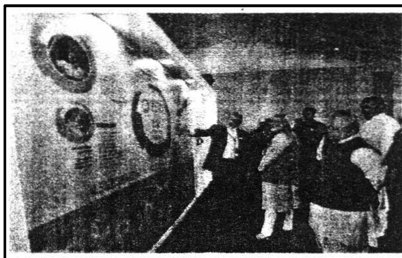


Figure 5: Prime Minister at the Launch of ZED programme

EASE OF DOING BUSINESS

Apart from the aforementioned efforts, Government of India's efforts with regard to 'Ease of doing business' are praiseworthy. India leapfrogged 30 places to rank 100th in the last World Bank's 'ease of doing business' ranking report of 2017.1ndia's ranking is expected to improve further in the World Banks' ease of doing business report this year on the back of reforms carried out by the government. Some of the Rules and Regulations the Government has taken up for reform and implementation are: Land Acquisition Bill, Labour Laws, The Apprenticeship Act, The Factories Act, etc. to name a few. Of fcourse the GST has been implemented and other reforms are also underway. It goes without saying that the rigour with which the reforms are implemented is what is going to matter.

CHALLENGE FOR MECHANICAL ENGINEERS TO HAVE THEIR VOICE REACH OUT TO THE RIGHT QUARTERS

What is significant is that mechanical engineers will have to ensure that within the political circles their voice is heard which is best done by ensuring that engineers implant themselves in the political milieu so that there is a deeper appreciation of the rules and regulations and consequently appropriate rulings are passed and adopted. To be able to achieve this desirable target it is essential that the civil society is fully apprised of the potentialities of the mechanical engineering discipline, so that they bring in the right people for right laws to be brought in. Whichever country follows this wise course of action, will always be in a better position to oversee the formulation of the right laws. Otherwise, some fool-hardy dictates get issued which have wide ramifications and cause long-term harm, which sometimes take years to correct.

CONTINUAL KNOWLEDGE UPGRADATION FROM MYTH TO REALITY

To reach agy level of competence, Mechanical Engineers as leaders or executioners will have to have a mechanism whereby they are constantly updating their knowledge, so as to be ahead of the knowledge curve, as they land up building products which have never been seen or heard, working on jobs which have never been envisaged and tackle problems which have never been confronted.

So only a good solid foundation of dynamic learning will prepare the leaders of the future to be able to address all the engineering issues, which have a social bearing. Furthermore in future we must as engineers know that problems will be more multi-disciplinary in nature and as such we should train our minds and soul to work to be multi-skilled sufficiently enough and simultaneously be able to work in teams. There is nobody better than mechanical engineers to take the lead, since times immemorial they have worked with different engineering disciplines. This unique trait must ever remain razor sharp.

Apart from the several challenges which are broad-based and of a generic nature, specific challenges will have to be addressed by mechanical engineers, challenges such as: -

Grappling with Flexible Automation & Still Newer Technologies

Flexible automation is a key contributor in the manufacturing sector today and will become a dominant player in the future. In advanced countries, even small industries are becoming adept at flexible manufacturing, since even mid-size companies have access to automation. This will result in more workers having to be redeployed elsewhere on jobs where more thinking caps are required, as mundane jobs will be handled through automation. Allied with the above, collaborative robots will soon become the norm and not remain as just show-pieces. In fact in future we will see a still large number of Rethink Robotics' robots, which shall have sort of thinking mechanisms to be able to tend machines and do repetitive works smoothly. All this and more are the challenges, which have to be faced and required to be adopted early for success of the mantra 'Make in India' of the PM.

Going Beyond 'Make in India' - the Challenge of 'Made in India'

Allied with 'Make in India' we must also embrace 'Made in India' concept which enjoins Indian industry to surge ahead in design and engineering and R&D, so that the "Made in India' product becomes a beacon for industries around the world. This is a major challenge, which only a few companies have picked up. So from aping and being just mass copiers and applicators of designs and engineering and being just mere passengers we will have to move to the driver's seat in the all-encompassing manufacturing chain. This is the need of the hour and the real challenge.

Other Crucial Challenges Engineers will be Facing in the Future

Product Development & Innovation

Product development and innovation means allocating of sufficient resources towards R&D. Only companies which can innovate fast and simultaneously produce qualitatively profound products, will survive well into the future, as old designs and concepts however no longer robust to catch the eye of discerning customers, who are legion in number and more of a rule rather than an exception. Also, product customization and personalization will become more and more demanding necessitating quicker responses, where total mastery over the new tools of manufacturing will have to be ensured, rather than just familiarity and 'learn as you go' attitude. There will be no second chance in the new industrial world. With still higher stringent standards, companies can ill afford to lose on quality or on deliveries, however small or even miniscule in impact they be.

Internet of Things & Related Technologies

Internet of Things is the common denominator in a company of today as much as much as Computerized Numerical Controlled Machine of yore. The advancements in Artificial Intelligence, cloud computing, machine learning and automation are impacting factory operations like never before. Readiness to face such and similar challenges is crucial. Using of Real time Data to monitor machines, will lead to Overall Equipment Effectiveness, culminating into better quality standards, shorter cycle times and more productivity.

Cyber Security

Cyber security is becoming crucial as any company today is dealing with a lot of data (both internal and external) in manufacturing processes, personnel and related to product attributes, design and engineering. Any company has to protect itself well enough to be able to survive in the present day world. It is not just a question of theft of data but intrusions can be very disruptive and can put a company back by several weeks. And all such intrusions have heavy costs attached to them.

Manufacturer's Forte-importance of Networking With Academia

Manufacturers will necessarily have to be well net-worked with academia. For example, even a hallowed institution such as Research Design and Standards Organization(RDSO), Lucknow, of Indian Railways has tied up with Institutions of Excellence. While it goes without saying that the manufacturer is generally well versed in applied engineering matters, but often when the problems are deeper with no easy solutions, then going back to the basics becomes of paramount importance. This is where if the company has some reputed Institution of Learning to fall back upon, then solutions which are complete, accurate, up-to date and holistic in nature are reached in double quick time. This as an important fact, some big companies tend to overlook.

Criticality of Unsettled Boundary Issues In Healthcare & Safety

Healthcare and Environmental issues are costly and must be understood and embraced. Over the last several decades there has been an awakening of sorts, but the boundary and fringe issues, of which there are myriads, which often seem harmless must also be addressed fully and early by companies. This is the need of the hour.

The Challenge of Bringing Reworks & Rejections in the Factory to an Astounding 'NIL' Figure

In factories of the future, production losses, whether it is re-work or rejections will have to be NIL. This may look far-fetched, but this is the scenario we will have to move towards, sooner than later. Companies will have to tighten the quality protocols to such an extent that reworks and rejections are a thing of the past and thrown out of the technical lexicon. But there is a price attached to it rigour and ruthlessness. For complaints from the clients side, a closer on-line interaction between the customer and the manufacturer will have to be in place, so that the smallest and the most innocuous demand(s) of the customer are incorporated in the manufacturing processes.

Global Competition cannot be Staved but Must be Faced

Also global competition will have to be fought fiercely and squarely. It cannot be wished away or brushed aside. The competitors' strengths will have to be imbibed and his weaknesses avoided. Simultaneously the company's manufacturing and work ethos in absolute terms will have to be fool proof, so that one is ahead of the competition at all times, irrespective ofthe industry standards.

360 Degrees Marketing Strategies (the Icing on the Cake)

Also engineers will have to devise, robust marketing strategies, whether they be B2B or B2C or any other configuration which will have to be very thorough. In today's market conditions, one-size fitsall strategies (which have universal application) have no place at all. The old traditional marketing methods, however much they may have served a company well, will no longer have the potency or the reach required in today's market scenario. So be savvy.

So for all of us mechanical engineers, bracing ourselves to the above challenges is the need of the hour. Taking advantage of the above ever-changing eco-system is what is going to matter to companies. Some companies have even formed dedicated teams to just monitor such opportunities, situations and challenges. Check up, if yours has?

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

Natural Fiber Reinforced Polymer Composites for Automotive Applications: Mechanical and Tribological Properties: A View

Dr K Palani Kumar
Department of Mechanical Engineering, Sri Sai Ram Institute of Technology, Chennai
palanikumar_k@yahoo.com

Introduction

The interest in natural fiber-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants, such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana, etc., as well as wood are used from time immemorial as a source of lignocellulosic fibers. Hence they are often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers, which are used for the manufacturing of composites. The natural fiber-containing composites are more environmentally friendly, and are used in transportation (automobiles, railway coaches and aerospace) military applications, building and construction industries (ceiling paneling, partition boards), packaging and consumer products. Natural fiber reinforced biodegradable polymer composites are the materials, that have the capability to fully degrade and compatible with the environment (Sahari 2011). However, there is still uncertain prevails on which type of manufacturing processes is suitable for producing these natural composites. For small to medium sized components, injection and compression mouldings are preferred due to their simplicity and fast processing cycle. However, for large structures, they are typically manufactured by open moulding and autoclave processes.

Similar to other plastic products, the complexity of shape of a product also influences the type of manufacturing processes to be used. For example, filament winding is the most suitable method for manufacturing pressure vessels and cylinders. Pultrusion is mainly used for producing long and uniform cross section parts. In some extent, optic fiber is integrated into the pultrusion process to produce self-structural-health monitored composite structures (Mei-po Ho et al. 2012).

Mounting global environmental and social concern, high rate of decline of petroleum resources, and novel environmental policy have enforced the search for green composite materials, attuned with the environment. The strategy is discussed in this report; it aims to add value to the crops by processing the fibers into so called natural fiber composites (Abilash & Sivapragash 2013).The success of natural fiber reinforced polymeric composites is always dependent on the appropriate processing techniques and modification of fibers is to improve the adhesion between fiber and the biopolymer. Matrix modification and after treatment is also be adapted to improve the performance as well as long-term durability and fire retardancy for the composites (Omar et al. 2014).

Agricultural wastes such as rice husk, rice straw and the waste extracted from sugar cane, pineapple, banana and coconut have produced huge quantity of biomass, which are denoted as natural fibers in various industries as an alternative to the raw materials for producing biocomposites, automotive component, biomedical and others (Rudi et al. 2016). Palmyra epoxy composite is fabricated with the volume fraction of 40-60, and it is suggested for the sound absorbing application (Nithyakalyani et al. 2016). Helmet outer sell manufacturing is carried out by hybrid natural fiber composite, instead of plastic. This is due to its high stiffness (Prasannasrinivas & Chandramohan 2012). Applications of natural fibers, natural fiber composite and hybrid natural fiber composite are reviewed and discussed for various applications in engineering sectors such as automotive, aerospace, marine, sporting goods and electronic industries (Sanja et al. 2016).

Classification of natural fibers

Fibers are a class of hair like material, that are continuous filaments or in discrete elongated pieces, similar to pieces of thread. They can be spun into filaments, thread, or rope. They are used as a component of composites materials. They are also matted into sheets to make products such as paper or felt. Fibers are of two types, natural fiber and man made or synthetic fiber. Fig. 1 illustrates the woven natural fibre mats produced from aloevera and sisal plants and Fig. 2 shows the classification of natural fibers. Natural fibers are those made from plant, animal and mineral sources. Natural fibers are classified according to their origin. Animal fiber generally comprises proteins; examples mohair, wool, silk, alpaca, angora. These fibers are extracted from animals or hairy mammals, for example sheep's wool, goat hair (cashmere, mohair), alpaca hair and horse hair.

Silk Fibers are collected from dried saliva of bugs or insects during the preparation of cocoons, and the examples include silk from silk worms. Avian Fibers are taken from birds, example feathers and feather fiber. Mineral fibers are naturally occurring fiber or slightly modified fiber procured from minerals. The Asbestos is the only naturally occurring mineral fiber. Ceramic fibers are glass fibers (Glass, wood and Quartz), aluminum oxide, silicon carbide, and boron carbide, where as aluminum fiber is one of the metal fibers.

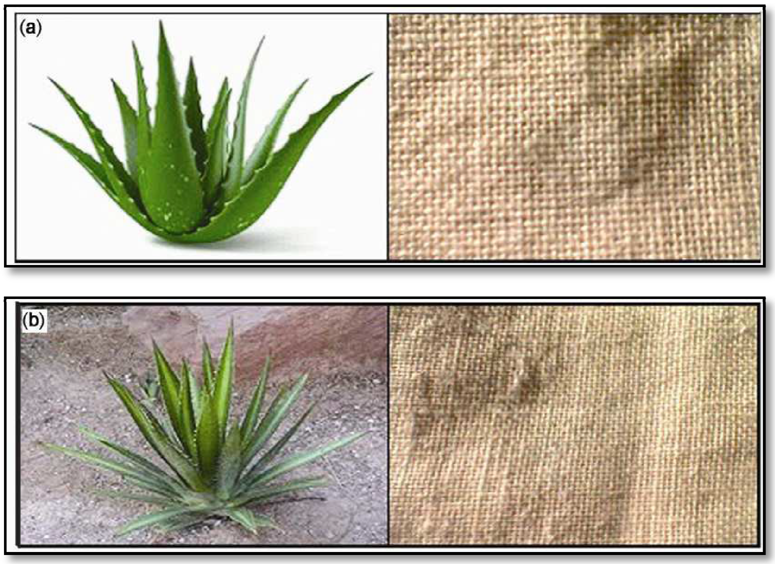


Fig. 1 Woven natural fibre mats produced from aloevera and sisal plants (Source: Shadrach et al. 2015)

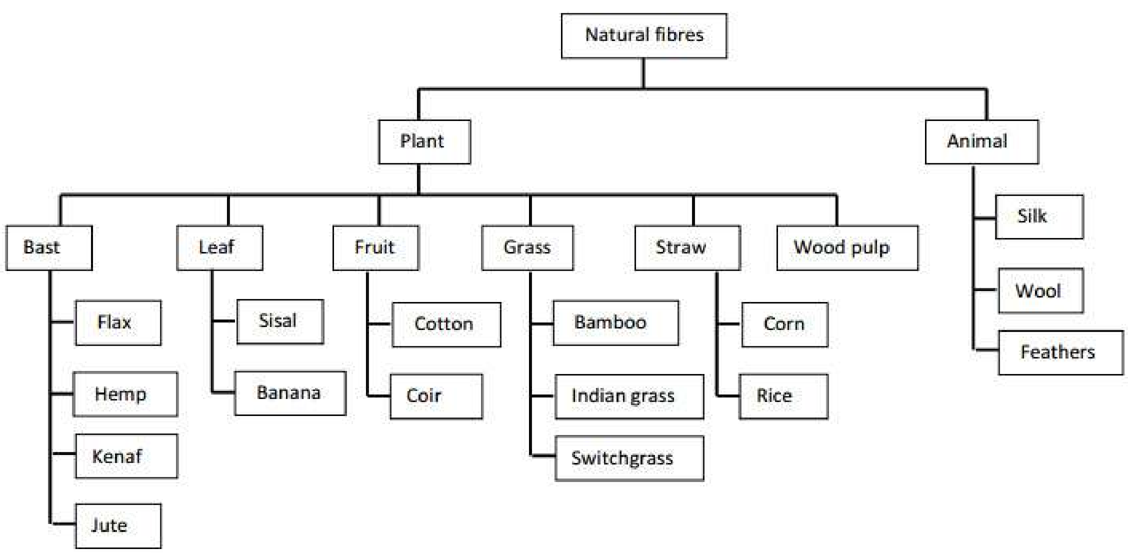


Fig.2 Classification of natural fibers which can be used as reinforcement of Polymer(Source: Shehu et al. 2014)

Plant fibers are generally comprises cellulose, and the examples include cotton, jute, flax, ramie, sisal and hemp. Cellulose fibers are used in the manufacture of paper and cloth. Fibers are collected from the seed and seed case example cotton and kapok. Fibers are collected from the leaves example sisal, aloevera and agave. Fibers are collected from the skin or bast surrounding the stem of their respective plant. These fibers have higher tensile strength than other fibers. Therefore, these fibers are used for durable yarn, fabric, packaging, and paper. Some examples of plant fibers are flax, jute, banana, hemp, and soybean. A typical fiber and its microbril are presented in

Fig. 3. Fibers are collected from the fruit of the plant, example coconut (coir) fiber. Fibers are actually the stalks of the plant example straws of wheat, rice, barley, and other crops including bamboo and grass. Tree wood is also a fiber.

The natural fibers are used to reinforce both thermosetting and thermoplastic matrices. Thermosetting resins, such as epoxy, polyester, polyurethane, phenolic, etc. are commonly used today in natural fiber composites, inwhich, the composites require higher performance applications. They provide sufficient mechanical properties, in particular stiffness and strength, at acceptable low price levels. Considering the ecological aspects of material selection, replacing synthetic fibers by natural ones is the first step to support our environment. The emission of green house effect is restricted to avoid gases such as CO_2 into the atmosphere and an increasing awareness of the depletion of fossil energy resources. It leads to develop new materials that are entirely based on renewable resources.

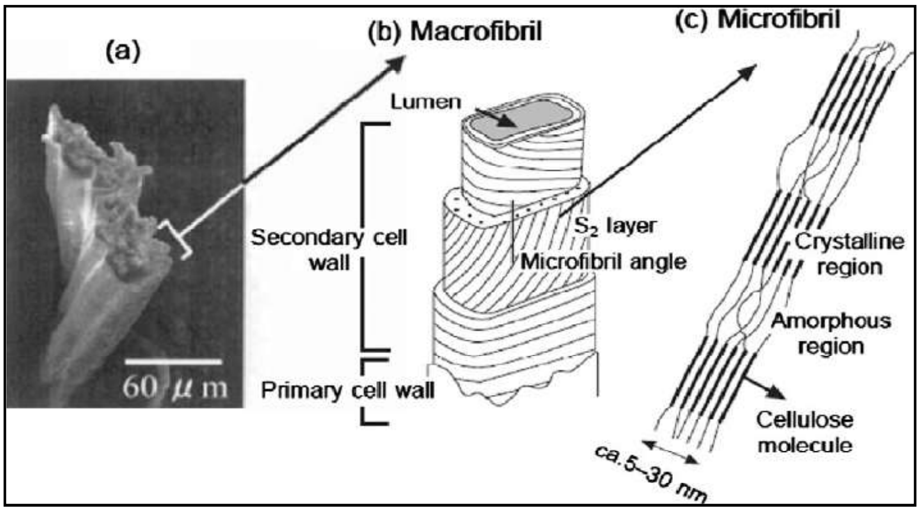


Fig. 3. Typical fiber (kenaf): Scanning electron micrograh (a) schematic macrofibril (b) and natural plant microfibril (c) (Source: Baillie, 2004 and Mei-po Ho et al. 2012)

3. Applications and advantages of natural fibers as automotive components

The natural fiber composites have very cost effective material for following applications. The reasons for the application of natural fibers in the automotive industry include:

- Low density, which leads to a weight reduction of 10 to 30 %.
- Acceptable mechanical properties, good acoustic properties.
- Favorable processing properties, for instance low wear on tools.
- Options for new production technologies and materials.
- Favorable accident performance, high stability, less splintering.
- Favorable eco balance for part production.
- Favorable eco balance during vehicle operation due to weight savings.
- Occupational health benefits, when it is compared to glass fibers during production.
- No off-gassing of toxic compounds. Reduction of fogging behavior.
- Price advantages both for the fibers and the applied technologies.

The main advantages of natural fiber composite are,

- Low specific weight results in a higher specific strength and stiffness than glass fiber.
- It is a renewable source, the production requires little energy, where CO_2 is used..
- Producible, with low investment at low cost.
- Minimal wear of tooling, healthier working condition, and no skin irritation.
- Thermal recycling is possible, because glass causes problem in combustion furnaces.
- Good thermal and acoustic insulating properties.

In construction, automobile and manufacturing industries, composites with natural fibers are highly expected because of its high tensile strength and modulus, as well as for its low density and low elongation. The proper research right now always focuses and attracts various sectors to move towards these natural fiber composites

(Venkateshwaran & Elayaperumal 2010). Industrial waste, mainly seeds and fibers, of acai fruit and these fibers are used to obtain composites with natural rubber from different clones and it is investigated for its mechanical and thermal properties. They are comparable to those with other fibers used in polymer composite industries (Martins et al. 2008). Recently, human hair fiber is used as an alternative reinforcement for fiber reinforced polymer due to its well characterized microstructures (Akarsh et al. 2016).The components made by the natural fiber reinforced composite for Mercedes-Benz car is presented in Fig. 4. The mechanical properties of the natural fibers are presented in Table 1.The natural fiber composites used in various automobiles are presented in Table 2.

Mechanical Properties of Natural Fiber Reinforced Composites

Composites made from short sun hemp, banana, and sisal are studied for its tensile properties and it identifies the sun hemp, which shows favorable tensile strength (Udaya et al. 2007).Increment of tensile strength up to 90 % is noted on the composite, which is made from pseudo-stem banana woven fabric reinforced into epoxy resin, when it is compared with virgin epoxy (Maleque et al. 2007). Mechanical properties of particle size, short fiber and long fiber are randomly oriented and are intimately mixed with Hibiscus sabadariffa natural fiber reinforced along with urea formaldehyde resin composite. This is tested for its tensile and compressive strength for its various fiber loadings and the mechanical behavior of this composite is observed to be more effective (Singha & Vijay 2008).

The cellulosic content of the fibers varies from fiber to fiber, influences the mechanical properties of composites mainly by the adhesion between matrix and fibers. Chemical and physical modification methods are incorporated to improve the fiber–matrix adhesion resulting in the enhancement of mechanical properties of the composites (Ramakrishna et al. 2009). Flax fiber reinforced epoxy composites are arranged by quasi-unidirectional method, which shows an increment of tensile and flexural strength (Igor et al. 2010). The alkali treatment is found to be an effective for improving the tensile and flexural properties, while the impact strength is decreased for Roystonea regia (royal palm) natural-fiber-reinforced epoxy composites (Govardhan & Rao 2011).Hybrid composites of sisal/banana and its tensile properties are determined by the Rule of hybrid mixture. Its values are found to be higher when compared with experimental values. Variations of tensile properties are also observed due to the occurrence of micro voids in the composites during the fabrication (Venkateshwaran et al. 2012).

Fig.4 Components made by natural fibers for Mercedes-Benz E-Class components (source: Sue Elliott-Sink, 2005)

Table 1 Mechanical properties of natural fibers

Fiber	Density (g/cm^3)	Diameter (µm)	Tensile strength (MPa)	Young's modulus (GPa)	Elongation at break (%)
Jute	1.3 -1.45	25-200	393-773	13-26.5	1.16-1.5
Hemp	-	-	690	-	1.6
Kenaf	-	-	-	-	2.7
Flax	1.5	-	345-1100	27.6	2.7-3.2
Ramie	1	-	400-938	61.4-128	1.2-3.8
Sunn	-	-	1.17-1.9	-	5.5
Sisal	1.45	50-200	468-640	9.4-22	3-7
Cotton	1.5-1.6	-	287-800	5.5-12.6	7-8
Kapok	-	-	-	-	1.2
Coir	1.15	100-450	131-175	4-6	15-40
Banana	-	-	1.7-7.9	-	1.5-9.0
PALF	-	20-80	413-1627	34.5-82.5	1.6

Source: Ramakrishna et al. 2009

Table 2 Automotive models, manufacturers, and components using natural fiber composites

Model	Manufacturer	Components
A2,A3,A4, A4 Avant, A6, A8 Road star, Coupe	Audi	Seat back, side and back door panel, boot lining, hat rack, spare tyre liner
C5	Citroen	Interior door paneling
3,5,7 series	BMW	Door panels, headliner panel, boot-lining, seat back, noise insulation panels, molded foot well linings
Eco Elise	Lotus	Body panels, spoiler, seats, interior carpets
Punto, Brava, Marea, Alfa Romeo 146,156	Fiat	Door panel
Astra, Vectra, Zafira	Opel	Instrumental panel, headliner panel, door panels, Pillar cover panel
406	Peugeot	Front and rear door panels
2000 and others	Rover	Insulation, rear storage shelf/panel
Raum, Brevis, Harrier, Celsior	Toyota	Door panels, seat backs, floor mats, spare tier cover
Golf A4, Passat, Variant, Bora	Volkswagen	Door panel, seat back, boot-lid finish panel,boot-liner
Space star, Colt	Mitsubishi	Cargo area floor, door panels, instrumental panels
Clio, Twingo	Renault	Rear parcel shelf
Mercedes A,C,E,S class, Trucks EvoBus (exterior)	Daimler-Benz	Door panels, windshield/dashboard, business table, Piller cover panel, glove box, instrumental panel support, insulation, molding rod/apertures, seat backrest panel, trunk panel, seat surface/backrest, internal engine cover, engine insulation, sun visor, bumper, wheelbox, roof cover
Pilot	Honda	Cargo area
C70,V70	Volvo	Seat padding, natural foams, cargo floor tray
Cadillac Deville, Chevrolet Trial Blazer	General Motors	Seat backs, cargo area floor
L3000	Saturn	Package trays and door panel
Mondeo CD 162, Focus, freestar	Ford	Floor trays, door panels, B-piller, boot liner
Source: Omar et al. 2014		

Fibers obtained from rice husk, jute, banana, and coconut have an excellent physical and mechanical property. Among this, mechanical properties of banana fiber reinforced composite are optimally good (Naresh & Kumar 2012). Higher tensile strength is observed for the treated fibers by Silane and Alkali in plantain empty fruit bunch fiber than that of untreated fibers (Chimekwene et al. 2012). The mechanical properties of the hybrid composites are found to be enhanced linearly with the volume fraction of high strength fibers up to certain maximum value, beyond which a negative hybrid effect has been observed because of the formation of agglomerates (Srinivas Nunna 2012). Fig. 5 shows the typical stress strain curve for some the omposites tested.

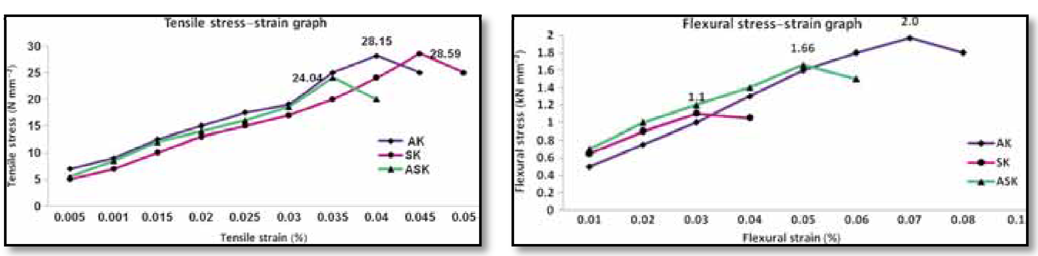


Fig. 5 Typical stress-strain curve observed for tensile and flexural loading of different composites (AK alovera and kenaf, SK sisal and kenaf, ASK alovera, sisal and kenaf) (Source: Shadrach et al. 2017)

Resin transfer moulding and compression moulding methods are used to make banana fiber phenol formaldehyde resin composites and its tensile properties are determined as a function of fiber length and fiber loading. Fiber loading values are found to be higher for RTM when compared with CM composites for its tensile properties (Indira et al. 2013). The mechanical properties for some of the natural fiber composites with GFRPS are evaluated and their comparisons are presented in Table 3.

Table 3 Mechanical properties of natural fibre composites compared with regenerated cellulose composites and GFRPS

Fibre	Matrix	Fibre content (m%)	Tensile strength (MPa)	Stiffness /Young's Modulus (GPa)	Flexural Strength (MPa)	Flexural Modulus (GPa)	Impact strength (KJ/m^2 or J/m)	Notes: Processing /length/treatment
Sisal (aligned)	Epoxy	~73	410	6	320	27		Alkali treated bundles CM/leaky mould
Sisal (aligned)	Epoxy	~77	330	10	290	22		Untreated bundles CM/leaky mould Enzyme extracted RTM
Flax (aligned)	Epoxy	46/54	280/279	35/39	223	14		CM
Harakeke (aligned)	Epoxy	50/55	223	17				
Harakeke (aligned)	Epoxy	52	211	15				CM
Sisal (aligned)	Epoxy	48	211	20				RTM
Sisal (aligned)	Epoxy	37	183	15				RTM
Flax yarn (aligned)	Epoxy	45			311	25		Not stated
Hemp (aligned)	Epoxy	65	165	17	180	9	15 (c)	CM
Flax yarn (aligned)	Epoxy	~31	160	15	190	15		Hand lay up (Knitted yarn)
Flax yarn (aligned)	Epoxy	45	133	28	218	18		Autoclave
Flax (aligned)	Epoxy	37	132	15				RTM
Flax hackled (aligned)	Epoxy	~28			182	20		Pultruded
Flax yarn (aligned)	VE	~24	248	24				RTM
Flax (silver) (aligned)	UP	~58	304	30				Soxhlet extracted Vacuum impregnated/CM
Flax yarn (aligned)	UP	~34	143	14	198	17		RTM (knitted yarn)
Alfa (aligned)		48	149	12				Alkali treated then bleached
Flax yarn (aligned)	UP	72	321	29				Filament wound
Flax yarn (aligned)	PP	30	89/70	7/6			88/115 (c)	Pultrude flax/PP yarn
Flax (aligned)	PP	50	40	7			751 (i)	Needle punched flax/PP mats CM
Kenaf (aligned)	PHB	40	70	6	101	7	10(c)	CM
Flax silver biaxial/major axis	Epoxy	~46	200	17	194	13		Wrap spun, silver woven,weft:warp strength 10:1
Flax (woven)	Epoxy	~50	104	10				Sized and dried prior to pre-preg
Flax yarn (woven)	VE	~35	111	10	128	10		RTM
Jute (woven)	UP	35	50	8	103	7	11(c)	RTM
Harakeke (DSF)	PLA	30	102	8				Alkali treated CM
Hemp (DSF)	PLA	25	87	9				Alkali treated CM

Source: Pickering et al. 2016

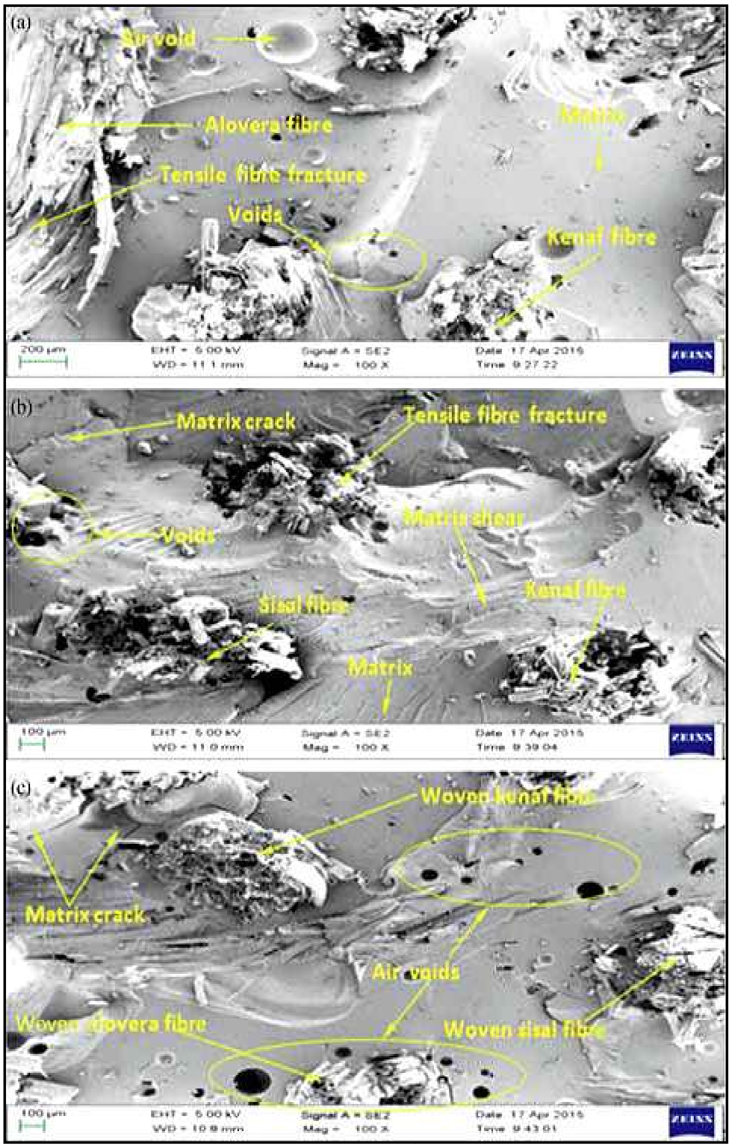


Fig. 6 SEM micrograph observed for the alovera and kenaf, SK sisal and kenaf, ASK alovera, sisal and kenaf (Source: Shadrach et al. 2017)

Treatment of the natural fibers shows an improvement in adhesion and reduction of water absorption by beating and heating in physical treatments and alkalization, silane, acetylation and benzoylation in chemical treatments, and hence there is an improvement in the mechanical properties of the natural fiber composites (Venkatachalam et al, 2016). Mechanical properties such as impact, flexural and compression strength on the pseudo stem banana woven fabric reinforced unsaturated polyester composite is found to be good compared to virgin unsaturated polyester composite (Bushra et al, 2010). Impact strength of natural fiber has been gradually increased along with its stiffness by including the effect of moisture and weathering on these properties. This is due to the improvements in selecting, treating, extracting and processing the fiber to composites, made its applications to a greater extension (Pickering et al, 2016). Tensile, compressive, flexural and hardness strength are observed to be varied in human hair fiber reinforced epoxy composite by varying fiber and resin percentage (Prakash & Christu 2016).

Tribological Properties of Natural Fiber Reinforced Composites

The wear over the material is simply defined as the loss of mass on a surface of a solid progressively during relative motion, leads to surface damage or rupture (Bressan et al. 2007). With the drastic improvement in material science, particularly natural fibers, which are light in weight and have high mechanical properties, research on tribological properties is carried out by reducing the weight of various wear components, thereby reducing weight of machines (Semenov 2007). Natural fibers are utilized in various applications of wear and friction. The advantage of natural fibers over traditional reinforcing materials includes low density, low cost, biodegradability and recyclability. Abrasive wear rate is tested by using a two body abrasion wear tester and the bagasse fiber reinforced epoxy composite strongly depends upon load and abrasive grit size. With an increase of load and grit size, the wear rate increases. The orientation of fiber in composites has a significant influence on the wear rate of composite (Punyapriya & Acharya 2010).The importance of natural fibre with the advent of sustainable development is narrated, and the composite material has now become more prominent in many applications. Many natural fibres in polymeric composites are being introduced in aviation industry, construction, industrial applications, automotive parts, bearing and many others, making tribo-testing more demanding (Nirmal et al. 2011). The typical wear testing machine used is presented in Fig. 7. Natural fibres application is an important material substitution, which traditionally takes place also in automotive industry. This paper from the application point of view, deals with the friction properties, analysis of polypropylene and polyactide, which are filled by selected natural fibres of vegetable and animal origin mainly coconut, fleece, flax and cellulose fibres (Lubos 2012). Abrasive wear behavior of Lantana camara fiber reinforced in epoxy matrix is experimented. Wear tests are carried out in dry conditions on a pin-on-disc machine against 400 grit size abrasive paper with the test speed of 0.314 m/s and normal load 5,10,15,20 and 25 N. The optimum wear reduction is obtained, when the fiber content is 40wt %. It is observed that, abrasive wear loss increases with an increase in the normal load (Chittaranjan & Acharya 2010).

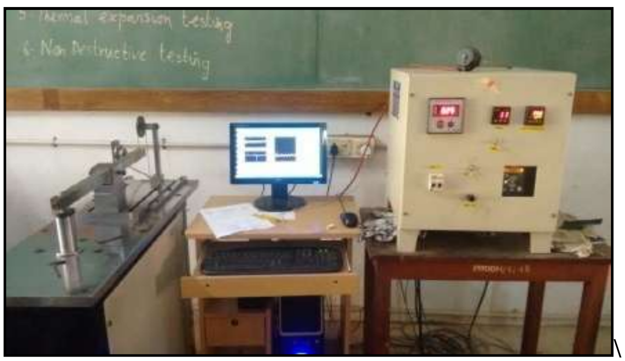


Figure 7 Pin on disc wear tester used for dry sliding wear test

Wear studies are carried out on bio-waste coir dust reinforced Polymer composites in erosive and abrasive mode ,it is found that, coir dust loading influences the erosive and abrasive wear behaviour of the composite (Aireddy & Mishra 2011). The friction and wear behaviors of polyimide composites sliding against GCr15 steel rings are evaluated on an M-2000 model ring-on-block test rig. The results show that, the surface of the treated carbon fiber becomes rougher and it forms lots of active groups after rare earth treatment. The friction coefficient and wear rate of polyimide composites with rare earth treated carbon fiber are lower than the untreated carbon fiber (Zhang et al. 2007).

The effect of the reinforcement of thermosetting polyester with short glass fibers has been investigated for its tribological behavior. The wear rate of polyester composites is much lower than that of the unreinforced polyester. The wear rate and the coefficient of friction are both at a minimum with a fiber-glass proportion of 10 percent weight, and they both increase, when this proportion is made either lower or higher. With increasing sliding speeds, the wear rate increases but there is no significant effect on the coefficient of friction (Bahadur & Zheng 1990). The incorporation of rice husk in to epoxy significantly reduces the abrasive wear loss. The optimal wear resistance property is obtained at a fiber content of 10 percent weight fraction. Wear resistance of the rice husk reinforced epoxy composite is increased, if the surface of the rice husk is treated suitably (SudhakarMajhi et al. 2012). Many types of nano- filling martials, including SiC, Si_3N_4, SiO_2, ZrO_2, ZnO, $CaCO_3$, Al_2O_3, TiO_2, and nano-CuO, have been used to different types of polymers such as PEEK; PMMA; PTFE and epoxy. Good tribological properties are obtained for polymers filled with nano-scale fillers, when it is compared with the filled micro-scale particles. The friction and wear resistance of these composites are found to increase by increasing the filler concentration (Ayman et al. 2012).

Tribological behavior of Short PALF reinforced Bisphenol-A composite is investigated. The composites reinforced with the fiber length of 2, 4, 6, 8, 10, 12 and 14 mm are subjected to wear test. The wear behavior of the composites is performed using pin on disc machine at varying loads of 5 N, 10 N and 15 N and at constant sliding distance, velocity and speed. The result shows that, the wear rate increases with an increase in load for the composite specimen, which has less interfacial bond strength. From this experimental study, it is observed that, the fiber length greatly influences the wear properties of reinforced composites (Supreeth et al. 2014).There-body abrasive wear of the hybrid composites are studied under different filler loading, treatment of the coir sheath, and abrading distance. The results of the abrasive wear test have revealed that, the wear volume increases with an increase in the abrading distance and specific wear rate is high for the untreated composites, when it is compared to alkali treated composites and silane treated composites (Divya et al. 2014). Fig. 8 shows the typical three D response graph for wear loss and co. efficient of friction for kenaf fiber reinforced composites.

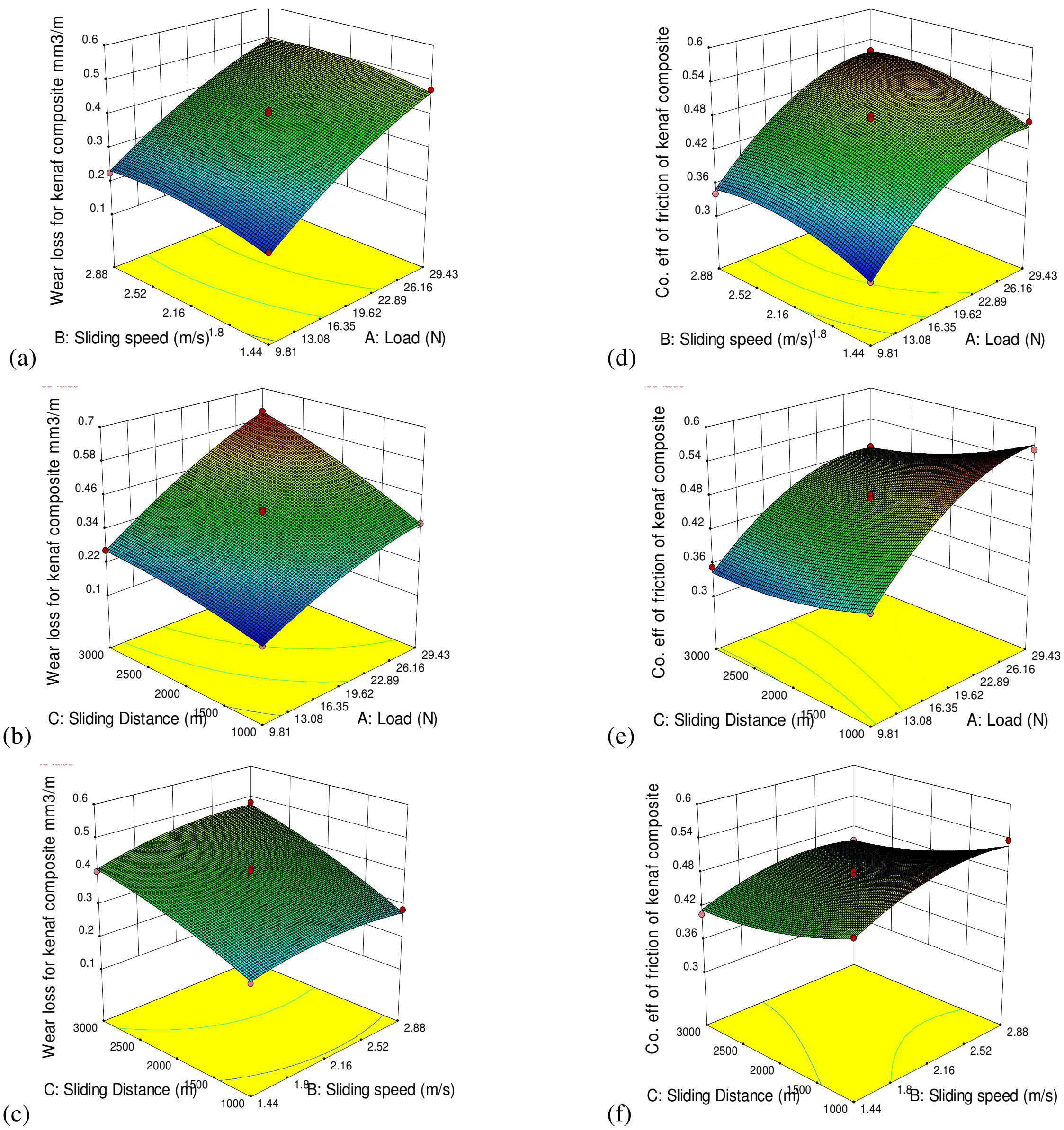


Fig. 8 Typical three D response graph for wear loss and co. efficient of friction for kenaf fiber reinforced composites with respect to two different parameters by keeping the third parameter at constant middle level

Mechanical properties for the fabricated wool fiber reinforced polypropylene composites is optimized by using Box-Behnken method with three levels and three variables using temperature, time, and pressure, as independent variables and tensile, flexural, and impact strengths as dependent variables. Molding pressure and time are significant for tensile and flexural strengths, while they are insignificant for impact strength (Rajkumar et al. 2014). Ultra-high molecular weight polyethylene composites with talc and glass fiber as particulates are fabricated. Pin-on-disc tribometer is used to determine the wear and friction properties of these hybrid composites with different operating conditions of applied loads, sliding speeds and sliding distances based on response surface Box–Behnken design. GF/ZnO/UHMWPE has exhibited better wear performance, when it is compared to talc/ZnO/ UHMWPE hybrid composites. (Boon et al. 2014). Groundnut Shell Vinyl Ester Composites are prepared with different process parameters, namely, particle size, filler loading and alkali treatment of particles From parametric analysis, it is revealed that tensile strength and tensile modulus increase with an increase in the filler loading up to 50-wt % and beyond 5 % NaOH treatment of particles (Raju et al. 2015).

Woven flax/PLA composite mechanical properties are optimized with the application of RSM using Box Behnken design The ANOVA data shows that, the variables have affected the impact strength significantly. (Mat Kandar & Akil 2016).Short palmyra fiber reinforced epoxy composites are tested for dry sliding wear and it is observed that, the fiber content and the sliding velocity are the most significant, factors that affect the wear performance of the composites. ANN specific wear rate is predicted beyond the experimental domain (Somen & Alok 2016). Hence, silicon carbide is used as a filler material in the hybrid glass and basalt epoxy composite, and its flexural modulus and flexural strength are found to be increased. Specific wear rate decreases with an increase in the sliding distance for all the samples. When 6 % Silicon carbide is used as filler material, it shows better dry sliding wear resistance (Prasanna et al. 2016). Carbon and coir fibre polyester composite are filled with graphite and coconut shell powder, and they are used as particulate reinforcements. Wear rate and co efficient friction are calculated by using Pin on disc tribometer for various speed and loads and wear resistance is higher for fiber loaded composite (Ibrahem 2016). Natural fiber reinforced composites have comparable mechanical properties and also have improvement in tribological properties. Experimental study reveals that, normal oriented fibers exhibit better friction and wear behavior than the treated fibers. Normal orientation of fibers against sliding direction is found to be the best orientation and it is one of the factors, that affects wear and friction behavior. Fiber and matrix selection based on volume fraction and applied load vary in friction and wear performance. Generally, the wear rate increases by increasing the applied load (Emad et al. 2016).Fig. 9 shows the US composite industry revenue based on the fiber used. The figure clearly indicates the trend of future usage of natural fibers and hence the natural fibers are playing vital role in the parts manufacturing of the automotive industry.

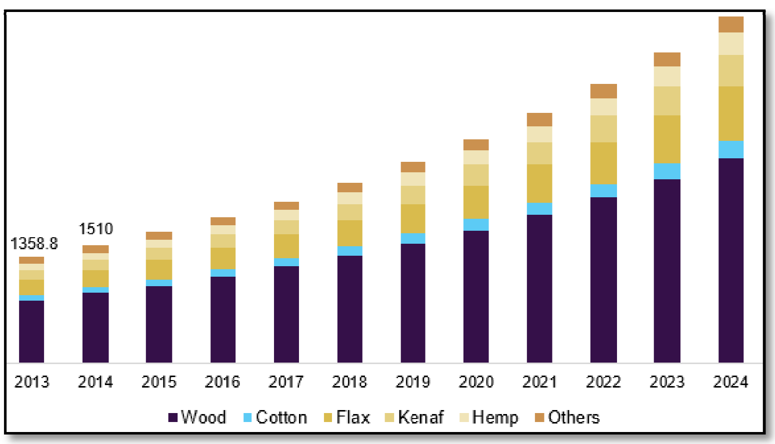


Fig. 9US composite industry revenue based on the fiber used (Source: Grand View research)

Conclusions

- In the present work, the use of natural fiber composite materials in automotive industries and related trends are discussed and reviewed.
- Natural fiber reinforced composite materials posses good strength and triblogical properties and hence, these composites can be used as a replacing materials for plastics which is commonly used.
- Many components related to the automotives are manufactured by means of natural fibres. World car manufacturers are using natural fibers in their cars and related vehicles.
- The natural fibers are environmental friendly and are able to replace the synthetic fibers.
- The trends in usage of natural fibers indicate that the natural fiber industries are growing world wide rapidly.

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