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G C Sen Memorial Lecture

A Compilation of Memorial Lectures
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Background of
G C Sen Memorial Lecture

Gopal Chandra Sen, graduated in mechanical engineering from College of Engineering and Technology, Jadavpur in 1933 and gathered first-hand experience for two years, first in a private firm and then in a distinguished workshop in Howrah. He joined the National Council of Education, Bengal as Instructor in 1935 and became Lecturer in 1940. In 1946, he went on a Government scholarship to the USA for higher studies in engineering. He got the degree of Master's of Science in Engineering from the University of Michigan. On return, he resumed teaching at Jadavpur University and became Professor of Mechanical Engineering in 1952. In June 1969, he was appointed Dean of the Faculty of Engineering and from August 1970 until his demise on the December 30, 1970, he was the Vice-Chancellor of Jadavpur University.

Prof Sen was the pioneer in India of the teaching of production engineering and was the author of a number of very useful books including textbook on the Principles of Machine Tools and Metal Cutting, which are adored in many universities abroad. Prof Sen belonged to that vanishing 'tribe' of teachers who would take up teaching as dedication rather than profession. He was a disciplinarian with a difference.

Apart from his academic brilliance, he was a poet and an artist – one who was an expert in drawing and an adept in drawing pen pictures.

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

G C Sen Memorial Lecture

presented during **National Conventions** of **Production Engineers**

Beyond Integrated Production Technology, Quality and Workers

Dr Krish Pennathur

President, World Academy of Productivity Science

INTRODUCTION

The most recent World Bank study, entitled 'The Long Term Outlook for the World Economy', has warned that the rich-poor gap will widen during the Nineties unless the developing countries take positive remedial actions right now. All slowly developing nations must pay serious heed to this warning if they are to come anywhere near the rich industrialized economics.

Some road blocks to higher rate of economic development, like poverty, population explosion, illiteracy and the problems that would arise from a unified market in the European Community has been dealt with by the author in a previous article ('Pep to Productivity in the Third World'. Financial Express, March 5, 1991).

Three other important factors - technology, quality and industrial relations-can affect the developmental growth rate of the Third World and blunt the edge of their export efforts. It would be expedient to examine these factors briefly.

TECHNOLOGY

Countries like Japan, South Korea and Taiwan, have adopted and adapted the technological innovations of the USA, and even improved them slightly, with the result that they are now exporting to the USA.

While R&D is expensive and time-consuming, 'improving on somebody else's mouse trap' is a more pragmatic approach recommended by Theodore Levitt of Harvard University. In 'innovative imitation, a competitor's product is selected, improved upon technologically through 'additive R&D' and the refined and upgraded product marketed aggressively. There is nothing humiliating or unethical about such a corporate policy.

Each country's strategy should be to produce products best suited to its current state of technology at which level she can produce them at globally competitive rates. Technology does not merely mean chips, lasers and orbiting satellites. Technology covers a vast spectrum comprising innumerable are as like agriculture, fisheries, biotechnology, hospitality industry, tourism, transport systems, irrigation, flood control, drought management, sericulture, medicine, adding value to national resources and agricultural products, novel forms of power generation, jewellery design and manufacture, ready-made garments, the services sector and soon.

Technological advances in these areas would bring the developing nations abreast of developed countries which have, so far, been concentrating on conventional industries to the neglect of the non-conventional industries and the services sector.

The article on 'The Slow Yarch of Technology' under the section 'Science and Technology', published in the January 13, 1990, issue of the London Economist, gives an insight into how developing countries can benefit from appropriate technologies suited to their specific industrial, developmental and economic requirements. This is an article which would be of great practical value to growth-oriented developing countries.

QUAUTY

It is universally recognized that quality and reliability contribute to customer loyalty, national reputation and a greater share of overseas markets. Yet, the developing countries, in general, and India, in particular, pay scant attention to this vital aspect of productivity.

There are many reasons for this lack of quality consciousness. Many countries are highly permissive about quality standards. Customers are tolerant about Sub-standard goods. In a sheltered domestic market, the manufacturers and processors take advantage of this situation and are content into making poor quality products and higher profits. Top management does not make quality a personal and an organizational commitment.

Quality must be everybody's concern. The operator who produces a component must be personally responsible for the quality of the work he does.

But this concept is vitiated by entrusting 'quality control' to a separate Quality Control Department. This generates the feeling that quality is the sole responsibility of that department and no one else's. The role of the Quality 'Assurance' Department must be radically changed. It must be made responsible for establishing quality norms and standards, analysis of defects, and introducing 'once-for-all' remedial measures. They should not be line and stage inspectors. That creates an adversative relationship between the inspector and the operator.

The responsibility for the organisation, direction and control of quality must be 'vested at the highest level and implemented by everyone concerned'.

Doing the right thing right the first time increases productivity and reduces costs.

Quality assurance demands a strictly disciplined approach to the performance of a task, brooking no deviations from authorized standards.

The experience of Japanese entrepreneurs in setting up factories in other Asian countries is that the guiding principles of discipline and 'Zero Defect' are not being adhered to in India and the Philippines. They find Thailand, Malaysia and Indonesia adhere to prescribed quality standards, particularly in enterprises run and manned by some of South East Asia'~ 30 million people of Chinese descent. Mr Asao lto, President of Sunitomo 3 M Ltd, a Japanese-USA joint venture, says 'Japanese business almost always links up with overseas Chinese when they make their Asian investment in manufacture.'

James R Houghton, the CEO of Cornina Glass Works avers 'Quality applies to everything we do. This is a life-long journey and not a destination.'

The detailed aspects of quality are dealt with in my book 'Value Analysis' being published by the South Asian Division of the World Confederation of Productivity Science. If we are to acquire a high industrial reputation domestically and internationally, increase our productivity and sharpen our competitive edge in foreign markets achieving and maintaining the requisite high standards of quality and reliability are of utmost importance.

INDUSTRIAL HARMONY

The greatest detractor of productivity is industrial disharmony. In some of the developing democratic countries which have won their political freedom after the Second World War and follow a 'socialistic pattern' of the government, some of the workers tend to equate political freedom to freedom from performing a fair day's task and strive to get more wages for less work. Their question is: What can the country do for my welfare? This leads to constant demand for wage hikes and industrial indiscipline.

In India, for example, the officers and workers of some private enterprise organizations are demanding that their companies be nationalized with the sole intention of reducing their work load to the minimum.

In some other countries, following the wake of higher economic growth and increased productivity, there are demands, protest marches and strikes in support of unreasonable and, sometimes, unjustifiable wage hikes.

The Republic of Korea (South Korea) is a recent example of this phenomenon. Following the heady summer of demonstrations in 1987, there was a rush of strikes and protests and wages have gone up by over 20% and the government has raised its rice-buying price by more than 30% since 1988. The economy began to slide two years ago. The current trend is to shed labour-intensive businesses and move on to high technology areas. Japan, because of its rising wages, is locating her industries in other Asian countries like Thailand, Malaysia, Indonesia and the People's Republic of China. Developing countries like India and the Philippines cannot afford the luxury of these industrial strategies.

It is, therefore, imperative that the governments of developing countries persuade the labour leaders to act as real leaders by moderating their demands to affordable levels and discharge their moral obligation of inculcating in the workers a sense of discipline, an involvement in improving productivity, a spirit of work ethic and, most important of all, a national pride which places the motherland's development above petty self-interest.

Soon after the Second World War, West Germany's government had the foresight to bring management and trade unions together to discuss the national wage policy annually and determine what the wages should be that particular year based on 'what the traffic can bear' for export purposes.

This is something that the developing countries ought to do, if they have to gain edge in exports.

WAGES

We tend to imitate the west whenever it suits us. If the President of the USA has an Air Force 1 at his disposal, the presidents/prime ministers of developing countries must have their own Air Force 1s. But, we cannot afford this luxury.

Similarly, since the wages in the west have been escalating, our trade union leaders and labour demand wage hikes at frequent intervals. We cannot afford this either.

With our limited technology and even more limited resources (having to depend on imports involving hard currency), the only way our products can be competitive in international markets is through reduced labour cost. We lose even this advance by our increasing cost of wages.

The wages in the organized sector are pretty high for our state of development. An unskilled labourer, a loader in a colliery, earns more than a junior lecturer. Drivers earn more than junior officers. If this is the state of affirs, we can bid goodbye to our export aspirations and, thus, our hopes of economic development.

We talk about a 'Minimum Wages Act'. In our present condition it should be 'Maximum Wages Act', till we become really affluent and advanced.

There should be a moratorium on wage hikes till out state of development improves radically. Shri Mohan Dharia of the Planning Commission of the previous government had called for a ban on industrial disputes for 15 years. This is right thinking.

WAGES LINKED TO PRODUCTIVITY

The first requirement for linking wages to productivity is to have reliable means for measuring productivity. Most industries do not have these. Hence, the modality of productivity measurement has to be determined for each industry has to be developed. Knowledge, information and data can be pooled region-wise. This has then to be extended to the non-conventional industries like agriculture and fisheries and to the services sector.

The second factor to be considered is that wages should be based on predetermined levels of expected productivity. If a person does not come up to this standard level, he or she should not be paid a guaranteed basic wage. The wage must be cut according to the shortfall in productivity. This is a radical practice that developing countries must adopt.

The linkage of wage to productivity should not be on a 1 to 1 basis. We just cannot afford. It is the duty and obligation of every citizen of a developing nation to put his/her best foot forward and give forth the best in the cause of national development. Increases in wage because of appreciably high productivity rate must only be a symbolic reward factor. The basic wage itself must be related to a reasonably high rate of productivity. Anything higher in productivity should be linked to the wage on a 'low slope' basis. Shortfalls should result in cuts in wages.

Linkage to productivity should be confined to labour's contribution to increased productivity and should exclude factors like modernization, mechanization, automation, etc. The above are not capitalistic views but strategies for the very survival of developing nations.

THE PLACE OF QUALITY IN WAGES

Everybody talks about productivity-linked wages. Everybody also agrees that quality improves productivity through reduction/elimination of waste. But nobody links quality with wages.

Let us take the case of X and Y doing the same kind of a job. X produces 10 pieces of a component whose cost price is $ 100 per piece, at the prescribed standard productivity rate. Y produces 12 pieces of the same component during the same duration of eight hours. Whose productivity is higher? Who is going to get a slightly higher wage? Of course, Y.

X had produced during his shift 10 pieces of standard quality without any rejects. Y had produced 13 pieces; one was outright scrap; and two had to be reworked on account of several defects. The cost of scrapped part is $ 100 (opportunity cost). The cost of reworking was $ 50 for each of the two pieces. As per current day practice, Y will get a higher wage linked with 'productivity' as compared to X. Yet, the productivity of X had really been higher than that of Y.

Y should have been penalised for lower productivity because of scrap and reworking. Yet, he is rewarded. If the cost price of goods and services of export is to be low, we cannot afford to have scrap and reworking. We must get things right the first time. There must be an incentive for through quality-linked wages woven into the productivity-linked wages scheme. To reiterate, these linkages have to be a modest scale and not on a 1 to 1 basis until we reach a stage when we can afford it.

THE CASE OF ROBINSON CRUSOE

What wage did Robinson Crusoe pay his man Friday? And, what productivity-linked earnings?

They were fighting for their survival. Highest possible productivity, including quality and innovation was a basic requirements and not a luxury to be rewarded. The same is the case with slowly developing countries and 'sleeping giants'. If they do not pursue productivity for their own betterment and, instead, accept the philosophy that work above a certain minimum level must be rewarded (with a guaranteed basic wage even for very low productivity) they will always remain backward and poor.

To repeat, the author is not a capitalist. He was the personal productivity adviser to the late Shri Satish Loomba, a left-wing trade union leader and assisted him to fight a case for the staff against the All-India Radio. But, he must emphasize the fact that many of our developing nations will continue to be developing even after two decades if they do not watch out for the effectiveness of labour and the cost content of the labour input into their export products. We can learn a great deal by studying the wage policies of South Korea and Thaiwan during the seventies and up to 1988 (when dictatorship was replaced by democracy).

For this we need enlightened trade union leaders. But then, when politicians themselves are not enlightened, this may be too much to ask for. Still, without the labour understanding the predicament we are in, we cannot make much headway in our export promotion policies, with the several constraints they are already suffering.

CONCLUSION

Most of the developing countries whose progress is slow suffer from some common ailments: balance of payment problems: fiscal deficits; short-term 'rolling' foreign borrowings and non-profit-making public sector undertakings. The remedies for these lie with the government. In the case of the largest country in SAARC, India, the external debt is over US$ 70 billion 'rolling foreign borrowings US $6 billion and fiscal deficit around US$ 6 billion.

One way among many to avoid the 'debt trap' is exports. These exports which are in tune with the state of technological development of the country must be competitive in the overseas markets in terms of quality and cost.

Restrained wage claims and 'low slope' linkage of productivity and quality (as a separate factor) will go a long way in establishing a competitive edge in foreign markets.

Flexible Automation — A Tool for Agile Manufacturing

Mr S N ROY

Executive Director,
Bharat Heavy Electricals Limited, Bhopal (M.P)

SYNOPSIS

Industries are embracing the concepts of agile manufacturing, which favour nimble principles over the ageing techniques of mass production. These advanced manufacturing concepts are characterized by their ability to allow a rapid response to continuously changing customer requirements. At their very core are flexible automation systems that can reduce product cycle time, increase quality and allow rapid changes in design.

Flexible Automation (FA) is an emerging trend in manufacturing technology in the world class industries. The recent hi-tech innovations like Flexible Manufacturing System (FMS), Computer Integrated Manufacturing (CIM), Intelligent Manufacturing System (IMS), Rapid Prototyping (RP) etc., have made it a reality to successfully implement flexible automation in industries to achieve the goal of "Maximum Productive Flexibility". These hi-tech systems, which have emerged from technological convergence of information technology, computers, and telecommunications, have been discussed in this paper.

1. INTRODUCTION

Traditional factories derived their competitive advantage from a combination of size, volume and standardisation. But the computer integrated manufacturing (CIM) and flexible manufacturing system (FMS) of today and tomorrow differ in their greater flexibility. Advanced technology has fundamentally changed the nature of manufacturing and opened up opportunities for new styles of competition in many industries. The convergence of information technology, computers and telecommunications in manufacturing systems is the key reason for the fundamental change towards achieving the goal of' economy of scope' — a combination of variety and low cost.

In the "factory of the future" variety and innovation will no longer have to be traded off against productivity. These will become the vital weapons to compete in the evolving global marketplace.

The drive towards agility has led to the development of flexible automation systems. An attempt has been made in this paper to describe the concept of flexible automation through hi-tech innovations like FMS/CIM/IMS systems in the world class industries.

2. NEW AIMS FOR PRODUCTION

As a result of the internationalisation of economic life, conditions within the global companies in highly industrialised countries like Germany, Japan, U.S.A. etc., demonstrate very similar development trends:

• Shorter market lifetimes and compressed product lifecycles, which imply increased demands on the speed and frequency of development of products, and requirements for versatility and ability to reorganise in the area of product development.

• Intensified competition, which forces companies to make use of short-term marketing opportunities and to accept lower profit margins,

• An accelerated rate of technical development, which makes it important to follow technical advances, and to be able to convert new technology quickly into marketable products.

• Declining Profit Margins and more frequent fluctuations in the economy, which necessitate rationalisation and optimisation in all areas and on all levels within the company, and which require a short reaction time.

• Increased demands on the augmented products, which express themselves through a desire for unique products, just-intime delivery, reasonable price, and a high, uniform quality.

Movement towards web-based/e-commerce based interconnectivity.

• Shift from fragmented to integrated supply and demand chains.

• Shift from domestic to global sourcing and manufacturing.

• 'Shift from pyramid - like organization to networks.

Shorter market lifetimes and shorter innovation times lead to increasing demands on a company's preparedness, adaptability and versatility.

The world class companies must, therefore, accept new business environment and pursue new strategies, for example:

• Develop new products with increased frequency.
• Offer a great number of variants.
• Attempt to shorten delivery times.
• Reduce costs by all means.
• Ensure high quality during all phases of the product's lifetime.
• Embed the uniqueness of the product more and more deeply into the manufacturing process.
• Incorporate increasing level of product customisation.
• Integrate the global supply chain.

3. EVOLUTION OF MANUFACTURING TECHNOLOGY

Looking back over the history and evolution of manufacturing technology, one can observe following three general stages development in the utilisation of the basic factors or production:

• In the first stage, manufacturing was dependent on human labour and human intelligence (age of specialisation).

• The second stage saw the replacement of human labour by machines, while still relying on human intelligence (age of mechanisation)

• Today in the third stage, human intelligence is being replaced by artificial intelligence and integrated with machine labour (age of automation/convergence)

These changes have been accompanied by an evolution in manufacturing policy as indicated in Figure 1.

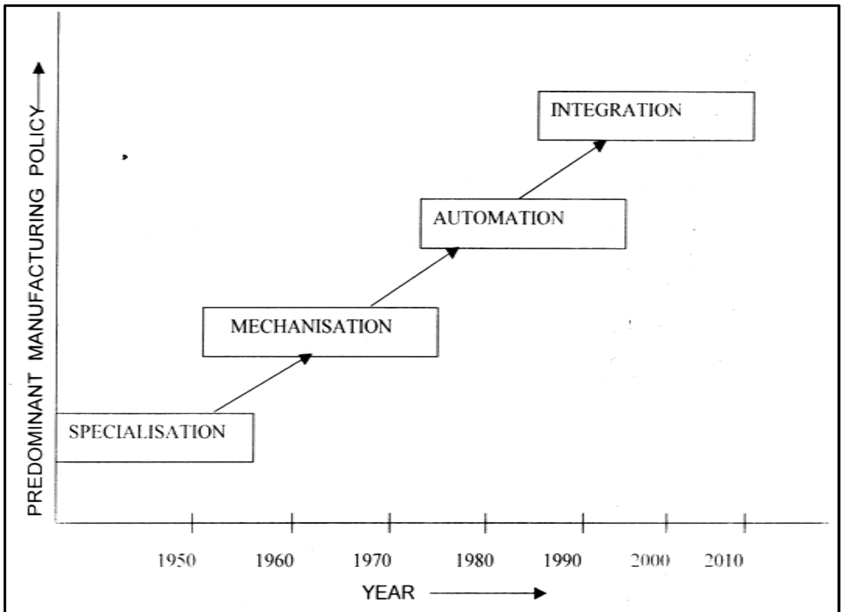


FIG. 1 : EVOLUTION IN MANUFACTURING POLICY

Evolution to the third stage is made possible and/or accelerated by the availability of low cost electronic computing and control, telecommunications, and sophisticated measurement and sensor technologies.

Manufacturing is now moving from functions where we manage people, materials, and costs, to systems where we must manage information, continuous change, and time.

4. THE TRADITIONAL BASE"OF MANUFACTURING

The traditional factory derives its competitive advantage from a combination of following attributes:

- Economy of scale
- Task specialisation
- Standardisation
- Repetition

Unfortunately, the 'better' this factory gets, the less able it is to respond to the rapid changes occurring in today's marketplace, intense global competitive pressures and increased demands on the 'augmented' products. In effect, the traditional manufacturing technology offers a formidable barrier to accelerated product development/ innovation due to its inflexible characteristic. Hence traditional manufacturing technology can not be used as a competitive weapon in the niche marketing environment of today and tomorrow.

5. e-MANUFACTURING

In the new economy of today, the world has become a global village with no economic border. World class companies are choosing to carry out different operations like design, manufacturing, research & development, assembly etc., at different locations depending upon local core strengths. Web-enabled choice board concept of the customers has resulted in higher degree of custornisation of the products. In almost every advanced industry, tightly integrated supply chain models, such as those popularlised by Dell Computer and its extensive web of suppliers, are emerging. In these new models, connection of the plant-floor to the broader supply chain is essential, and information access is more critical than ever.

In fact, the most strategic advantage of any organization today is information. The plant-floor is the starting point for greater information connectivity. Computer based shop floor controls for manufacturing facilities, material handling systems and related equipment generate a wealth of information about productivity, product design, quality and delivery. And a contemporary automation architecture is the key to unleashing this information in a costeffective manner.

A global company requires following key competencies for implementing-e-manufacturing concept :-

- An integrated plant-floor automation architecture.
- Seamless connections to the enterprise systems enabled through software and services.
- Comprehensive computer aided tero-technology management.
- World - class supply chain coupling

The core of an e-manufacturing strategy is the technology roadmap for information transparency between the customers, manufacturers and suppliers.

In the today's era of digital management, the Internet has converged the plant-floor, enterprise and supply chain. In this context, Flexible Automation plays a key role in implementing an integrated plant-floor automation architecture.

Micro to Nano Finishing

Dr V K Jain

Department of Mechanical Engineering, Indian Institute of Technology Kanpur

1. Introduction

Many industries involved in the manufacture of equipments related to aerospace, nuclear, automobiles, missiles and similar others require materials having super qualities like very high strength, heat resistance, high wear resistance etc. To shape and size such materials to the requirements of these industries is a challenging task for manufacturing engineers. The problem becomes still more difficult when 3-D complex shaped components like a turbine blade are to be machined and finished. The traditional finishing processes like grinding, lapping and honing (Table 1) are capable to produce surface finish in the range of l-4llm (Ra value) or even a fraction of 11mwith the limitation of shape and size of workpieces. But to achieve surface finish better than this on different types of components (difficult-to-machine materials and complex shapes) is not possible by these traditional finishing processes. One needs to use advanced finishing processes to achieve nanometer (nm) range surface finish, as discussed in this article. The performance of the advanced fine abrasive finishing processes can be evaluated by their achievable surface finish, form accuracy and resulting surface integrity. These fine abrasive finishing processes are capable to produce accuracy of form (figure) in the nanometer range and the surface damage in the range from micrometers to nanometers. Table I summarizes the attainable surface finish during some conventional and advanced fine abrasive finishing processes:

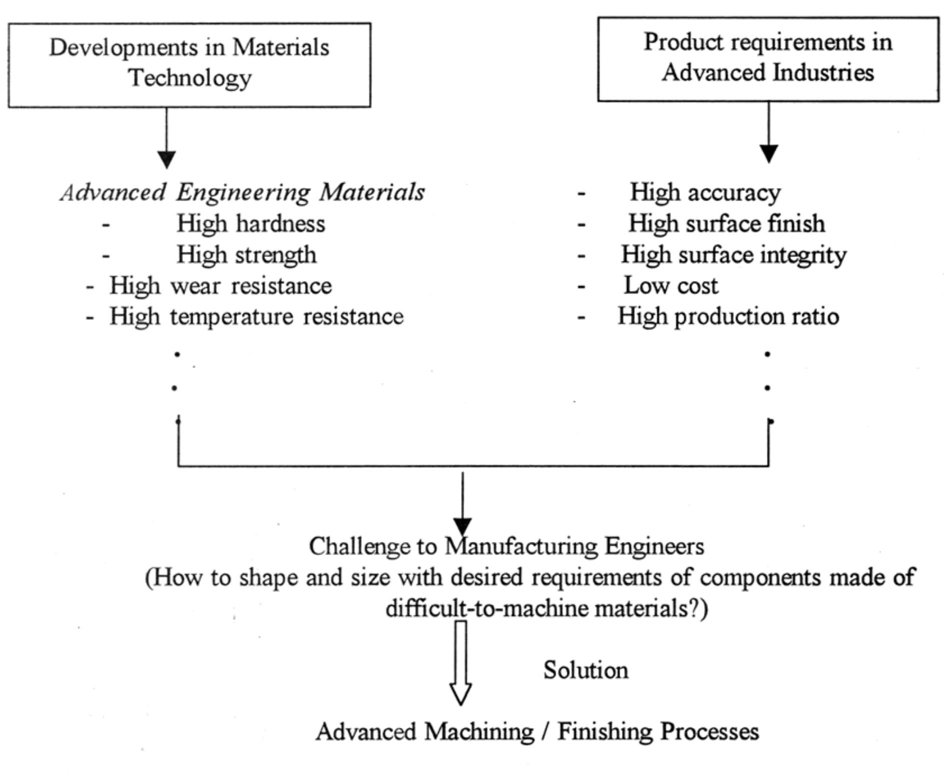


Fig. 1/Table 1

To make different products in various shapes and sizes, many times, the traditional manufacturing techniques do not work well. One needs to use advanced manufacturing techniques in general and advanced machining and finishing processes in particularly [Jain, 2002]. Further, the need for high precision in production was felt by manufacturers world over, to improve interchangeability of components, quality control and wear / fatigue life [McKcon, 1987 and Taniguchi, 1983]. Nowadays, new advances in materials syntheses have enabled production of ultra fine abrasives in the nanometer range. With such abrasives, it has become possible to achieve nanometer surface finish and dimensional tolerances. There is a process (ion beam machining), which can give ultra precision finish of the order of an atom or molecule size of the substance. In some cases, the surface finish obtained has been reported to be even smaller than the size of an atom.

This articles deals with some of the advanced finishing processes viz, Abrasive Flow Machining (AFM), Magnetic Abrasive Flow Machining (MAFM), Magnetic Abrasive Finishing (MAP), Magnetic Float Polishing (MFP), Magneto Rhelogical Abrasive Flow Finishing (MRAFF), Elastic Emission Machining (EEM) and Ion Beam Machining (IBM). These advanced finishing process can be divided in two categories- (A) Magnetic field assisted methods (MAFM, MAF, MFP, MRAFF) and (B) others (AFM, EEM and IBM). Both categories of advanced finishing processes have been discussed here.

2. Abrasive Flow Machining (AFM)

Abrasive flow machining process was developed to deburr, polish and radius difficult to reach surfaces and edges by flowing abrasive laden polymer, to and fro in two vertically opposed cylinders (Fig.2a). The medium (mixture of viscoelastic material and abrasive particles) enters inside workpiece through tooling. The abrasive particles penetrate in the workpiece surface depending upon the extent of radial force acting on them. The tangential force is responsible to remove the material in the form of chips as shown in Fig.2b. The debris obtained during AFM were collected and examined under the scanning electron microscope. It was found that very fine chips are produced. However, under .certain machining conditions the occurrence of ploughing has also been observed [Gorana, 2003], Fig.2c. In this case, one may get shining polished surface but almost no material removed. AFM can finish internal as well as external surfaces with even complex geometries.

AFM system has three major elements — Machine, Tooling, and Medium. The machine controls the process variables. The tooling confines and directs the medium flow to the areas where abrasion is desired. Rheological properties of the medium determine the pattern and aggressiveness of the abrasive action [Jain, et al, 2001]. Fig 2d shows a photograph of the AFM setup designed and fabricated at LIT. Kanpur [Sunil Jha, 1998].

AFM has some peculiar applications where no other traditional as well as advanced finishing process can work, For example, many small diameter holes (say, diameter = 3 mm and depth = 30 mm) can be finished by this process at a time by appropriately controlling machining parameters. This process can be used to control surface finish of the cooling holes in a turbine blade, stator, or rotor blades of a turbine.

3. Magnetic Abrasive Flow Machining (MAFM)

Some efforts are being made to enhance material removal rate (MRR) during AFM by the application of the magnetic field while using magnetic abrasive particles (MAPs) in place of simple abrasive particles. This process is named as magnetic abrasive flow machining (MAFM) [Singh and Shan, 2002]. The principle of working can be seen in Fig. 3 where the application of magnetic field attracts and densifies the MAPs near the surface of the workpiece to be finished. As a result, effective abrasive concentration increases near the wall as compared to the rest of the medium. It enhances MRR in comparison to normal AFM because of two reasons: (a) increased effective concentration of the abrasive particles near the workpiece surface to be abraded, and (b) increased radial force acting on the abrasive particles leading to the increased depth of cut and hence increased MRR and comparatively rapid improvement in surface finish in the initial stages.

Magnetic abrasive finishing process uses granular magnetic abrasive particles (MAPs) composed of ferromagnetic material (as iron particles) and abrasive grains (A1203, SiC, or diamond) as cutting tools. The necessary finishing pressure is applied by electromagnet generated magnetic field. Fig 4a shows a photograph of the setup designed and fabricated at I.I.T. Kanpur [Singh]. Fig. 4b:shows working principle of MAF process. The magnetic abrasive particles are joined to each other magnetically between the two magnetic poles (S and N) along the magnetic lines of force forming a flexible magnetic abrasive brush (FMAB). When there is a relative motion between the FMAB and workpiece, the abrasion takes place and gives a polished finish. This finish can be as good as approaching to the hundredth of a micrometer depending upon the machining conditions and workpiece material.

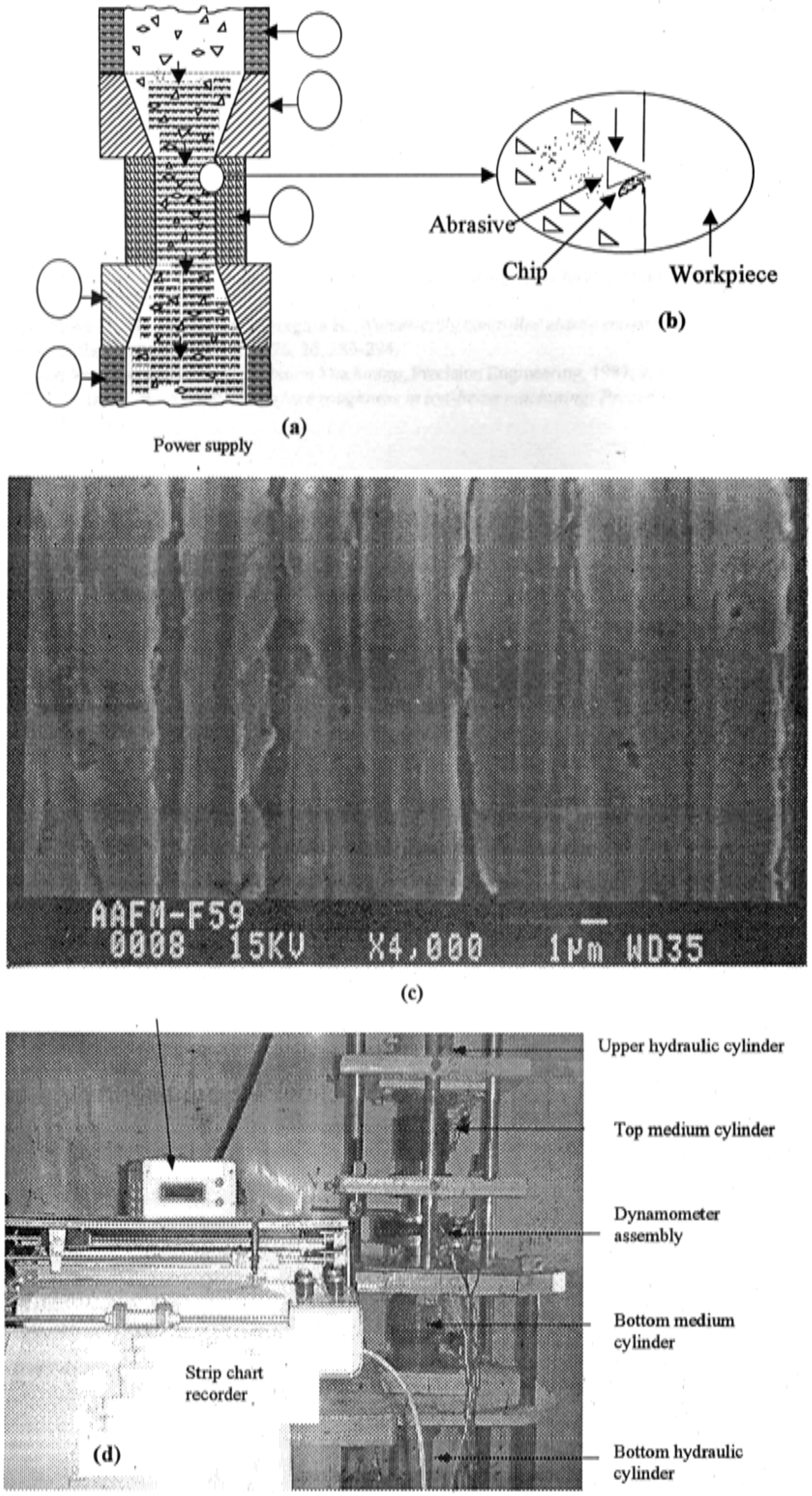


Fig 2.(a) Schematic Diagram of Abrasive Flow Machining set–up (1) Cylinders, (2) Tooling, (3) Workpiece, (b) Enlarged view of a circled part shown in Fig. 2(a), (c) Photograph showing enlarged view of the ploughed surface after AFM, (d) photograph of the AFM set-up designed and fabricated at I.I.T.Kanpur [Sunil Jha, 1998;Gorana].

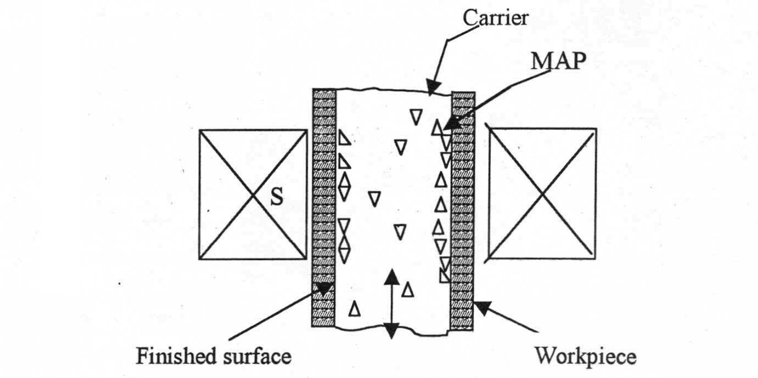


Fig.3 Densification of magnetic abrasive particles near the wall surface of the workpiece due to the magnetic field (S and N are south and north poles, respectively)

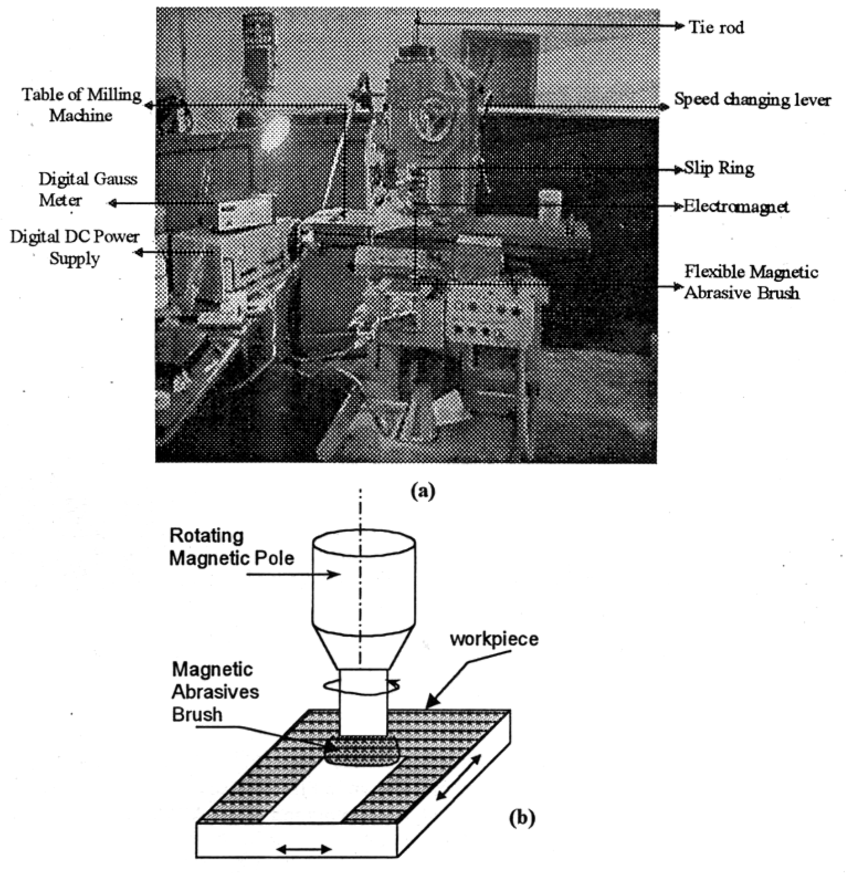


Fig.4 (a) Magnetic abrasive finishing set-up mounted on a milling machine
(b) Working principle of plane magnetic abrasive finishing

4. Magnetic Abrasive Finishing (MAF)

The performance of the process depends on the parameters such as MAPs (type, size, and mixing ratio), working clearance between the workpiece and magnetic pole, rotational speed of workpiece or pole, vibration (frequency and amplitude) of the workpiece, properties of work material and magnetic flux density [Jain, 2002, Jain, Eta1200 1]. Fig. 5 shows FMAB photograph [Singh].

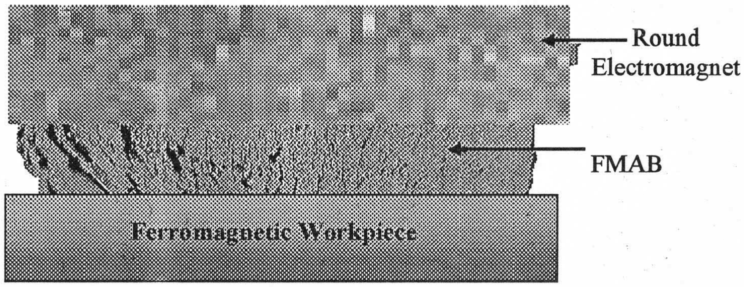
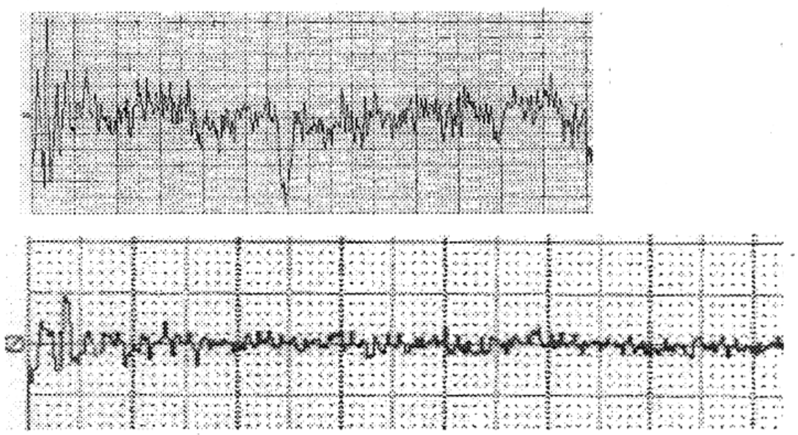


Fig.5 Digital Photograph of Flexible Magnetic Abrasive Brush (FMAB)

Fig. 6 shows surface finish before and after on a stainless steel workpiece [Jain et al. , 2001]. This figure shows substantial improvement in Ravalue (≈ 52 %) and peak to valley height, Ry value (≈ 60 %). This process can also be used to improve surface properties by the process of diffusion of particles in the workpiece surface. Proper tooling can be developed even to finish 3-D intricate shapes because FMAB is deformable, and adapts to the shape of the workpiece but it is not as flexible as AFM medium. Achieving uniform surface finish near the discontinuities or edges in the magnetic poles is difficult.

Before MAF
$R_a = 0.45$ μm, $R_q = 0.63$ μm, $R_y = 5.85$ μm



After MAF
$R_a = 0.23$ μm, $R_q = 0.31$ μm, $R_y = 3.35$ μm

Fig.6 Surface roughness plots before and after magnetic abrasive finishing of a stainless steel pipe [Jain et al., 2001].

Effect of various parameters on the responses like MRR, surface roughness and out of roundness (in case of cylindrical workpiece) have been reported [Fox and Agarwal, 1994, Jain, 2001]. MAF has been successfully used to finish internal surfaces of the tubular workpieces as shown in the Fig. 7 [Kin, 1997, Umehara, 1994]. However, this technology of MAF needs to be brought out of the research laboratories so that it can be employed on shop floor for the industrial uses. It has been reported [Fox, 1994] that the final surface roughness (Ra) value of7. 6 nm from an initial surface roughness of 0.22 11m has been obtained on stainless steel rollers.

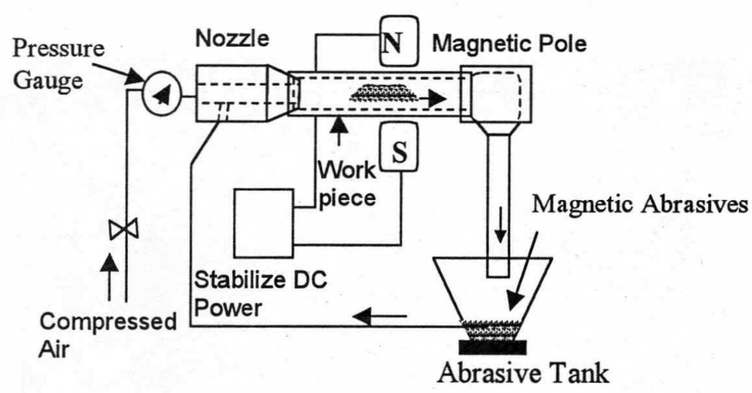


Fig.7 Magnetic Abrasive Jet Finishing

5. Magnetorheological Finishing (MRF)

Manufacture of a lens usually involves two operations - grinding and finishing. Grinding operation makes a lens close to the desired size while finishing removes the cracks and surface imperfections either created by grinding or could not be removed during grinding. Manual grinding and polishing are non-deterministic and a high local pressure may lead to sub-surface damage. To take care of these difficulties, magnetorheological-finishing (MRF) process has been developed which is automatic in nature. This process uses Magnetorheological (MR.) fluid, also known as smart fluid because it changes its properties under the influence of magnetic field.

Fig. 8a shows a schematic diagram of MRF process, Fig 8b shows a photograph of the set-up designed and fabricated at I.I.T. Kanpur while Fig, 6c shows an enlarged view of the charmel where lens finishing is taking place. MR. fluid consists of colloidal suspension of magnetic particles and finishing abrasives which reversibly stiffens under the influence of magnetic field. The stiffness is directly proportional to the strength of the magnetic field, The stiffness of this temporary finishing surface (stiffened fluid) can be controlled in real time by varying the magnetic field's strength and direction. This process is used for finishing glasses, glass ceramics, plastics, etc.

In MRF,MR fluid ribbon is extruded between workpiece and rotating wheel rim (Fig. 8c). As a result of extrusion, wear of the workpiece (convex, concave, or flat) takes place. It has been reported that the surface accuracy is achieved of the order of 10-100 nm (peak to valley). This setup has been used to finish a lens from RMS roughness value of 41 nm to 11 nm in 50 minutes of finishing time using the setup shown in Fig. 8c.The photograph Fig.9 of the finished component obtained using the setup shown in Fig. 8 have been obtained from atomic force microscope.

6. Magnetorheological Abrasive Flow Finishing (MRAFF)

In this process, magnetorheological finishing (MRF) and abrasive flow machining (AFM) processes are combined together to make the hybrid process applicable to the difficult-to-machine materials to achieve desired surface finish. This process is named as Magnetorheological Abrasive Flow Finishing (MRAFF), and is being developed at I.I.T Kanpur. This process can. finis11. complex geometries and inaccessible areas of a product to the level of nanometer range. This process use, smart magnetorheological fluid whose rheological properties can be controlled through the magnetic field. This smart fluid is mixed with abrasive particles (Al_2O_3, SiC, or diamond), and extruded through the workpiece surface to be finished. In the' area where finishing is to be done, magnetic field is applied to stiffen the fluid so that abrasion of the workpiece surface takes place. Fig. 10 shows a schematic diagram of the setup [Jha and Jain]. This process imparts more accurate control of the process behavior compared to the AFM process. This process is applicable to the very hard materials to be finished.

7. Magnetic Float Polishing (MFP)

Magnetic Float Polishing (MFP) process is used for gentle finishing of very hard material products like ceramic balls and bearing rollers. Such materials develop defects during grinding leading to fatigue failure. This process is known as Magnetic Float Polishing (MFP) in which low level of controlled forces are used. This process is based on the ferro-magnetic behavior of magnetic fluid that can levitate non-magnetic fluid and abrasives suspended in it by magnetic field. The levitation force applied by the abrasives is proportional to the magnetic field gradient. It is a good method for super finishing of brittle materials with flat and spherical shapes [Umehara, 1994, and Komandari, 1996]

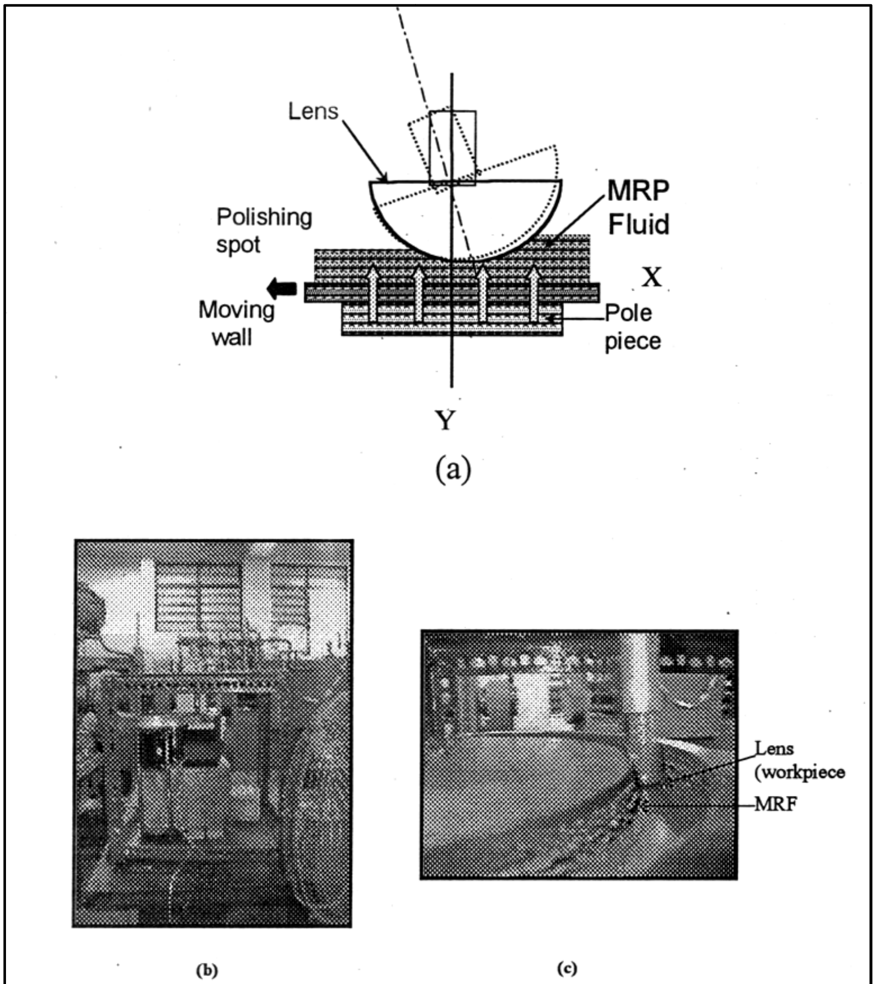


Fig. 8 Schematic diagram of magenetorhelogical finishing process, (b) Photograph of a MRF set-up, (c) Enlarged view of finishing section

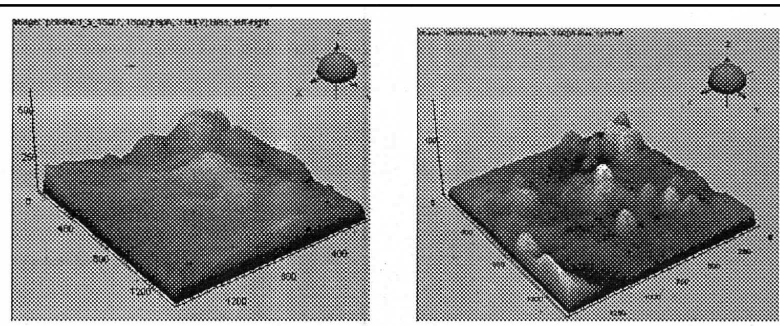


Fig. 9 Surface profiles obtained from atomic force microscope at (a) Before finishing (RMS value 41 nm), (b) after 50 min of finishing (RMS value 11 nm)

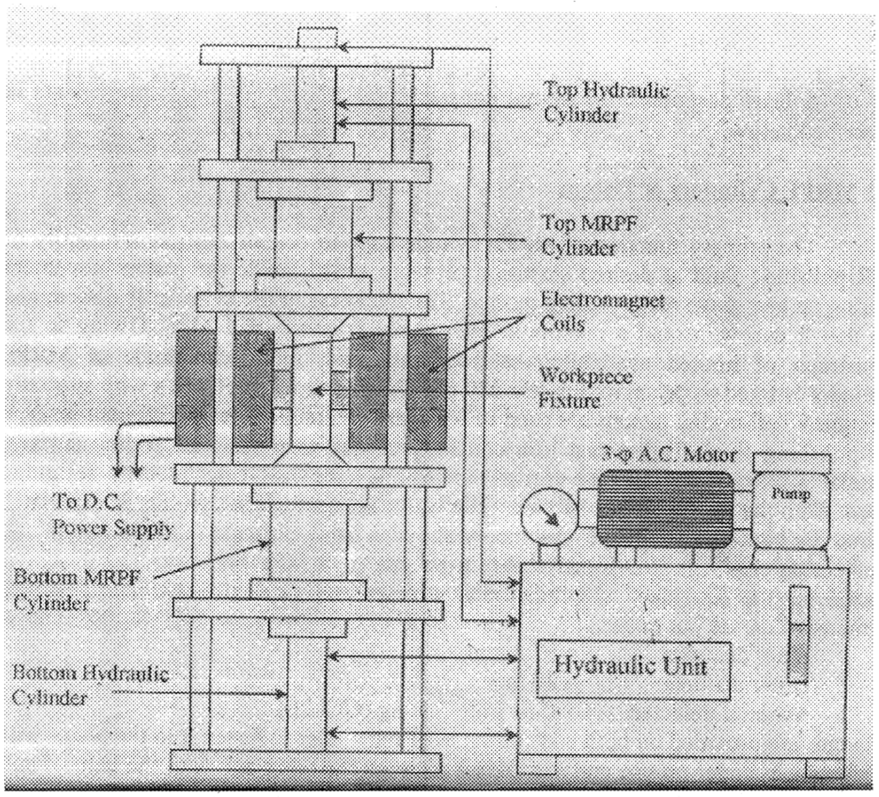


Fig.10 Schematic diagram of MRAFF experimental set-up

The magnetic fluid consists fine abrasive grains and fine ferromagnetic particles in a carrier fluid (water or kerosene) (Fig. 11). On the application of the magnetic field, the ferro fluid is attracted downwards which is the area of higher magnetic field. Simultaneously, the buoyant force acts on non-magnetic material to push them upward in the area of lower magnetic field.

The abrasive grains, the ceramic balls, and the acrylic float inside the chamber all being of non-magnetic material, are levitated by the magnetic buoyant force. The drive shaft is fed down to contact the balls and to press them down to reach the desired force level. The balls are polished by the relative motion between the balls and the abrasives.

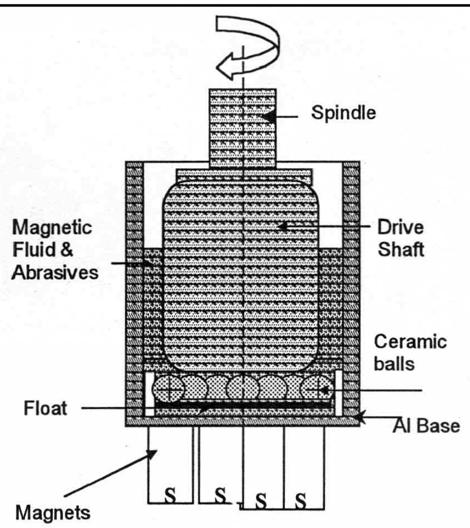


Fig.11 Schematic Diagram of the magnetic float polishing apparatus

OTHER PROCFSSFS

8. Elastic Emission Machining (EEM)

Elastic Emission Machining (EEM) can give surface finish of the order of atomic dimensions (~ 0.2 nm to 0.4 nm) [Komandari, 1996, Mori and Yamauchi, 1984]. In this process ultrafine abrasive particles collide with the workpiece surface to remove the material at the atomic scale by elastic fracture without plastic deformation [Mori, et al. 1987; Morietal,1976].

Fig. 12 shows working principle of EEM in which polyurethane ball is (~56 mm diameter) used. This ball is mounted on a shaft whose axis of rotation is inclined at about 45° to the vertical axis, and it is driven by a variable speed motor. The workpiece is immersed in the slurry of ZrO_2 or Al_2O_3 (size, 20 nm to 20 urn) abrasives and water as carrier. The slurry is circulated in the gap by a diaphragm pump, and maintained at constant temperature with a heat exchanger. Material removal takes place due to slurry and work interaction which involves erosion of surface atoms by the bombardment of abrasive particles without introduction of dislocation. The thickness of the material removed may be as low as 20 nm and roughness value as low as 0.5 nm. In this process, abrasive particle can remove a number of atoms after coming into contact with the surface.

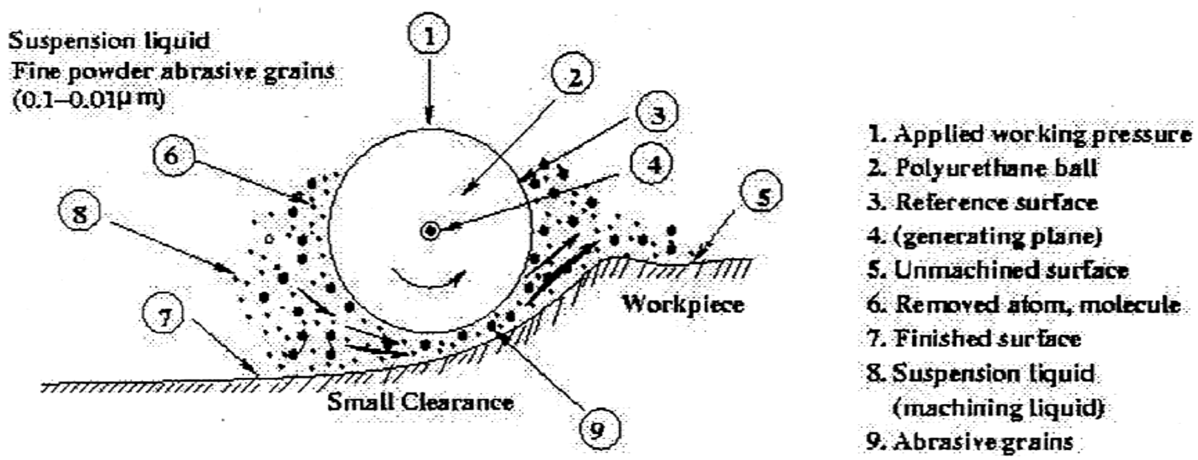


Fig.12 Rotating sphere and workpiece interface in EEM [Taniguchi, 1983]

9. Ion Beam Machining (IBM)

Ion beam machining is a molecular manufacturing process which works on the sputtering off phenomenon of work material by bombardment of energized ions. This process can be applied to manufacture ultra- fine precision parts of electronic and mechanical devices [Shima and Inoue 1990; Kazuyoshi et al, 1995]. The sputtering off is a knocking out phenomenon of surface atoms of workpiece by the kinetic momentum transfer from incident ions to the target atoms. Removal of atoms from the work surface will occur when the actual energy transferred exceeds the usual binding energy of atoms (5-10 ev) (Fig.13a). Ions of higher energy may transfer enough momentum such that more than one atom causes a cascading effect in a layer near the surface, removing several atoms. Ions of still higher energy although not desirable may get implanted deep within the material (Fig.13b) after ejecting out several atoms or molecules. Bombardment of high energy ions may damage the workpiece surface. Factors which affect the machined surface characteristics are properties of work material, ion-fetching gas, angle of incidence of ions, ion energy and current energy. IBM can be employed in many cases for example sharpening of a diamond style for profilometer having tip radius of about 10 nm, and asymmetric and aspheric mirrors for telescope. It is an ideal process for nano-finishing of high melting point, hard and brittle materials such as ceramics, semiconductors, diamonds, etc. However, surface roughness value increases with the increase in the size of grain structure, ion energy, and current density.

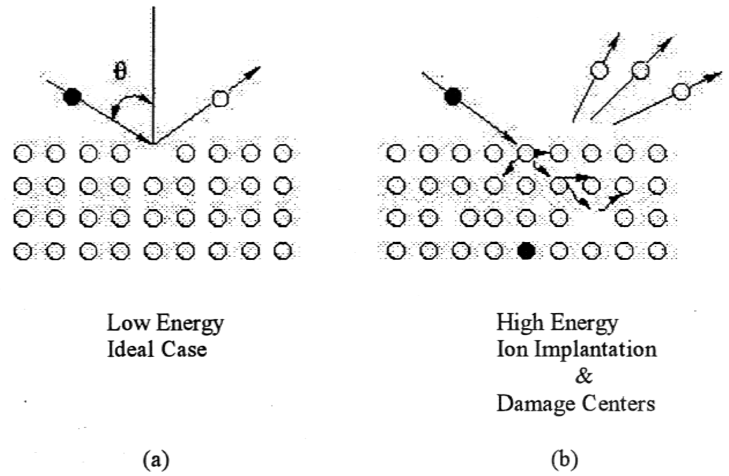


Fig. 13 Ion Beam Machining

10. Conclusions

The importance of ultrafine finishing processes using abrasive as cutting tool, and their capabilities to achieve surface finish of nanorange are discussed. Working principles of seven such advanced finishing processes have been explained in brief. Fine finishing of brittle materials like ceramics, glasses, and semiconductor wafers can be done in nanometer range. The exact mechanics of abrasive interaction with the workpiece surface in most of these processes is still a subject of in-depth research, and needs involvement of multidisciplinary sciences.

11.Acknowledgement

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A Futuristic Trend in Manufacturing Technology

Dr P K Mishra

Professor
Department of Mechanical Engineering, Indian Institute of Technology Kharagpur

1. Introduction:

"The most startling advances have their origin at the boundaries of the specialties, where the techniques developed in one field are applied with fertile effect, to the subject matter of another... If this cross-fertilization dwindles, the rate of scientific advance will almost surely dwindle as well, and so any thing that encourages cross-fertilization is all to the good ... " said the great Philosopher, Isaac Asimov.

In aeronautics, nuclear reactor, automobiles, or electronics industries, manufacturing is the main activity to create wealth for any nation, industrialized and (some) developing. Since 50s, world trade in manufacturing has grown more than tenfold and the tradable nature of products has created a dynamic change in the nature of manufacturing economics too! The GDP in the UK, US and Japan shows a contribution by manufacturing (a single largest single element) to the tune of about 20, 23 and 29% respectively. Manufactured goods represent 62 % of all exports and is greater than the exports in banking, insurance and oil combined'[1]. Off late, manufacturing in China is picking up very fast as well, giving a threat to the Global trading, then why not India? To quote here, in the Global economic crisis today India is not affected much because-of our economy is mainly based on manufacturing (including agriculture)!

India's GDP is about US$ 480 billion per year; where as export of IT would be only US$ 12 billion per year. Worldwide business in Software & IT is about US$ 530 billion per year; whereas in Manufacturing is about US$ 9600 billion per year! Even Tourism & Travel business worldwide captures about US$ 3700 billion per year, 7 times of IT, Health care: US$ 2700 billion per year, 5 times the IT and Education: US$ 2500 billion per year, about 5 limes the IT! So IT is not every thing [2]! The Business areas 2, 3, 4, & 5 are 18, 7, 5 & 5 times the size of IT, respectively. So question may be asked that: do we give them that much of importance? Probably this is a missed opportunity tor CDP improvement & employment generation in India.

The only way to ensure high standards of living, which leads to a high quality of life for our nation is to develop support and maintain an active, to bring in innovations in manufacturing industries. But the one, which is based on advanced technologies, can operate successfully in world markets. "WORLD CLASS MANUFACTURING OPERATES GLOBALL Y" is the only answer to the problems.

The most contribution for the dramatic improvements in standards of living (if not the quality of life) of people, enjoyed over the last forty years is primarily due to the new products of technology:

• Domestic appliances such as refrigerators, microwave ovens, automatic washing machine, television, VCRJDVD, CD, CCD cameras, convenience foods etc.

• Computer, telecommunication, satellite TV, fax and copier systems etc.

• Automobiles, high-speed trains and aircrafts.

The development in the methods of producing these products due to the advances in the manufacturing technology and its judicious management, have brought in such dramatic effects on our culture, in terms of the improved living standards.

2. The Problems:

The problems for catering to the needs are for the follows reasons.

• Population growth.

• Declining natural resources.

• The products now possesses feature with more functions and needs fewer discrete components (in Mechatronics approach).

• The component parts would be of more complex in shape, utilizing improved materials and processes for higher precision and quality.

• The manufacturing systems would then be more complex, are to be simplified to p adopt more variables to control, with better flow and integration of information for higher accuracy, surface integrity and ecological conditions [3].

• The processes need to be efficiently designed to meet the above requirements removing the drawbacks of the conventional practices.

3. The Solutions:

To cater to the industrial needs, one must bring in the innovative changes to the existing (traditional) practices, .and

• Sustain productivity with increased strength of work material (to bring in compactness, environmental fitness and higher strength to weight ratio, working in any Inertial systems) e.g. stainless steel, titanium, nimonics and similar HSTR alloys, fiber-reinforced-composite, stellites (cobalt based alloys) ceramics, silicon and other difficult to process materials;

• Maintain productivity with components with desired shape, accuracy and surface integrity requirements (for better quality [4] and integration); and

• Improve the capability of integration, automations and decreasing their sophistication (decreasing the investment cost) requirements, e.g. converting 3D control to ID control of work-tool movements (higher performance).

While manufacturing, in achieving higher precision and accuracy[5] in components, one must also think of

• Low-stress condition (clamping, deformation etc.) or complete elimination on the job,

• Vibration free operation, and

• Elimination/minimization of errors in tool path motion for the generation mechanism/s with the principles of zero play between the perfect kinetic references and kinematic pairs.

To meet these challenges, one must change his/her attitude towards manufacturing processes without having any prejudices over the mundane conventional practices, using mechanical means. The adoption of the energy to which the (work) material shows weakness, seemed to be a good proposition to deform, as the processing technology would be beneficial.

The simplicity in concentrating the form of the energy to which the material is weaker and directing it in a desired contoured path on a low-inertial system, brings in the concept of manufacturability (subtractive or additive) of components having diversified material structure, shape, size, accuracy and finish with a tailored surface integrity.

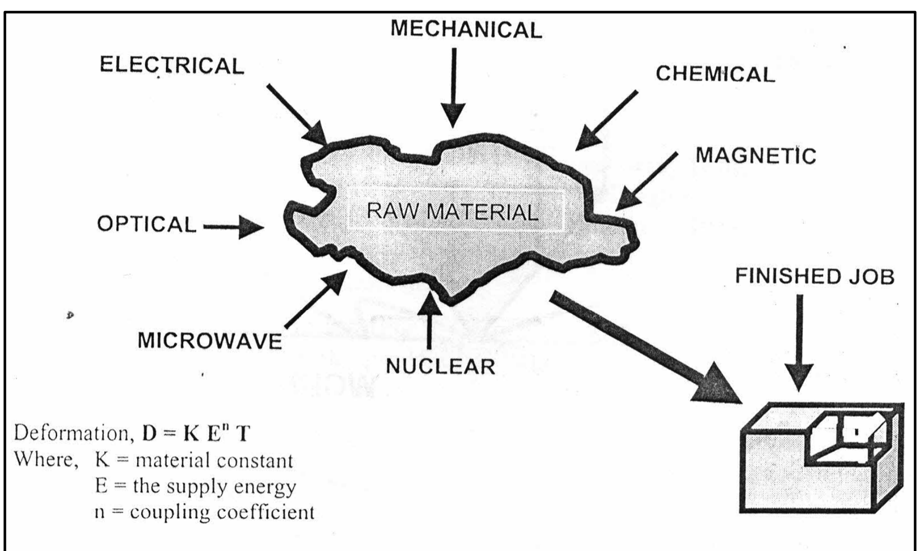

Fig.1 Nontraditional Energy Approach to Manufacturing

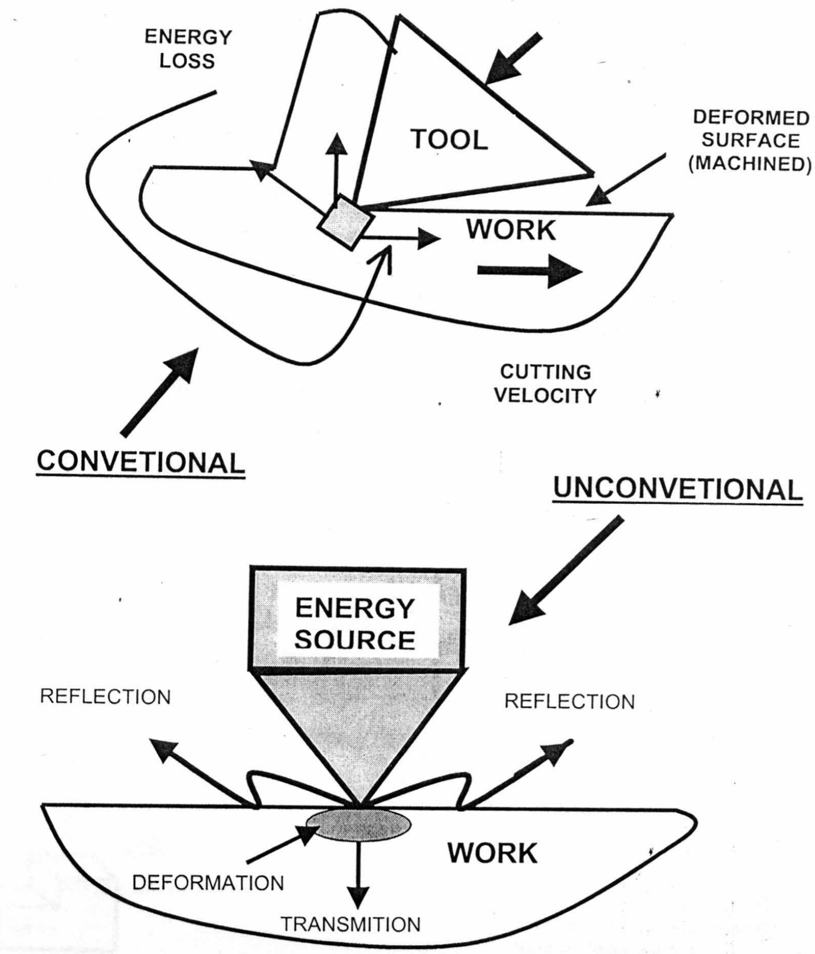

Fig.2 Conventional and Unconventional Energy Approach to Manufacturing

If the processing principles are analyzed critically, it must be observed that the noncontact, and practically stress free processing are not jeopardized by material strength unlike traditional processes. A spectrum of non-traditional processes, mostly used is shown in fig.3 and many more are in the horizon (research stage). Moreover, Since, the mechanism of each process involves different energy forms, the surface integrity assigned to- the work would differ from each other and the component performance characteristics would also change. Or in the other words, two or more processes can be combined (hybridized) to take the advantage of the worthiness of the constituent processes.

So when components requiring surface different properties to improve their performance characteristics (as evident from stress free and crack free, non-directional surface finish, surface hardness etc.) can be processed easily by hybridized nontraditional processes even in conjunction with conventional ones. This gives a way to the idea of flexible machines in processing a job component even in one station!

Though nonconvcutional or nontraditional machining methods are always talked upon, but it would be wiser to survey upon the manufacturing spectrum covering machining, heat treatment, welding, alloying, cladding etc using the technique or techniques when hybridized.

Moreover, most of these nontraditional processes can be used for macro to micromanufacturing and even some of them can be extended to nano level. Manufacturing to higher precision is also gathering momentum as well [6], where,

- Precision engineering
- Microengineering
- Nanotechnologies

play a very dominant role in the future, miniaturization of components and systems are detrimental. Moreover, miniaturization improves the strength to weight ratio, sensitivity to thermal response (heating and cooling for higher surface to volume ratio) etc., however requires a newer materials (e.g. silicon) for increased stress level.

One more thing detrimental for higher precision/accuracy is the minimization of number kinematic linkages and mechanical forces. The fundamental requirements of machines to achieve higher precision are through: a. precision of perfect kinematic reference; b, precision of perfect kinematic pair; c. construction to prevent noise, either internal or external; and finally, d. the accuracy in movements and its assessment.

When one talks of manufacturing for miniaturization, it is pertinent to discuss some the processes, which would sustain the productivity under complex surface configurations (monoblock design to avoid loss of precision in assembly), stringent material properties etc.

Micromanufacturing or microfabrication techniques involve processes where concentrated deformation energy at selective path or areas is applied to bring in the required changes. They may be classified as in the following table (Fig.3).

Fig.3

MICROMANUFACTURING

FORMING		MACHINING (Subtractive)	GENERATIVE (Addition or Creation)
CASTING [7]	FORMING [9]	PHOTOLITHOGRAPHY [13]	Laser Assisted CVD [18]
INJECTION [8]	STAMPING [9]	LIGA & SLIGA [13]	Micro Stereolithography [19]
VACUUM CASTING [8]	LASER FORMING [10]	DIMOND Milling [14]	Electro Deposition [20]
	ELECTROFORMING [11]	MicroAJM [14]	Micro Plasma Spraying [21]
	Electrohydro FORMING [12]	MicroUSM [15]	EB Deposition [22]
		MicroECM [15]	FDM using ECD [23]
		MicroEDM/EDG [16]	
		LASER Micromachining [16]	
		PLASMA Micromachining [17]	
		EB Micromachining [17]	
		DRY ETCHING [17]	

LASER/EB/ED MICRO Heat-treatment/alloying/cladding/welding [26]

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In the development of flexible machines, to achieve precision irrespective of job specifications, it is prudent to hybridized different techniques at one station.

While processing, it may be convenient also to start at a point source on the job and. Then to extend it to any contour (a generation principle) to the requirement would be beneficial as well.

For an example in thermal processing, a single laser beam may be used t? process a material for heat treatment, alloying and machining on a surface simultaneously with different process conditions at a speed faster than the conventional techniques.

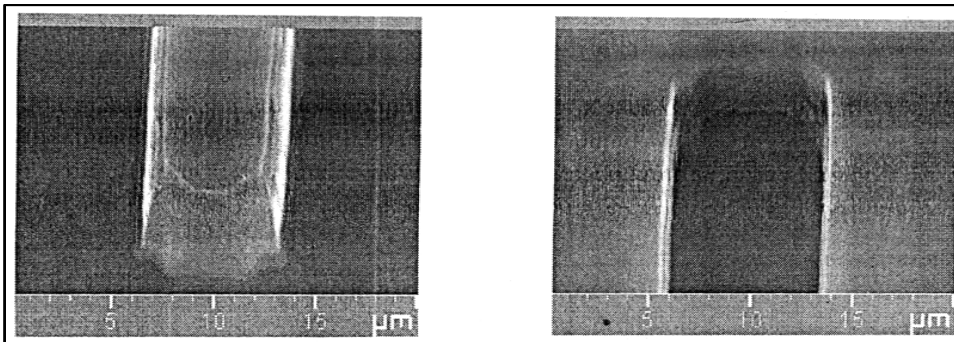
Micro-patterns and casting systems, e.g. Solidscape from Solidscape, Inc., USA is capable of producing patterns with minimum feature size of 0.25 mm and 0.1% dimensional error [7] and PPC 3200s from Schultheiss GmbH, West Germany is a high temperature casting unit for casting metal components of materials with melting temperature up to 2100°C [5]. Minimum feature size of about 0.5 mrn in materials: steel, nickel-chromium alloys, gold, silver or Ti-alloys is possible.

The Battenfeld Microsystem50[8] from UK MIG has the accurate dosing and high injection rates required for micromoulding combined with features such as an integrated clean room and modular assembly which makes it an appealing choice for manufacturers of medical and MEMS devices. Fabrication of 3-D controlled surface microgeometry by the technology of plasticity is being done at Materials Fabrication Lab., RIKEN, Japan.

The University of Bradford/Rondol Micromoulding In-Line Compounder [7] has developed machines with small shot masses associated with the micromoulding process. Residence times of polymer melt can be quite high even in the small extrusion screws found in these machines. This can be a problem when processing temperature sensitive materials. The MIC machine was a result of a design originally conceptualized two years ago to address this kind of problem. The machine consists of a 16mm twin screw extruder feeding a metering and injection piston system, allowing compounding of novel materials such as nanocomposites directly followed by injection. This process subjects the material to a single heating-cooling cycle and causes lower thermal degradation than two separate compounding/moulding processes. The screw is starve fed which reduces the amount of material in the barrel when compared with a single screw machine and it is capable of efficiently feeding even very low molecular weight materials. However, IIT Kharagpur has taken an initiative in developing micro powder feeder with single 4mm screw with ultrasonic assisted levitation.

From the same company, the Rondol High-Force Micro-Injection Moulding Machine uses a single electric motor with a system of mechanical toggles to clamp the mould and inject the shot in one process. The machine is very efficient, takes up very little space and can mould shots ranging from 15g to a fraction of a gram.

Hot Embossing[9] is in great demand for low-cost methods for high volume production of micro-components and systems, requiring a low-cost substrate material in one hand and an easy way of microstructuring in the other. Hot embossing of polymers fulfills both criteria (Fig.4).



A part of an embossing tool fabricated with reactively etched silicon [9].

Structure embossed in PMMA. Extremely high accuracy of the replica is claimed [9]

Fig.4 Embossing of Microparts.

Micro Electroforming [11] is again extremely powerful technique to produce micro metallic parts as a stand-alone process or by hybridization (as in LIGA & SLIGA). Precision electroforrning is the process whereby a metal object is built-up, atom-by-atom, onto a contoured surface called a mandrel. Nickel or another desired metal is deposited onto a contoured mandrel to a precise tolerance and thickness in order to manufacture objects with a unique shape or surface detail. Often the contoured original or mandrel is a 'one-of-a-kind' object that has been specifically created for its use as the original. Some examples are CD and DVD masters, and special lens molds. Often the surfaces and contours of electro forming mandrels are made to tolerances exceeding ± 0.05 micron. Electroforming can faithfully reproduce these tolerances.

Through manufacturing of components of pure materials is successful, yet process technology for alloys are in search. Metallic microstructures with relatively large thickness (i.e. 10-1000um) in the field of MEMS can be manufactured. For example, metallic microstructures with higher thickness for higher structural rigidity and/or higher actuation force are required, greatly needed in the actuation system. Metallic micronozzles and microchannels, as the essential fluidic parts in inkjet heads, are in need with the growth of printer market. Metallic microstructures with small feature and high aspect ratio are demanded as precise hot-embossing masters for plastic micromachining.

Micro Electrohydro forming of polymers/metals thin sheet components are possible with micro spark discharge energy from condensers [12].

Micro Laser forming [10] can be used for micro forming of tubes and thin sheets of materials. The laser-induced thermal distortion is used to the advantage bending of materials, here a tube.

Many more, e.g. spray forming, plasma forming, spark deposition forming etc. are yet to come into practice. Higher accuracy and precision are achieved by micro machining processes that are in vogue.

The most prevalent method in MEMS/MS technology is Photolithography [13], discussed by many. In the process (as in the scheme, Fig.5) a suitable mask is created on a substrate and its thickness is controlled by single or multi layer spay or spinning, and fixed. After generation of the pattern either by contact/projection printing or pattern-generator, it is metal coated to fill the voids, inspected and repaired. Then the resist is stripped to leave the chromium pattern on the surface before etching (micromachining). However, the resolution of the pattern depends on the illuminating radiation wavelength, mask thickness, depth of focus etc. as shown in the equations below.

For Proximity and Contact Printing:

$$\text{resolution} = \sqrt{\lambda\ (\text{gap between mask and resist} + \text{resist thickness})}$$

where, λ is the wave length of illuminating radiation.

For Projection Printing:

$$\text{resolution} = (K_a\lambda) / (NA);\ \text{Depth of focus} = (K_b\lambda) / NA^2$$

where; K_a, is a process constant ~ 0.75, K_b, is a process constant ~ 0.5 and NA is the numerical aperture of the optical system.

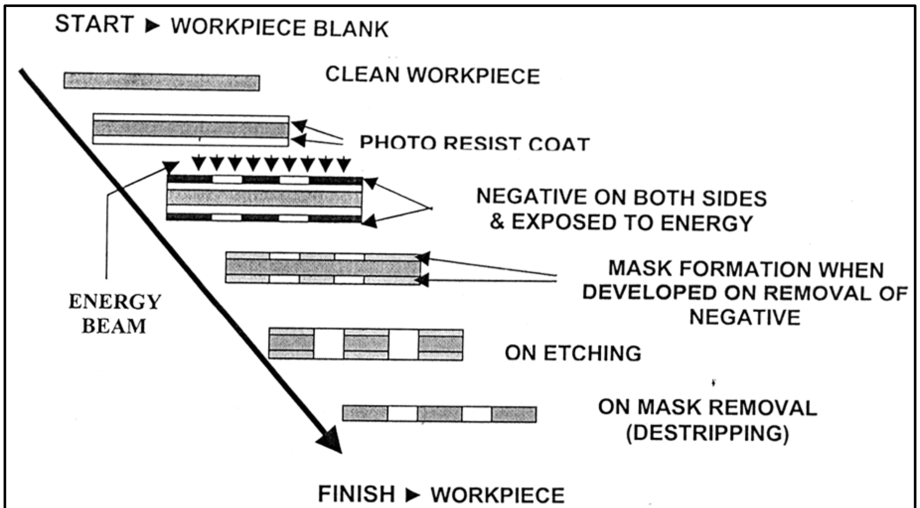
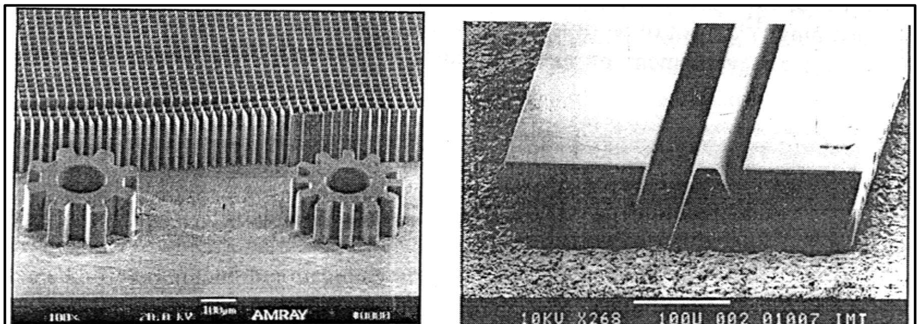


Fig.5 Basic Scheme of Photolithography

To increase resolution, ultraviolet (UV) and deep ultraviolet (OUV) sources, include excimer lasers, which operate at wavelengths of 248 nm, 193 nm, and less are used; however wavelength 193 nm and below are associated with problems in its absorption. Much shorter[13] wavelength of the electrons is one reason for increased resolution using E-beam lithography. X-ray lithography uses collimated rays as the exposing energy. Being much shorter in wavelength than the previous, x-ray provides higher lateral resolution. For its penetrating power, x-ray deep into the photoresist, micromanufacturing of microstructures with "great height" and "high aspect ratio" are possible. An example of micro gear and even inclined slots (with inclined beam projection) from Precision & Microengineering[14] is shown below (Fig.6).

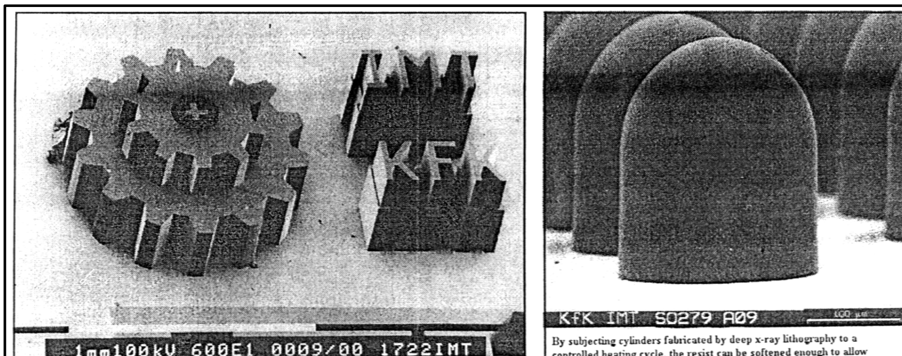


Typical structures made by deep x-ray lithpgraphy. Gear-shaped structures are used in air turbines, as encoders, stepper motor rotors, etc. High aspect ratio rectangular structures can be used for channel plate detectors, for example.

By tilting the mask-resist-substrate combination to the incident x-ray beam, non-vertical sidewall structures are possible. This procedure can be extende to three-dimensional tilting to create far more complex structures. Scale bar = 100 micrometers. Photo courtesy IMT-KFK

Fig.6 A gear and inclined slots machined by LIGA [14]

LIGA (Lithograph ie, Galvanoformung, Abforrnung): Lithography, electroplating, and molding are hybridized process to manufacture micro components. X-ray lithography is used to create a mold with PMMA resist, placed on a thin metallic base. The PMMA resist is ablated to the plating base and, when developed, reveals the metallic (plating) base. The plating base is used as the cathode as in an electroforming process to fabricate a metallic microstructure within the mold. The metallic negative of the PMMA mold is used as a mold insert for subsequent injection molding or hot embossing. These create duplicates of the PMMA mold fabricated previously by the x-ray. This helps replicate the components for mass production or microsystems. Some examples of microcomponents and microsystems fabricated by x-ray lithography are shown bellow[14].The spherical surface is obtained softening on controlled heating.

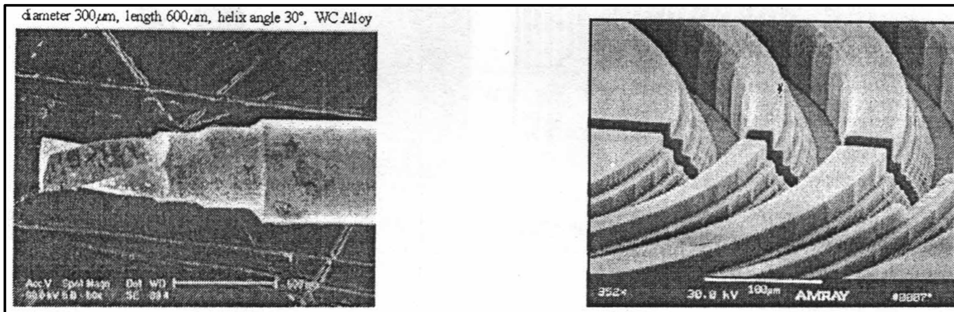


By doing multiple x-ray exposures with different masks through multiple layers of photoresist, stepped structures are possible. Scale bar (white line) = 1 mm. Photo courtesy IMT-KFK.

By subjecting cylinders fabricated by deep x-ray lithography to a controlled heating cycle, the resist can be softened enough to allow flowing into a spherical shape. Scale bar = 100 micrometers. Photo courtesy IMT-KFK.

Fig.7 Components manufactured by LIGA[14]

Mechanical micromaching is also used to micro mill of components with features down to 50-100 microns, with aspect ratio 3-10 for non-ferrous materials, and 1-2 for ferrous materials with Kern HSPC 2216[13]. The cutting tools, double or multi flute are manufactured by EB or Ion Beam machining [12]. A lot of work is being done at Northwestern University and MEL, NIST Japan on the development of micro machining (turning) with micro work-handing systems.



Fig,8 Photograph of a micro mill [27] and a spiral milled groove [14]

Marcel Achtsnick [14] from Delft University of Technology reports of using micro Abrasive-Air-letting to machine minimum dimensions reachable to about 30 urn in width and down to I urn in depth. It uses 3 to 50 micron size in a working area of about 600 × 600 × 300 mm is carefully closed and exhausted.

National Research Laboratory of Korea [15] uses micro USM to machine holes as small as 70 μn in ceramics. Masuzawa Laboratory of University of Tokyo has developed micro USM to achive small features precisely. One of most delighting development is micro Water Jet which not only can be used for achieving micro features but also aggressively used in surgery and biomedical applications.

Micro ECM (15) is the method to produce micro tools in large quantities by electrochemical etching method. Micro ECM can produce sharp tips used in various fields such as electrochemistry, cell biology, elecrodischarge machining, field-ion, electron microscopy, nano electronics, and field emitters. Moreover, it can be used in surface finishing of machined feature. With the use masking technique, it is now possible to use micro Electrochemical machining to etch electrically conductive components with micro features, is under development at IIT Kharagpur. However, the replenishing of the electrolyte into the working zone would have to be improvised with Ultrasonic assistance.

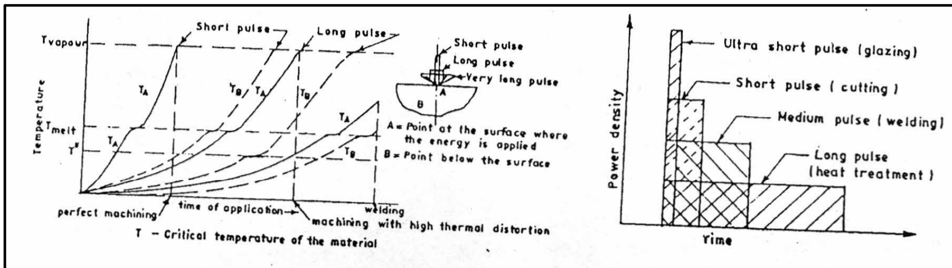
However, each process has its limitations but the most advantageous that the processes are non-contact type, giving the chances for hybridization. On suitable mixing of the processes in conjunction with conventional one would improve the surface integrity and production speed and precision, giving a chance for future developments.

In the domain of manufacturing, besides machining, other processing techniques, e.g. heat-treatment, welding, alloying etc. are also necessary for micromanufacturing. These being in the domain of thermal processing, the existing nontraditional methods like EDM; Laser, Electron and Ion-beam are used successfully to tailor the surfaces (surface rather than bulk manufacturing technology). These methods may be considered as futuristic technology for the development of flexible machine. It would be clear from the basics of the following fig.9, on the application of the very localized heat source at the point 'A' on the surface, a desired change (micro-structural change, melting or evaporation) is observed, while at a sub-surface point 'B' an undesired (but sometimes advantageous) change at lower temperature occurs. This undesired change might be referred as thermal damage, distortion or accuracy etc. in the processing operation. If one looks at the problem, finds that the application of high energy-rate results in faster rise of temperature at 'A' as compared to that at 'B' (conduction heat transfer). Gradually this temperature difference increases with increase energy dumping rate! So it is possible to achieve evaporation on the surface with or without any change at the subsurface point, 'B'. These phenomena can easily be predicted with a proper thermal analysis to tailor the surface. It is obvious that multiple processing operations is also possible by a single source of thermal energy with variable energy density and interaction time (Table below) bringing in the concept of flexible machine/s. However, there is no direct form thermal energy input (excepting Plasma Processing) but the energy absorption generates heat within a few micron depths below the surface (adsorption).

The widely used thermal processing is by Electrical Discharge and Laser. Micro EDM is of course the best for micromachined metallic components [16].

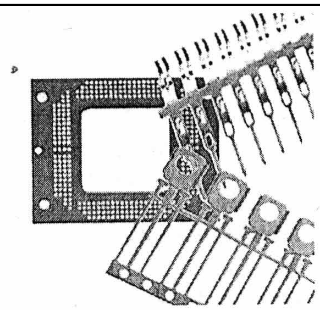
Table 1. Working domain for material processing

Processing	Specific Energy (J/cm^2)	Power Density (W/cm^2)	Interaction Time (Sec)
Shock Hardening	$10\text{-}10^2$	$10^8\text{-}10^9$	$10^{-8}\text{-}10^{-6}$
Glazing	1-10	$10^6\text{-}10^7$	$10^{-6}\text{-}10^{-4}$
Machining	$10^3\text{-}10^4$	$10^5\text{-}10^6$	$10^{-5}\text{-}10^{-3}$
Welding	$10^3\text{-}10^4$	$10^5\text{-}10^6$	$10^{-2}\text{-}10^{-4}$
Transformation Hardening	$10^4\text{-}10^5$	$10^4\text{-}10^5$	$10^{-4}\text{-}10$

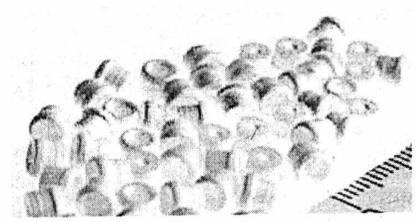


(a) Temperature rise with interaction time (b) Pulse definition

Fig.9 A basic concept of thermal processing



Microelectronics Parts [16]



Micro Molds: Aerosol spray nozzle with high quality finishing on precise micro holes [16]

Fig.10 EDMed micro components.

3. Futuristic Manufacturing (Laser based):

Micro manufacturing activity if can be maintained at one station would be the best solution, where the Lasers have many role to play for ideal hybridization. An attempt to this illustrates the feasibility.

The figure below (Fig. 11) shows the multiple processing operations by a single source (in this case, a Laser system).

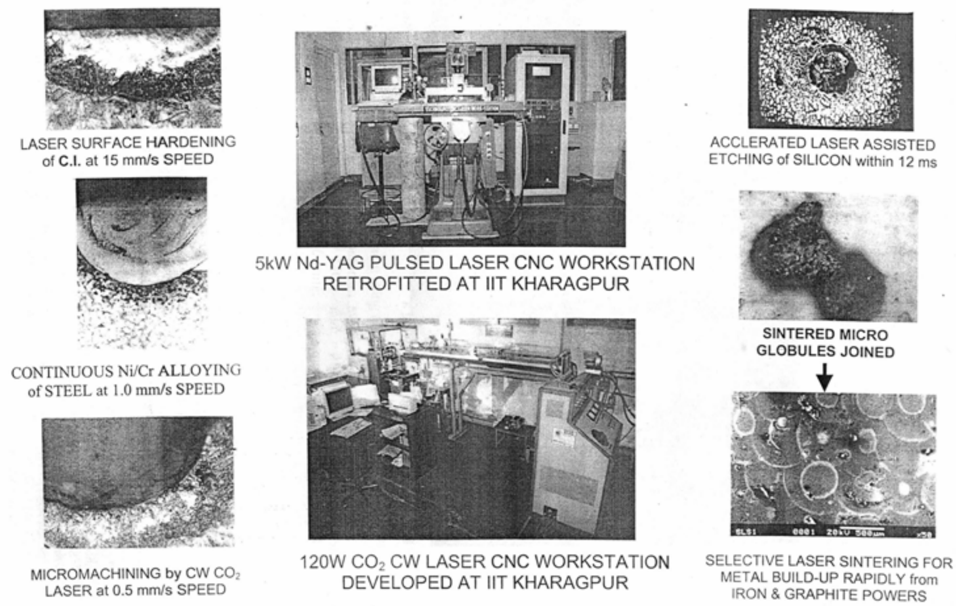
While mentioning about Laser microwelding, trial (Fig. 12-15) has been attempted [28] besides the many others, globally. Microwelding with Electrochemical discharge [29] is also successful.

When one comes to Generative manufacturing processes, Electrochemical Discharge Fused deposition finds application micro-FDM [29]. The new microstereolithography (IISTL) machine in the CMF [I9] is a system for creating 3 dimensional shapes from an AutoCAD design and a photo reactor with liquid resin. It has Lateral and Vertical resolution: 10 µm, Maximum field size: 10.24 mm × 7.68 mm and Structural height: up to 5 mm. 3-D printing is also commercially viable systems, useful for use of Rapid manufacturing of micro to nano level manufacturing.

There are many more innovations are in pipeline all over the world to produce micro components from any material with high precision and accuracy. However to mention here, a method of integration of different laser systems (Excimer and CO_2) have been integrated with a 4-axis CNC manipulation to process micro to macro level manufacturing at IIT Kharagpur (Fig.16). Few micro machined samples are shown in Fig. 17.

Fig.11

LASER MATERIAL PROCESSING



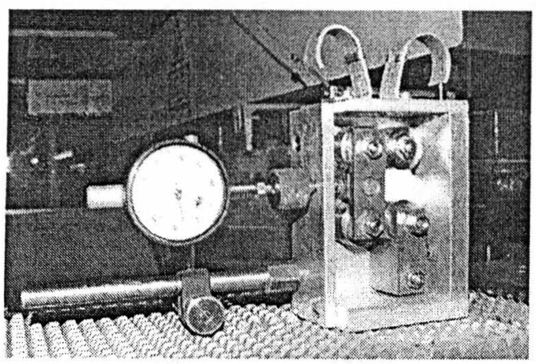


Fig. 12 Photograph of set up

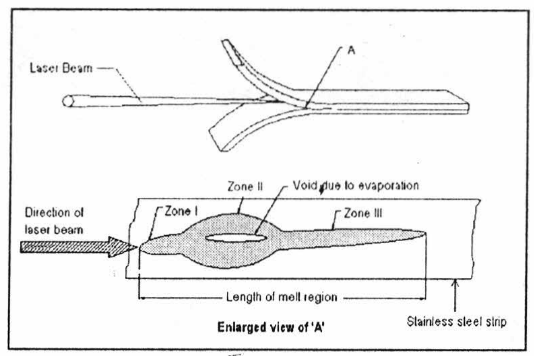


Fig. 13 Shape of typical nugget

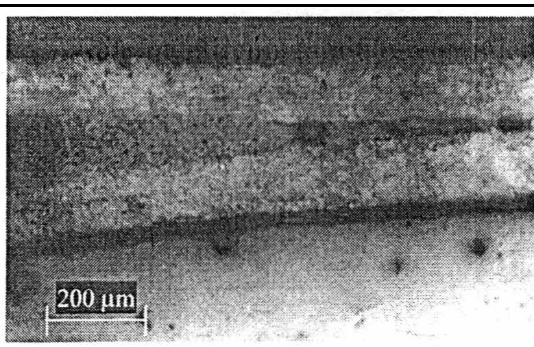


Fig. 14 Optical micrograph showing a good welded zone

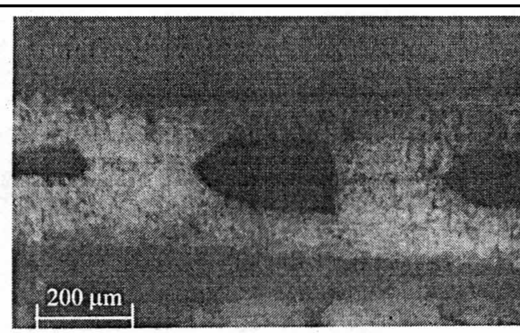


Fig. 15 Optical micrograph showing void in the welded zone

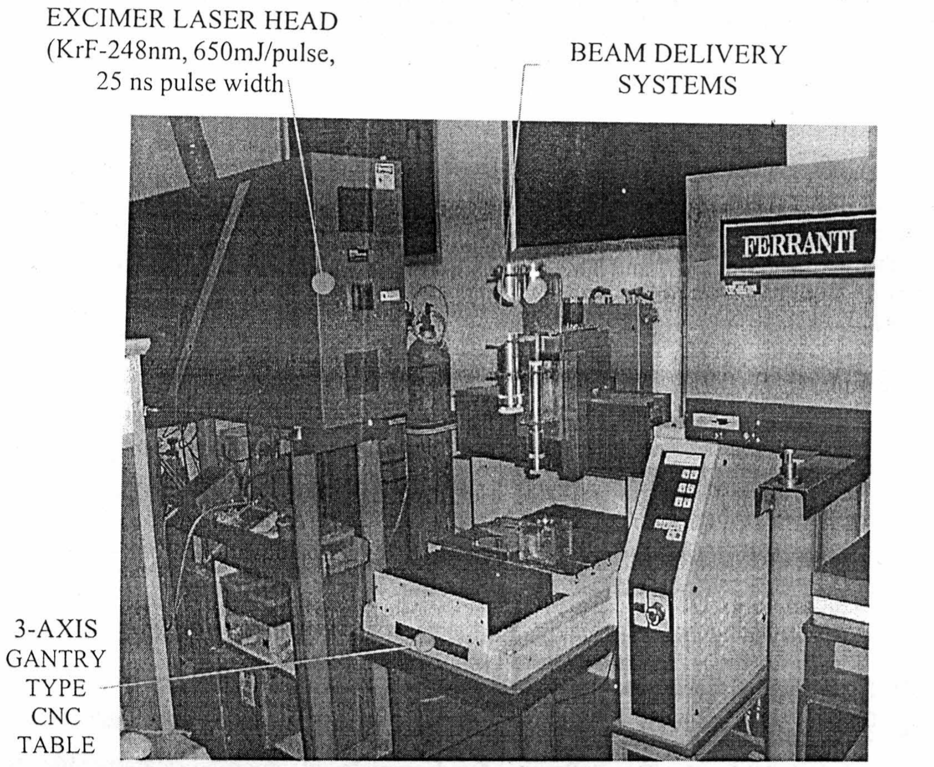


Fig. 16 A Flexible manufacturing system using an Excimer and a CO_2 Laser System.

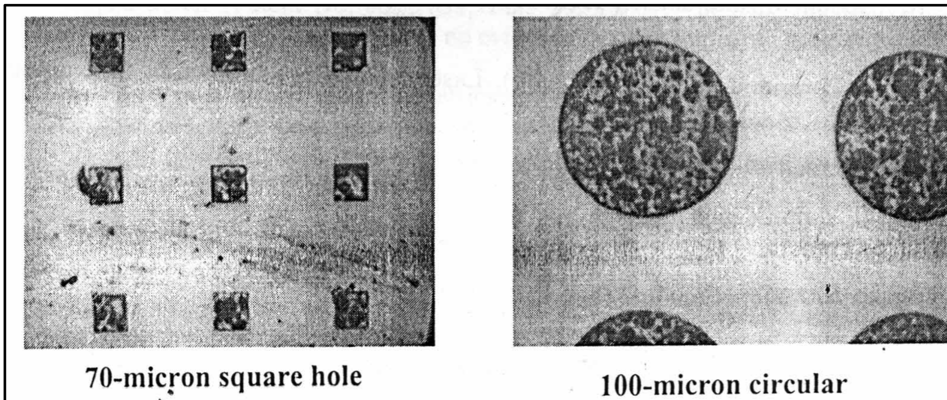


Fig.17 Micromachined PMMA with excimer laser

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The days are not far, when the manufacturing engineers can manufacture components in micro to macro level in one machine and would be able to deliver the components directly' from the design communicated through Internet to the machine, including the material development inside the fabricating machine! However, proper modeling of the processes is to be developed with micro energy transfer and micro mechanics principles:

Acknowledgement

I sincerely convey my gratitude to Dr. Partha Saha who has given his untiring assistance to buildup the systems available in EPP and Laser lab and experimentations at IIT Kharagpur. My due thanks remain also for my young colleagues, Dr. S Roy, Asoc. Professor; Dr. A Roy Chaudhury, Asst. Professor, and Dr. S Chakraborty, Asst Professor who have rendered their efforts on process .modeling along with many others (my students, collea~ues and staffs) who have rendered their helping hand in building up the infrastructure.

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Faculty Development for Excellence in Technical Education: Concerns and Strategies

Prof Prem Vrat

Former Director, IIT Roorkee and
Vice Chancellor, D.P, Technical University, Lucknow

INTRODUCTION

I am happy to have been invited by the Institution of Engineers (India) to deliver the Prof. G.C. Sen Memorial Lecture on the occasion of 22nd National Conference being organized by the Institution of Engineers (India) at Jabalpur. Prof. G.C. Sen's contributions for advancing the frontier's of education and research in the area of production engineering are outstanding. He was considered as a role model professor who contributed enormously through teaching, research and character building among his students. [therefore, feel privileged in having been chosen to deliver a lecture in his memory. I offer my sincere tributes to Prof. G.C. Sen as an outstanding engineering educator in the field of production engineering. In tune with the profile of this great teacher, [have chosen a theme of "Faculty Development for Excellence in Technical Education" because [perceive that today the technical education system is going through a major 'crisis' of acute shortage of talented and dedicated faculty who could inspire, involve and transform young minds to explore their fullest intellectual potential together with outstanding human values. We need to address this issue with priority if India is to progress on its dream of being a knowledge super-power in the current globalized knowledge society.

POTENTIAL OF INDIAN TALENT :

India can play ~ vital leadership role in a globalized, knowledge driven society. Some core competencies that we have that need to be leveraged to realize the vision of being a global knowledge superpower are:-

I. India had been a great centre of learning where knowledge seekers from the whole world came to India in search of knowledge and wisdom. Our ancient literature was considered to be an ocean of wisdom. ' Nalanda University and the wealth of knowledge stored in its famous library can be a case in point. Thus; we need to recognize our core strength and intellectual potential and try to regain the past glory to lead the world yet again on this front. The emerging knowledge society has given us a golden opportunity to focus on this issue.

2. The intellectual potential of a typical Indian, in my view, is very superior. By nature we are sharp intellectually, curious, investigative and possess capabilities of analyzing any complex situation very effectively. If we are motivated, we can be very innovative in finding novel ways of finding cost-effective solutions to quite complex problems. We are very high on 'integrative complexity' and do not enjoy 'simple, routine, step-by-step problems solving of repetitive nature, yet we are competent in resolving very complex, inter-connected problem. Perhaps the fallout of that mindset is that we allow simple problems to become complex till they become critical and then resolve it as a complex problem. Thus, we are ideally suited for innovation, creative problems solving, R&D and analytical modeling. In emerging knowledge paradigm and our superior analytical ability can get us the desired lead. We just need to harness our intellectual potential towards positive innovation and creative pursuits.

3. Analysis of global demographic situation reveals that while the developed world is ageing, India with 65% of its people being less than 35 years of age, is a very 'youthful nation'. Extending the age structure analysis 15-20 years from now, it is obvious that India would be the talent pool to supply 'Indian Talent' to the rest of the world. Thus new future of India is IT-The Indian Talent.

4. With the emergence of information technology, the world has shrunk to be a networked society and knowledge process outsourcing is a major future business proposition. India can be a major knowledge hub owing to its vast human resources, strong middle class market base and intelligent people. Indian R&D could be instrumental not only to make us a developed nation, outsourcing R&D globally can make us a strong nationeconomically.

5. Brilliant persons still like to study engineering and Indian parents even at their personal discomfort have a desire to see their children 'get good quality education.

MAJOR CONCERNS IN FACULTY SHORTAGE:

Despite a great intellectual potential, the current reality is that the Indian technical education is adversely affected by acute shortage of talented faculty. Despite quantitative growth of Institutions in private sector, there is enormous imbalance due to faculty shortage. The imbalances that can distort the technical education system are as follows:-

(i) Regional imbalance of technical education institutions concentrated in few clusters and not uniformly spread all over the country.

(ii) Disciplinary imbalance-80% enrolments and 80% colleges offering 20% brands of engg. and technology and most of these are variants of IT, CS, EC and ET while the core technical subjects such as Civil, Mech. Textile, Agriculture, Paper & Pulp. Leather, Glass, Ceramics, Metallurgy etc. are not having adequate enrolment. For a developed nation, we need to train people in all technical branches and not in IT alone.

(iii) Imbalance of compensation package and working conditions in academics and in industry. Industry always paid more but now-a-days the imbalance is alarming and as a result, brilliant people may not get attracted towards teaching and research as a first preference in career option. This will seriously erode quality of technical education and knowledge creation.

(iv) Age-profile imbalance-in many (or majority) of privately funded institutions, the faculty is either 20 plus or 60 plus with a gap in the middle cadre. Obviously a smooth career and succession planning is difficult in such an imbalanced age-structure.

(v) Imbalance in the salary structure even in the same institute, where, the retired professor as Director gets 15 times the salary that a young lecturer may be getting while the value addition being in the class "rooms/laboratories, this imbalance is not vary conducive to academic development.

ENABLERS OF ACADEMIC EXCELLENCE IN IDGHER EDUCATION

Good faculty profiles contribute to the prestige, popularity and excellence of an academic institution. Faculty members are the intellectual capital. They are a very sensitive group who are also the policy and opinion makers and therefore perceived as the role models for students. There is a saying that 'teachers teach as they are taught'. Members of the faculty, being highly sensitive members of society, seek to work in an autonomous environment. Often they shun direction and guidance since they are motivated by the 'psychic-income' phenomena, in addition to having their pay and perks.

Some key enablers of academic excellence are:

• Visionary and committed academic leadership.

• Facilitation systems-which are efficient, effective, flexible, and though technology driven yet have a human face and are participative in nature. Most importantly, they are accountable.

• Empathy with stakeholder - students, parents, employers, society, government and the nation.

• Nurturing, facilitating and exciting work ambience and work culture at the physical, social and intellectual levels.

• Excellence oriented resource support - such as learning resources materials, library, computational support, Internet, e-connectivity (e-journals), classroom and co-curricular support and financial resources.

• Outstanding faculty resources perceived as intellectual brain bank of the institution who are role models. Teacher who are sincere, intelligent, compassionate, innovative/ creative having academic integrity, human values, sprit of exploration and inspiring communication skills in order to be the prime movers of academic excellence.

ROLE OF TEACHER

Teachers (faculty members) constitute the most important critical success factor (CSF) for excellence in higher education. Good faculty can help to improve bad systems but even good systems with bad faculty cannot lead an institution towards excellence. A great teacher will inspire his/her pupils and leave a permanent mark in the process of personality development of students. It is hypothesized that a strong correlation exists between reputation of an institution and the quality and commitment of its faculty members. A good teacher will ignite creative minds and facilitate in developing great qualities of head and heart among students, who in turn will reinforce the teacher's own academic development process, because it is the effective synergy between the teacher and the taught that leads to academic excellence. Wherever institutions have shown signs of academic decline, a major role has been played by academic leadership and teachers, which eventually percolates down to all other stake-holder-employees and students alike.

PROFILE OF THE IDEAL FACULTY MEMBER

A great teacher has to be academically brilliant with outstanding academic credentials. He/she must have superb communication skills, an inspiring and charismatic personality profile. He/she should be fired with enthusiasm and sincerity. He/she must be committed to excellence, fairness, equity, academic integrity, moral values and strength of character. He/she must be a person with a capacity to mould students towards the pursuit of excellence. It is not oral communication alone that is important, rather the total value system of teacher as perceived by the students and society at large. All these factors together create a transformational impact on mindset of students. A good teacher is a person who is not driven by financial and materialistic considerations alone, but who enjoys interacting with students and scholars any time, has respect for self and respect for others besides taking responsibility for his/her actions. Obviously, this is a tall order because a great teacher has to be a great human being too, but this is the crux of the matter. There is no alternative to having a profile of teacher who matches these standards. It is certainly not easy to find someone with that 3600 perfect fit. Hence, the major challenge of the faculty development process is to attract, motivate and retain the best intellectual capital possessing the above -mentioned profile. It is necessary that brilliant people opt for the teaching profession as their first option is career choice, because people who join teaching out of other compulsions are unlikely to achieve the heights of excellence simply because their heart is not 100% in their job. Faculty development becomes, a core issue and determinant in the success of any university or institution.

NEED FOR FACULTY DEVELOPMENT

Faculty development is a process of identifying, attracting, retaining and motivating outstanding individuals to the teaching profession and facilitating and nurturing them to realize their truly enormous hidden 'potential.

There has been an exponential increase in the intake of students in higher education, particularly in higher technical education in sectors like IT in the past 10 years due to the impression that India is fast emerging as a future IT superpower. Various institutions have started new IT programmes with a slight variation in the nomenclature in order to maximize their sanctioned intake. Since good engineering graduates get attracted to MNC's for attractive job offers, there is an acute shortage of faculty in IT. The best of the talent does not get attracted to teaching and research due to comparatively low compensation package/growth opportunities in teaching and research in a university setup as compared to private industry. This has created an enormous gap between demand and supply sides of good faculty. If this gap is not bridged, the quality of IT education will go down, eroding India's competitive advantage in the global context. Hence, the need for faculty development is all the more critical. The scenario of IT may be more or less applicable in other subjects too. Even basic sciences/mathematics suffer from a lack of enthusiasm by students to study these subjects due to the perception that by studying these subjects, they can only opt for teaching or research, which is not an attractive proposition in their mind. Thus policy planners, educational administrators and other stakeholders have to take note of this as an early warning signal and take up faculty development process as a high priority area. India priority should be E-R-P (Education-Research-Planning), each requiring intellectual capital as the key input resource.

GOALS OF FACULTY DEVELOPMENT

The goals of faculty development process are to:

1. Encourage, inspire and prepare outstanding scholars to join teaching profession and engage in teaching and research.
2. Impart knowledge, skills and attitudes and value system in the student community. Life-long learning desire to be inculcated among teachers so that they continue to inspire students.
3. Create structures, processes, evolve policies to continually upgrade knowledge, skill and attitudes, (KSA) which are commensurate with globally changing scenario but in areas /aspects that are nationally relevant.
4. Integrate technology with teaching-learning processes.
5. Enhance performance of teachers by evolving a comprehensive and objective performance appraisal system using a multi-criteria model giving due weightages to teaching (including student-feedback) academic research, outreach and societal contributions. This is a key component in the process because unless performance and rewards (both extrinsic and intrinsic) are perceived to be strongly correlated, teachers may not feel committed to academic excellence.

6. Develop strong networking with universities/institutions within the country and beyond, with R&D centers, industry, government and society at large, so that they feel involved in the process of development and nation building.
7. Facilitate and encourage teachers to produce excellent quality learning-resource material using multi-media technologies to further enhance academic productivity.
8. Create the passion to Inspire-Involve and Transform (IIT) the students to achieve excellence.

STRATEGIES

Faculty development process must have strategic intervention at policy level. Some of the policy initiatives that have been taken by the Government and some others that need to be pursued are briefly outlined as follows:

• Early Faculty Induction Programme (EEIP) -AICTE has initiated and UOC may also like to evolve mechanisms to proactively locate potential talent having attributes of being a great teacher and offering them attractive opportunities to induct them in teaching and enabling them to pursue research simultaneously. For instance university toppers with a flair for teaching, as also having good communication skills and value system should be offered positions by other universities in a fast track mode, without delays and bureaucratic hiccups. Inbreeding to be avoided by encouraging a scholar to take up assignment at place other than their alma matter would also be significant step. UPTU has started a scheme of Teacher-fellowships is attract talented persons to join teaching profession.

• Quality Improvement Programme (QIP) of AICTE and concept of Academic Staff Colleges in universities needs a special thrust to upgrade and renew the skills of teachers. At present, provisions that are made are far less than the need for quality improvement of the current teachers. QIP schemes should also be made more attractive as the investment in teachers to improve their KSA will, in the long run be definitely cost effective; because the costs of low and inconsistent quality are far more serious than the investments that would be required to enhance teacher quality.

• While pay structure of teacher seems reasonable, a liberal provision of faculty perks like books allowance, membership of societies, LTC, housing on campus, international travel, and telephone and internet connectivity will help upgrade systems and enhance productivity.

• In addition to pay and perks, the 'psychic income' that the faculty receives must be the USP in attracting the best talent to join the area of teaching and research. This can be done by making provisions of having an inspiring work ambience ,work culture, autonomy, cadre flexibility which can ensure a performance driven career growth potential, faculty freedom, sabbatical leave for skills renewal provision of consultancy, industry fellowship Emeritus fellowship as some of the policy initiatives that will enhance this perceived 'psychic income'. This will greatly facilitate bright scholars to opt for teaching as a preferred career option and motivate them to stay in the profession rather than treat it as a stop gap arrangement.

• Facilitate networking among institutions/universities and R&D laboratories, through adjunct faculty, industrial, secondment, mentoring and joint faculty appointments in more than one department, within the same organization or between two organizations. Part-time involvement of scientists /engineers /managers as visiting or guest faculty must be encouraged with attractive compensation both financial as well as non financial.

• Break the 'resistance to change' among the experienced teachers in adopting technology-based pedagogical tools over conventional 'chalk and talk' mode by encouraging technology enhanced learning and showing impact of such newer methodologies in improved quality of teaching-learning process.

• Perceived transparency, objectivity and fairness in faculty selection and promotions.

NEED FOR PROCESS ORIENTATION IN ACADEMIC MANAGEMENT

Concept of Total Quality Management (TQM) in academic management of the institution requires the following:

1. Customer Orientation: in this case students (learners) are the immediate customers and employers/society/nation being the eventual customer.

2. Management by facts.

3. Transparency in processes at all levels.

4. Involvement of everyone in pursuit of excellence.

5. Encouragement of seamless, multi-disciplinary, cross-functional academic and research groups, rather than insulated departmental compartmentalization with no synergy among different groups.

6. Faculty /staff to be treated as resources rather than as burden on university finances.

7. Sense of 'ownership', enthusiasm, and commitment among faculty and others toward goal accomplishments to be encouraged. An instinctive gut-feel, conceptual model which attempts to recast famous Einstein's equation into academic excellence, is interpreted as follows to gain insight:

$E = MC^2$

where,

E = Academic excellence

M = Motivation for being a faculty

C = Commitment of the faculty

NEED FOR CHANGE OF FOCUS

The focus needs to change from being:

• Faculty and teaching centered to student and learning centered.

• "Means" (teaching) to "Ends" (learning).

• Data /Information centered -to knowledge/wisdom centered.

• "Examination" (Testing) centric to "Effective Knowledge Gain" centric.

• Self-centered to team -centered development of students with a judicious balance between concern for self and concern for others.

VALUE ORIENTATION AND ACADEMIC ETHICS

A teacher has to be perceived by his/her pupils as a role model and hence in addition to subject expertise, a faculty member must be an embodiment of supreme human values of academic integrity, empathy for students, compassion, respect for self and others, concern for others, respect for systems, nationalism with a global outlook, tolerance, self discipline, spirit of exploration, holistic thinking, service attitude and positive thinking .It is a demanding set of attributes, but such teachers are vitally needed as role models in educational institutions who will act as mentors, to truly transform these institutions from being teaching centers into temples of learning. Any investment of time, effort and resource in developing such faculty profiles, will be worthwhile.

It is the visionary academic leadership in these institutions of higher learning that must strive towards to developing their faculty members so that they are able to inspire, involve and transform their students to outstanding engineers, managers and great human beings.

CONCLUSION

Faculty related issues are most critical success factors for excellence in education. It is a great opportunity to make India a knowledge super power worth reckoning, in the next decade, by leveraging strengths inherent in Indian brain power, converting weaknesses into opportunities for improvement and; developing visionary academic leadership with sincerity of purpose and commitment to excellence. We need to proactively locate such role model teachers and facilitate them to act as 'mentors' in other institutions. We must also aim developing young faculty into excellent academics. It is hoped that issues outlined in this lecture provide a direction for future efforts, which can take us closer to achieving academic excellence.

Manufacturing Engineering Education in the New Millennium- in and Beyond Institutions

Dr P Radhakrishnan

Director, PSG Institute of Advanced Studies, Coimbatore, India

ABSTRACT

This paper highlights the need for strengthening the manpower training programs in manufacturing in India. A brief review of the pattern of engineering education is presented. The innovative programs to develop leaders in manufacturing are also discussed in this paper. The new millennium requires changes in skill sets and the training of new generation manufacturing engineers should be modified to inculcate these.

1. INTRODUCTION

Manufacturing industries face major challenges in the short-term — the global economic slowdown compounded by high input prices for energy and raw materials - and in the longer term, as the pace of globalisation continues to intensify. But at the same time, longer term changes in the global economy present tremendous opportunities. In the last decade India has emerged as one of the fastest growing economies in the world.

India's ability to serve the global information technology industry has been the primary contributor to its economic success. The country has been making efforts to accomplish the same in the manufacturing sector. Although the manufacturing industry has seen an impressive growth lately, especially in the areas such as automotive and pharmaceutical manufacturing, the country's ability to foster a dynamic manufacturing sector has not met with the same level of success as its service sector. Experts attribute this partly to the gaps in the manufacturing workforce development. There is also the need to create industry ready manpower to meet global challenges in manufacturing.

2. ROLE OF PRODUCTION ENGINEERING CURRICULUM IN MEETING WORKFORCE NEEDS

The manufacturing engineers required for Indian industries are drawn from two major engineering disciplines- mechanical engineering or manufacturing (often called as production engineering in India) or production and Industrial engineering. Traditionally, the mechanical engineering program provides manpower for manufacturing too. Initially, those who wanted to specialize in manufacturing had to take a graduate degree in manufacturing, or production engineering or industrial engineering. However, towards late seventies, many universities introduced undergraduate programs in manufacturing. India has more than 1500 engineering colleges and about 50% of them offers anyone or more of these programs. Though a manufacturing engineering program is tailored with more focus, the students and often industries prefer mechanical engineering graduates.

2.1 TYPICAL CURRICULUM

A typical engineering curriculum in Indian engineering schools has the following approximate composition

Category	Proportion %
Basic Sciences and Engineering Sciences	15
Humanities and Social Sciences	10
Technical Arts or Professional Courses	10
Courses in Manufacturing including Thesis	50
Elective Courses	15

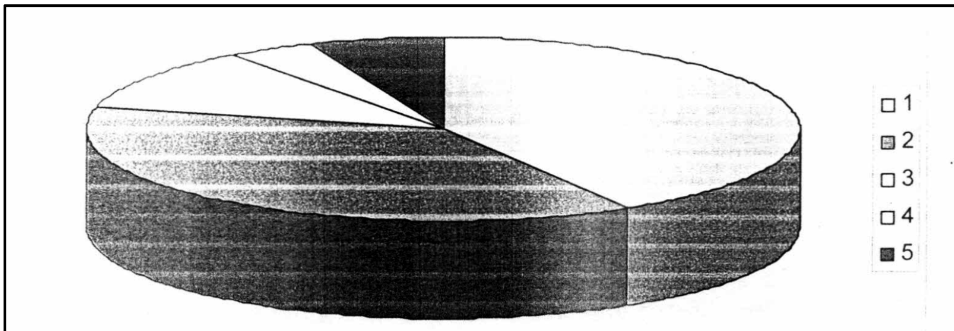
The proportion may vary from university to university. The course delivery is through a combination of class room instruction and laboratory instruction.

Since bulk of manufacturing engineers is with an undergraduate degree in either mechanical or manufacturing engineering, it will be interesting to make a comparative study of their respective curriculum The curriculum of a south Indian University which offers both programs is selected for this purpose. A mechanical engineering undergraduate program will have fewer courses in manufacturing. Typical courses are machine tools and manufacturing processes, computer integrated manufacturing, metrology, jigs, fixtures and press tools, process planning, total quality management, production automation etc. A typical undergraduate in mechanical engineering will have adequate laboratory/workshop courses in manufacturing, though thermal sciences and design may form bulk of core courses. However, the curriculum offers a number of elective courses in manufacturing which the student can opt for if he is interested to specialize in manufacturing.

3. DECLINE OF INTEREST IN MANUFACTURING — A CASE STUDY OF PROGRAMS

India has different types of engineering institutions at degree level – Indian Institutes of Technology (IIT), universities, deemed to be universities and engineering colleges affiliated universities. There are a large number of engineering colleges in India today with a combined annual intake of more than 0.6 million.

Though manufacturing is critical to increase the GDP of the country, manufacturing has never been a preferred course among the engineering aspirants. This true of not only India but in other countries too. Many academicians also tend to consider manufacturing as a technology program rather than an engineering program. With the increase in popularity of information technology, manufacturing has taken a back seat in recent years. In the best interests of the country, there is a need to attract good talent to manufacturing industry. Tamilnadu is a typical case where manufacturing further down in the list of preference of engineering disciplines in spite of the state being is one of the states in India with a progressive outlook in engineering education. The distribution of various specializations in programs offered by the technical Institutions in Tamilnadu is shown in Fig.1. The data refers to 2004. Since 2004, there has been considerable increase in IT related programs which has skewed the distribution but it will be hopefully corrected soon.

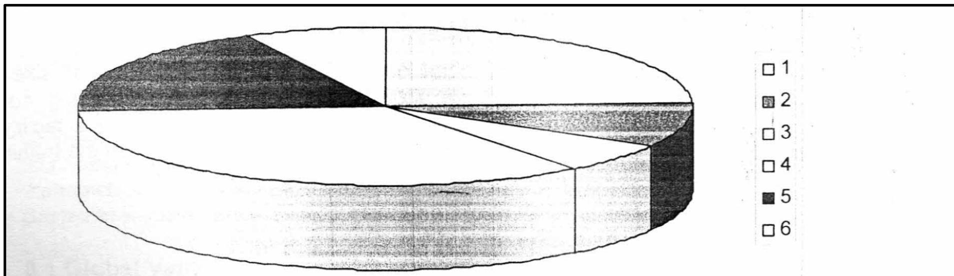


1. Electronics 2. Computers 3. Mechanical/Manufacturing 4. Civil 5. Others

Fig.1 Distribution of Different Disciplines of Engineering in Tamilnadu

4. GENERAL STRUCTURE OF A TYPICAL MANUFACTURING CURRICULUM

It is pertinent at this stage to take a look at the general curriculum structure in manufacturing engineering. A typical curriculum is given in Table 1 in appendix. It is true that over the years several new manufacturing technologies have been developed and they find a place in the curriculum. The distribution of the courses in this program is given in Fig.2.



1. Basic Sciences 2. Humanities 3. Technical Arts 4. Manufacturing Related Courses 5. Other Core Courses 6. Electives

Fig.2 Distribution of Courses in Production Engineering Program

One of the interesting observations on the curriculum is that most of the programs focus on technology courses. There is a need to increase the number of business courses as well as courses on intellectual property and entrepreneurship.

5. INDUSTRY-EDUCATION-GOVERNMENT PARTNERSHIP IN SHAPING THE FUTURE OF MANUFACTURING

Government of India set up the National Manufacturing Competitive Council (NMCC) in with the objective of devising strategies for revamping manufacturing in India. As a part of its mandate NMCC developed in association with Confederation of Indian Industry (CII), the premier Indian Industry confederation an innovative program called Visionary Leaders in Manufacturing.

5.1 VISIONARY LEADERS FOR MANUFACTURING

The Visionary Leaders for Manufacturing (VLFM) Program, a Confederation of Indian Industry (CII) initiative. is an innovative and path breaking program aimed at creating a critical mass of 300 leaders over a three year period to serve the manufacturing sector. These are drawn mostly from senior managers and young executives of various manufacturing industries. They are trained to lead the Indian manufacturing sector to the next stage of growth in the highly competitive global scenario. The program is designed to attract those with a passion to work to raise the competitiveness and innovation levels in India. The first batch of VLFM is expected to be path-breakers for Indian manufacturing. The vision of the National Manufacturing Competitive Council is to create a large pool such visionaries.

Japanese experts visited the training school and interacted with participants to provide an opportunity to absorb the expertise relating to the manufacturing leadership in Japan and transfer best practices from Japanese manufacturing industry to Indian industry.

The program consists of following four segments:

5.1.1 Program for Visionary Corporate Leaders in Manufacturing:

The objective of this program is to make senior managers from middle/small size companies having a minimum 5 to 10 years work experience capable of practising contemporary manufacturing practices through skill based training methodology. For this a facility has been set up at CII Naoroji Godrej Centre of Excellence in Mumbai. The 1st batch the training program has been competed and the 2nd batch commenced in July, 2008.

5.1.2 Program for Visionary Executives in Manufacturing:

This program was designed with the object of developing next generation manufacturing leaders through a well designed structured one year full time residential academic program. The services of the Japan International Cooperation Agency (JICA) were utilized in developing this program. The institutions involved are IIT, Madras, IIT, Kanpur, and Indian Institute of Management, Kolkata. This program targets junior and middle level managers having a minimum 5 years experience in manufacturing, from large/medium size companies. The program started at 11MCalcutta in August 2007. Prof. Shoji Shiba and other experts from Japan had been interacting with the participants. The program concluded in August, 2008 with the award of PGPEX-VLM Diploma. Second batch of the program has started in September, 2008

5.1.3 Short Program for CEOs

This 4-day program is meant for CEOs of manufacturing sector for creating innovative leaders.

5.1.4 The Visionary Small & Medium Enterprise Program (VSME)

VSME targets small and medium enterprises with good growth features for their further accelerated growth to make them and capable of meeting global competition. This is designed to identify the core competence to be nurtured with collaborative support system of the Government, Academia and the Industry. As the main focus is on competence with global benchmark, identification of such SMEs is done in a very careful, well-judged manner. The program consists of 5 Modules. Prof. Shiba of JICA is coordinating all the modules, apart from NMCC and CII, the institutions participating in this program are IIT Kanpur, IIT Madras, 11M Calcutta and Entrepreneurial Development Institute, Ahmedabad. Mentoring the selected companies for their growth is the core feature of this program. Participating companies are selected on the basis of company's philosophy, their size/turnover, market share, number of patents, and R&D Budget.

6. NEW INSTITUTIONS

Considering the need for more focussed institutions, Government of India has started institutions like Indian Institute of Information Technology- Design and Manufacturing (IIITD&M) at Jabalpur and Kancheepuram.

7. NEED FOR INNOVATION IN MANUFACTURING

Innovation in manufacturing is essential to India's economic prosperity and to improve the quality of life of its citizens. There is a need to raise productivity, foster competitive businesses, and meet the challenges of globalisation, all done in with sustainability in perspective.

8. NEW CONCERNS

There are a number of new concerns for the manufacturing engineers. It is necessary that the young graduates should be aware of global manufacturing dynamics. The need to exploit technology and move away from low wage dependence to technology and skill based manufacturing should be emphasized in the training of the manufacturing engineers. Sustainability is another issue of paramount importance. These are briefly discussed below:

8.1 Global Value Chains

Advances in technology, trade liberalisation and the rise of emerging economies are enabling manufacturers increasingly to unbundle different stages of the production process across the globe, in what is called a 'global value chain'. Manufacturers are specialising, not only in the fabrication of physical components, but in accompanying knowledge intensive services, such as research and development, inventory management, quality control, and other professional and technical services.

8.2 Technology Exploitation

Developing new technologies and harnessing their power is essential in order for UK companies to drive their competitive advantage. New technologies critically underpin improvements to productivity and the efficiency of processes, and provide the capacity for firms to develop higher quality or better customised products that allow them to capture higher value components of the value chain.

8.3 People and Skills

We in India have a distinct advantage of low wage economy. But, designing our manufacturing based on the low wage economy will not be good for India in the long run. As we move towards a developed economy, there is a need to raise the skill levels of the manufacturing work force. Manufacturing companies in the new millennium will require specialists with high level knowledge and a generic set of soft skills to work across disciplines. The young engineers should possess strong management and leadership skills vital to the operation of global value chains and making most effective use of skills of the workforce to deliver high value added products and services.

8.4 Low Carbon Economy

Modern manufacturing methods are spectacularly inefficient in their use of energy and materials Manufacturers have traditionally been more concerned about factors like price, quality, or cycle time and not as concerned over how much energy their manufacturing processes use This latter issue will become more important, however, as the new industries scale up – especially if energy prices rise.

The need to tackle climate change demands transformation in manufacturing around the world and India is also not an exception. Our manufacturing engineers should be trained to reduce carbon emissions and achieve greater environmental efficiency.

9 SUMMARY

Manufacturing has great potential in India to become the major segment contributing to GDP. The need of the hour is to attract bright talent to manufacturing. Revamping of curriculum to create interest in the young engineering aspirants is one of the methods of achieving this. There is also need for imparting skills among the manufacturing executives, and managers. The visionary leaders in manufacturing program are cited in this paper as an example. More such programs are necessary. There is also a need to make the manufacturing engineers conscious of the global business dynamics and exploit to strengthen manufacturing in India. Finally, the manufacturing engineers must be fully aware of importance of sustainability in manufacturing.

Multi-Sensors based on-Line Tool Condition Monitoring

Prof A B Chattopadhyay

Department of Mechanical Engineering,
Birbhum Institute of Engineering & Technology, Suri, Birbhum

Preamble

The golden name of Prof. Gopal Chandra Sen will ever shine for his profound knowledge, scholastic thirst and determination, remarkable achievements and vast contributions in the field of technical education. He was an excellent teacher, exemplary administrator and above all a great human being with wide and soft heart.

Professor Sen was the prime architect of engineering education not only in Jadavpur University but also in several other universities and IITs in the country. He introduced machine tools as a full and compulsory course first in India more than 50 years ago. He wrote jointly with Prof. Amitava Bhattacharyya the first book on machine tools in India. This authentic book is still followed as a text book all over the world.

Affection, love, help, guidance and blessings towards his students, colleagues and anybody whoever came to his contact, made Prof. Sen great and unforgettable to all. He spent his whole life for promotion and excellence of engineering education and even finally sacrificed his life for such great cause.

I like many others, I always remember him, Pranam.

1. INTRODUCTION

The standard of living and progress of civilization depend on how amply and efficiently goods and services are produced for men's material welfare. The manufacturing technologies essentially need to be rapidly strengthened and advanced to meet the growing demand of global cost competitiveness, competence and excellence through the best utilization of the existing resources and further development of effective and economic production processes and systems. Fulfillment of such goals inevitably needs proficiency in design, development and proper use of appropriate manufacturing processes and systems, achieving precision and quality as well as environment friendliness and their overall integration. Integration and use of sophisticated and expensive machining systems like CNC machines, Machining Centre and FMS, cutting tools, etc. demand for high precision and accuracy and ability of processing exotic and new materials which are coming up with the rapid progress in science and technology and need special care and attention for their best utilization. The overall machining and grinding performances depend not only on the use of sophisticated machining systems and cutting tools and selection of the processing condition but also on the continuous interactive behavior of the Machine-Fixture- Tool-Work (M-F- T-W) system.

Machining rate, dimensional accuracy and surface integrity depend largely upon the selection and condition of the cutting tool edges. Unlike systematic wearing, the random premature and catastrophic failure of the cutting tools by chipping, fracturing, seizure etc., not only hampers production but also may damage the M-F-T-W system which leads to heavy down time and cost. Therefore, the cutting tools need continuous monitoring preferably on-line, so that it can be withdrawn/replaced before severe damages are caused. Since direct on-line monitoring of the tool is not feasible, the tool condition has to be on-line monitored indirectly from the response signals like variation in the nature and extent of the cutting forces, vibration, dimensional deviation, sound level, acoustic emission etc. The signals collected together are then to be analyzed using suitable statistical methods like regression analysis or Group Method Data Handling or the modern powerful technique, like Artificial Neural Network (ANN), which precisely and reliably correlates the tool condition with the signals received.

The computer based analyzer will not only indicate the condition of the tool and the status of the machining and their effects but also may be used to indicate the remedial action to be taken either offline or even on-line adaptively by updating the part program through a proper circuitry interfacing the analyzer and the programming unit and the salient switches of the machining system. Such dynamic system, when implemented in the sophisticated and critical machining systems, will not only enhance productivity and quality of the products but also help in maintaining the M-F-T-W system in good condition over a long period and thus will contribute in improving the overall industrial economy.

The industries who are essentially using and will be using sophisticated machining systems for higher productivity, quality and economy particularly due to recent liberalization and need for cost competitiveness will be highly benefited by incorporating such dynamic and effective on-line condition monitoring and adaptive control system.

2. SYSTEM AND METHOD OF ON-LINE TOOL CONDITION MONITORING (TCM) IN ANY MACHINING

Unlike continuous machining such as turning, drilling, boring etc. milling is an intermittent cutting process leading to vibration, noise and rapid or premature failure of the cutting edges due to thermal and mechanical shocks. In this paper, TCM in face milling has been taken up.

In any machining, particularly in more complex machining like milling, single signal like cutting force or cutting temperature is unable to characterize the tool condition. For such work multisensor fusion is found to assess or predict the exact tool condition more accurately.

Dimensional deviations, tool-work electric resistance and radioactivity, optical sensors, camera etc may be used for direct TCM.

But for online TCM, several types of sensors or signals can be used for indirect assessment of the tool condition. Some of such effective sensors are:

- force (machining) sensors
- vibration sensors
- surface roughness
- cutting temperature
- spindle - current, voltage and power
- torque sensors
- sound pressure level
- acoustic emission (AE)

Fig. 1 schematically shows a possible system of indirect on-line TCM for a CNC machining centre.

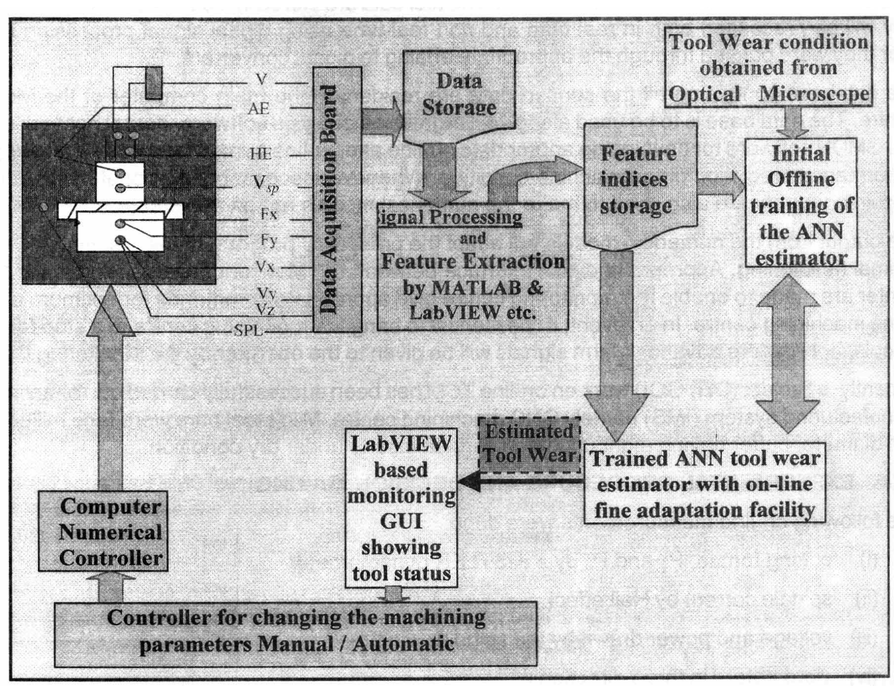


Fig.1: Schematic representation of TCM system

Such TCM work usually comprises of the following sequential steps:

- study of machining process and signals affected by it
- selection of signals for studying the effect of tool condition on them
- selection of sensors and their mounting location for sensing properly
- configuration and development of the data-acquisition system
- machining experiments and data acquiring
- processing of signals, extraction and selection of features
- developing neural network based intelligent estimator
- optimising and validating the estimator with different structures and inputs
- integrating the whole TCM for on-line operation.

The sensing system consists of transducers and necessary signal conditioning devices for monitoring both on-line and off-line conditions of the tool, job and the machine. The on-line conditions to be monitored are generally the cutting forces, vibration, radiated sound pressure level, acoustic emission from tool, tool temperature, along with machining parameters like speed, feed and depth of cut. The off-line parameters that need monitoring are tool wear, job dimension and its surface condition.

The usual pattern of wear and damage of face milling inserts is schematically shown in Fig. 2. The main .cutting edge out of the three shares the major load and its wear and tear plays the maximum detrimental role. The average of that flank wear is taken as the primary index of wear of such inserts.

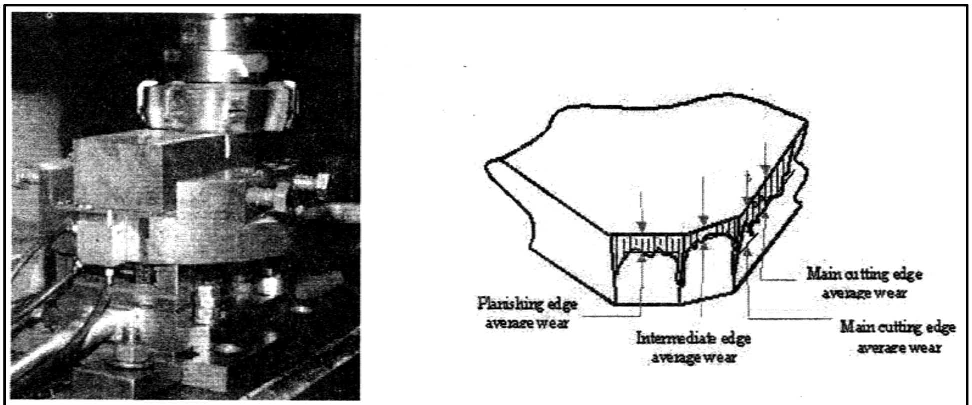


Fig. 2 Usual pattern of wear of face milling inserts

Before the measured off-line and on-line machine tool data are stored in a database for further analysis, they will be processed both in real time and non real-time using digital signal processing software after they were passed through the appropriate analog to digital converters.

The database containing all the sensed data are resident in the main computer of the Monitoring Centre. The data base is to be used along with regression analysis software, neural network software and GMOH software for developing appropriate off-line and on-line numerical models for the optimum performance prediction of the machine condition. Whenever necessary appropriate inputs from the machining theory are also used to make the numerical models robust and stable.

The output from the numerical models will adapt the preset NC program of the Machining Centre for optimal functioning. Appropriate digital interface between the Monitoring Center and the Machining Center are made to enable the monitoring centre give appropriate commands for optimum operation of the machining centre. In an event, it is essential to bring the machining centre to a stop for change of tools, appropriate advance alarm signals will be given to the operator by the Monitoring Centre.

Recently a Project (OIT, GOI) work on on-line TCM has been successfully carried out for an intelligent manufacturing system (IMS) namely CNC machining centre. Mild steel bars were face milled by a 80 mm diameter cutter having eight uncoated carbide inserts under dry condition.

3. EXPERIMENTAL PROCEDURE AND DECISION MAKING

The following on-line measurements were done:

(i) cutting forces, Px and Py by a KISTLER dynamometer
(ii) spindle current by Hall effect
(iii) voltage and power drawn by the spindle
(iv) vibrometers in three directions
(v) a sound level detector
(vi) one acoustic emission analyzer

It was difficult to measure the cutting temperature. The cutting tool wear was measured off-line at regular intervals for developing the correlations.

The raw signals were essentially chopped, filtered and then segmented properly as can typically be seen in Fig. 3.

From the processed signals the most sensitive and consistent features are extracted for onward signal fusion. This TCM system consists of six main modules and several sub modules, which are integrated in the Graphical User Interface (GUI) platform, using LabVIEWVer. 5.1 providing user friendly Human Machine Interface (HMI).

Fig.4 typically shows the RMS feature of the longitudinal force segments vs. off-line measured average flank wear.

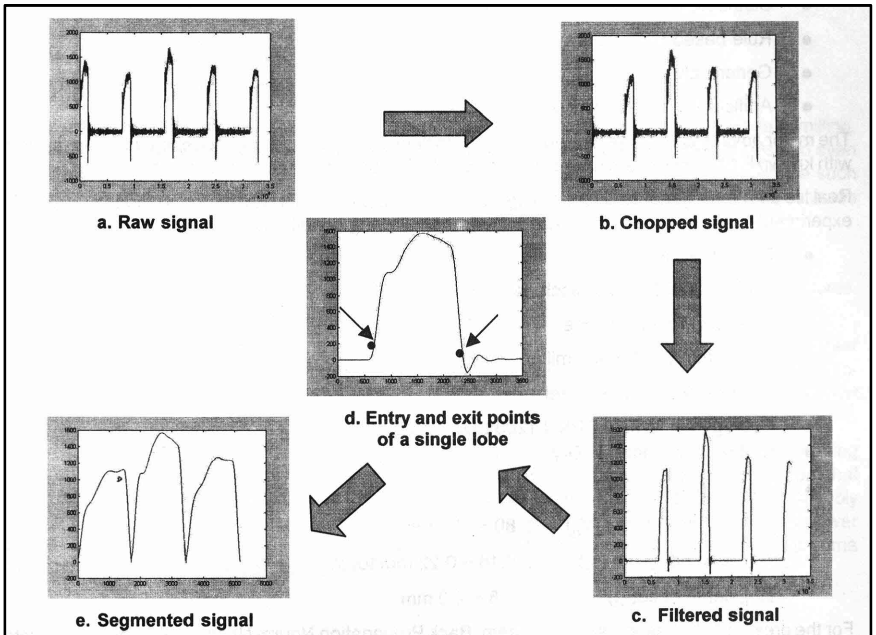


Fig. 3 Basic flow in the signal processing for a typical F_x signal with incomplete machining lobes at the start and also at the end

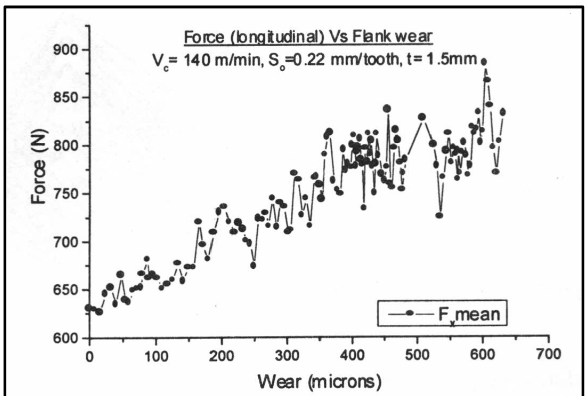


Fig. 4 RMS feature of F_x vs. flank wear

Similarly the significant features of the other signals were also extracted and plotted. Fusion of the features extracted from the various signals could be done by different tools such as

- Mathematical functions
- Distributed Blackboard Paradigm
- Rule based fuzzy sets
- Generic algorithm
- Artificial Neural Network (ANN)

The major advantages of the modern tool ANN include multi redundancy, modeling unknown systems with known limited inputs and outputs, adaptability, flexibility and self restructuring.

Real life data were generated for training, testing and validation of the ANN based models. Machining experiments and trials were conducted under the following conditions:

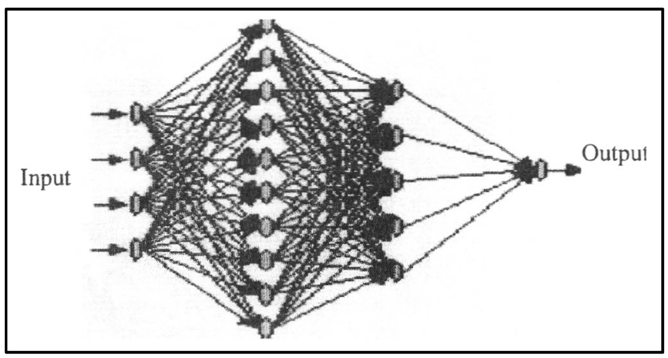
- Machine Tool
  - LMV Jr. CNC Milling Machine
  - Batliboi Milling Machine
  - Hainstein CNC Plano miller
- Work material: C-60 steel
- Cutting tool: WIDIA SPKN 1203 EDR TTMS
- Cutting environment: Dry
- Cutting parameters

☐ cutting velocity (V_c)	:	80 ~ 180 m/min
☐ feed per tooth (s_o)	:	0.16 ~ 0.22 mm/tooth
☐ depth of cut (t)	:	1.5 ~ 2.0 mm

For the present ANN based decision system, Back Propagation Neural Network (BPNN) was selected for its suitability for pattern classification problems and the following procedure was adopted.

- Feature space
  - Force rms (F_x, F_y)
  - Process Parameters (S_o, V_c, t)
  - Spindle power (Voltage and Current)
- Activation function

  Log sigmoid: $\frac{1}{1+e^{-\lambda x}}$



- Domain
  - Learning-rate (Ir) : 0.2 ~ 0.9
  - Momentum-parameter (mp) : 0.1 ~ 0.99
  - Layers: 3 ~ 4
  - Nodes in the hidden layer(s): (3 ~ 20) & (2 ~ 8)
- Final values
  - Ir: 0.9
  - mp: 0.9
  - Layer: 4 (two hidden layer)
  - Nodes in the hidden layer: (10-5)

4. ANN PERFORMANCE RESULTS

Because of randomness in any machining processes, specially in complex machining like face milling, caused by several interactive factors lot of scatters and inconsistency appear in the signals and even in its features. As a result the ANN-based tool wear estimates also get scattered. To reduce such inconsistency and scatters, Finite Impulse

Response (FIR) type filters have been used at the features level. The FIR filter used for the present analysis is as follows:

$X_{filtered}(k) = 0.6*X(k) + 0.2*X(k-1) + 0.1 *X(k-2) + 0.05*X(k-3) + 0.05*X(k-4)$

Often recurrent BPNN provides better result than BPNN in respect of growth trend of the signal features. But in this present work significant improvement was not seen due to recurrent BPNN. It has been reasonably expected that multi-sensor fusion would result in more realistic and closer estimate. But it should also be remembered that use of multiple sensors may not be feasible or economically viable in the industrial environment. Therefore, a judicious combination of sensors must be taken up.

Fig. 5 typically depicts the BPNN-based tool wear estimate compared to actual wear using cutting forces only and cutting power only without and with filtering in the estimate level also. It is evident that cutting forces' features are more effective than the cutting power (only) signals and filtering is remarkably capable of smoothening the curves. The estimate became more accurate when force and power sensors were fused as can be seen in Fig. 6. Such estimate could be further improved to some extent by optimising the ANN architecture.

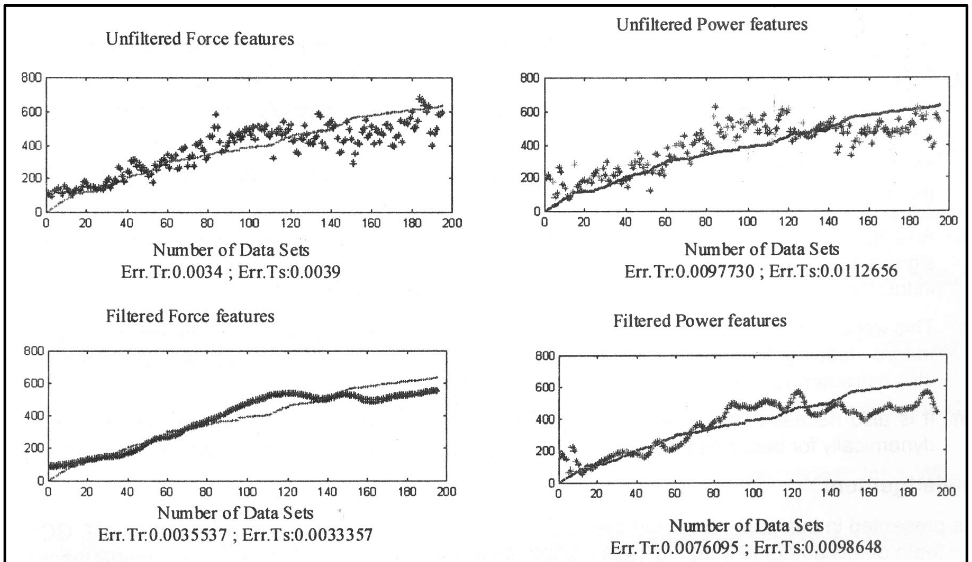


Fig. 5 ANN performance results: (comparison between force and power ANN)

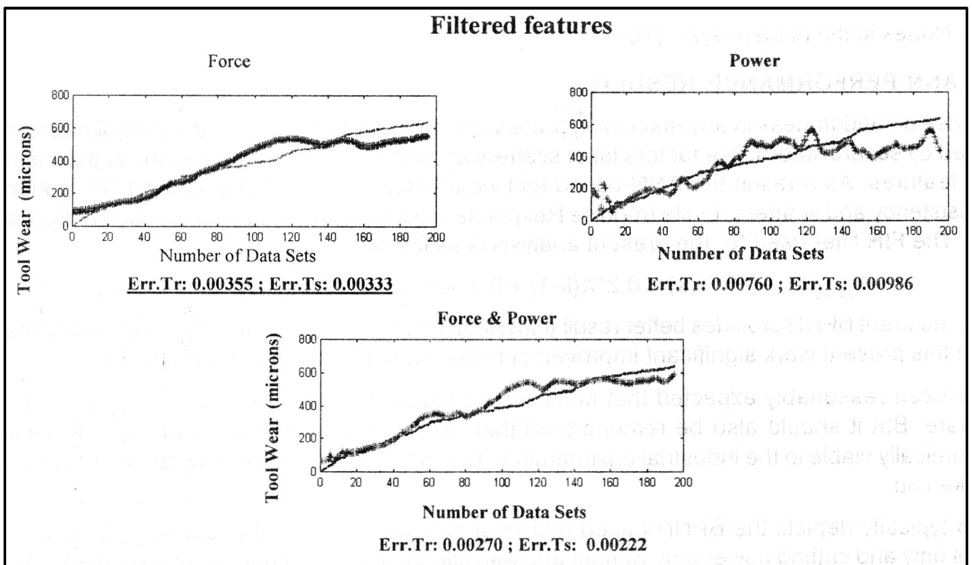


Fig. 6 ANN performance results : (comparison between single sensor and sensor fusion ANN)

Inclusion of vibration and sound features in the fusion of forces and power showed some benefit expectedly. However, no contribution was found from inclusion of the Acoustic Emission Sensors in the sensor fusion possibly due to the inherent complex' pattern of the face milling operation and inability to mount the AE probes properly at the cutting zone.

5. CONCLUSIONS

(i) Tool condition monitoring in Intelligent Manufacturing Systems is essential and also it is feasible and economically viable.

(ii) ANN-based decision system with appropriate sensor fusion, digital signal processing and feature extraction is quite capable for on-line TCM even in complex face milling process.

(iii) BPNN reasonably performed quite satisfactorily in tool wear estimate. But recurrent BPNN did not show significant improvement

(iv) The wear estimate became substantially accurate and consistent by application of proper filtering at the levels of the raw signals, features and also the final estimate

(v) Amongst all the treatments attempted, the fusion of the proper features of the cutting force and power signals provided the best possible results keeping in view accuracy and consistency of prediction, industrial feasibility and economy in the present work on face milling.

(vi) This work need to be extended and strengthened further to enable predict or apprehend occurrence of macro-chipping, fracturing or any catastrophic failure, which are not only random and premature but also extremely harmful for the whole machining systems.

(vii) It is also necessary to be able to not only monitor or estimate the condition but also take action dynamically for better and safe machining by adopting control using the monitoring system output.

Acknowledgement

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Latest Trends for Enhancing Productivity through Upgradation and Modinization of Facilities

Er R P Shrivastava, *FIE*

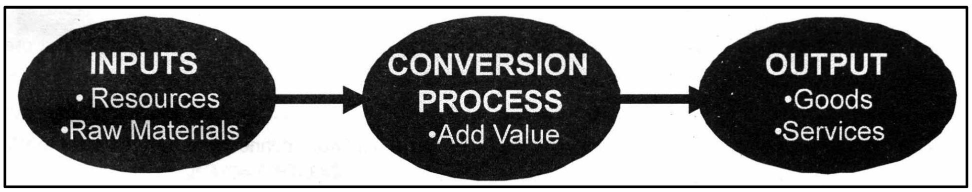
Addl. General Manager (Rtd.), BHEL, Bhopal

PRODUCTIONPROCESS

• Production:- Application of resources such as people and machinery to convert materials into finished goods and services.

• Production and Operations Management:- Managing people and machinery in converting materials and resources into finished good and services.

• The Production process: Converting inputs to outputs



The field of production engineering and technology continues to advance rapidly transcending disciplines and driving economic growth. This challenging and broad topic has continued to incorporate new concept at an increasing rate, making production technology a dynamic and exciting field.

Production technology is generally a complex activity involving a wide variety if resources and activities such as:-

- Product Design	- Production control
- Machinery & Tooling	- Support services
- Production planning	- Marketing
- Materials	- Sales
- Purchasing	- Shipping
- Manufacturing	- Customer services

Manufacturing Activities must be responsible to serve the following demands and trends:-

1. A product fully meets design requirements and product specification.

2. Quality must be built into the product at each stage.

3. Product must be made by the most environment friendly and commercial methods.

4. In a highly competitive environment production methods must be flexible to response to the changes in market demands. In today's environment a manufacturing organization must constantly strive for higher level of quality and productivity.

Until early 1950s, most manufacturing operation were carried out on traditional machinery such as lathe and milling machines which lacks flexibility and requires considerable skilled labours. Productivity also becomes a major concern. To obtain optimum use of all resources (materials, 'energy, capital, labor & technology) with rapid advances in the science & technology of manufacturing, the most important step in manufacturing technology was Automation.

Automation is generally defined as the process of having machines following a pre determined sequence of operations and with little or no human labour using specialized equipment and devices.

The major break through in operation began with introduction of numerical control (NC) of machines in the early 1950s. In manufacturing field and particularly in the area of metal working.

Numerical control technology has caused something of evolution with introduction of micro electronics and the never ceasing computer development, its impact on numerical control, has brought significant changes to manufacturing sector & metal working in particular.

CNC machine technology is emerging as the core strength of the manufacturing industry around the world because it has met today's demand in production technology which includes-

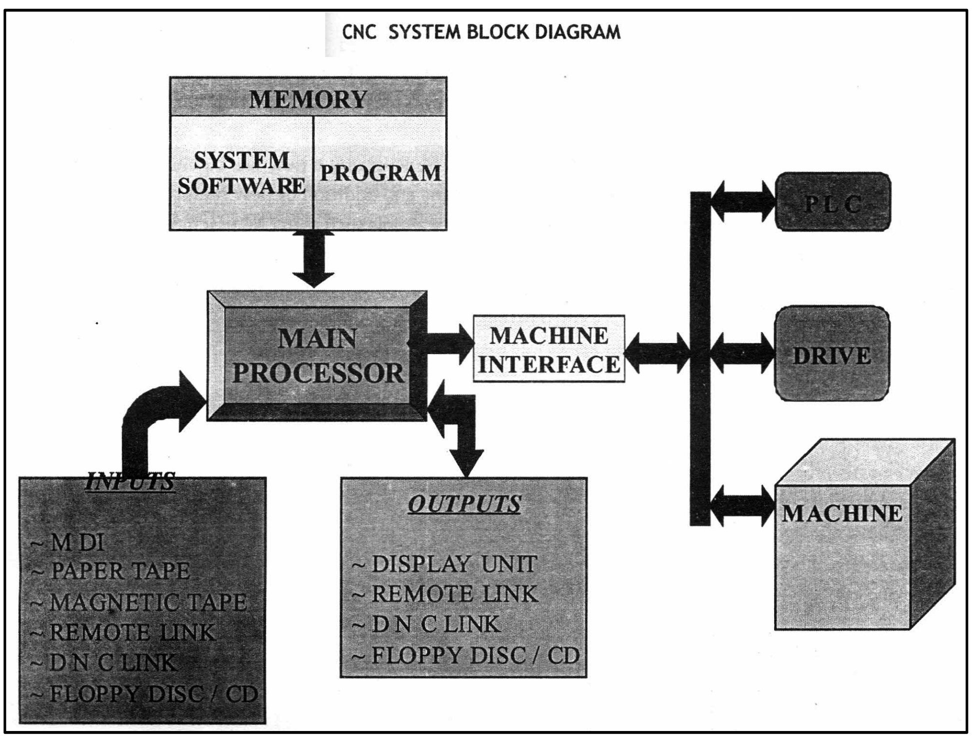
Perfect machining in minimum possible time and minimum operator interface. CNC machining center uses an internal micro processor i.e. computer which contains memory registers / stores a variety of routines that are capable of manipulating logical functions i.e. the part programmer or the operator can change any programme at the control unit. The instructions are stored as software instructions rather than hardware connections without intervention of operator.

CNC machines have high speed interactions, high accuracy and high quality system in built. At every step accuracy is checked. This has also higher flexibilities in operations. Machines monitor the operations by remote control through sensors and decoders.

• The cutting tools used are also specially designed high strength cutting tools. The cost of machining is also optimized because of well programmed cutting operations due to less setup times and lead time reduction in subsequent runs.

The above benefits have been achieved in CNC machines due to advancement in machine building technology such as use of ball screws, aerostatic and hydrostatic operations, ball linear guide ways. Control system etc. CNC operations can also controls simultaneous multi axis controls, pitch error compensations and zero offset compensations. Cutting tools used in CNC machines are also of special design standard tooling arrangement and using a robot for controlling different operations i.e. central command by computer assistance.

The synergy of the various sub systems in bringing out a highly versatile CNC manufacturing operation is really the key to today's manufacturing success.



TECHNOLOGYAND PRODUCTION PROCESS

Robots

Robot reprogrammable machine capable of performing numerous tasks that require manipulation of materials and tools.

Computer - Aided Design and Manufacturing

Computer - Aided Design (CAD) System for interactions between a designer and a computer to create a product, facility or part that meets predetermined specifications.

Computer - Aided Manufacturing (CAM) Electronics tools to analyze CAD output and determine necessary steps to implement the design, followed by electronic transmission of instructions to guide the activities of production equipments.

IMPROVEMENTS IN MACHINE DESIGNES OF CNC MACHINES

There have been improvements in structural design with proven stress free structure. Slides are also better designed with the help of balls crews and nuts which are backlash free, aero static and hydro static movements which are with lesser wear and tear, and advanced effective controls systems with no human error in operation. Machine uses automatic tool changer there by reducing tools setting time and a continuous conveyor for maintenance free operations. Machine has high speed spindle with better drivers and feed motors.

Machine after continuous use have wear and tear in components and sub assemblies leading to loss of accuracy achieved in the finish products. This relates to the rejection of finished goods and loss of revenue to the organization. To overcome the above defects reconditioning of the machine tools is a must. Reconditioning aims at achieving the desired accuracy as specified by the manufacturer. The measure of accuracy is listed in the specification of the machine itself at the time of installation of machine.

Apart from reconditioning retrofitting is another means of achieving a new life to old machine through cost effective modernization. This also includes capacity enhancement and addition of new facilities to the equipments. These facilities include modern gadgets available in modern machine tools such as in CNC machine.

For retrofitting of an equipment, it should be rigid and robust enough to work in future life time i.e. its parts especially base structure must be inline with original machine specifications without any misalignment. The reconditioning of the machine is required as pre requisite condition for retro fitting.

In reconditioning various operations carried out are as follows:-

- Dismantling the machine,
- Alignment and leveling of base structure.
- Grinding/ / finishing of slides and Guide ways
- Checking of various sub assemblies/ components.
- Replacement of old bearings and oil seals.
- Replacement of hydraulic components.
- Replacement of broken/ worn-out gears and shafts, Electricals contractors.
- Checking replacement of worn-out electrical components such as switch gears, electrical fittings, control units.
- Rewiring of all electrical circuit controls.
- Checking/ Replacement improvement in automatic controls, lubrication system and coolant system.
- Replacement of machine guards and telescopic covers.
- After assembly of different components replaced/ modify parts, Checking of geometrical accuracy of the machine
- Trial run of the machine for operation
- Job trial of finished product.
- Re-installation of machine.

ADVANTAGEOF CNC RETROFITTING

The advantages of CNC retrofitting on a machine are as follows:-

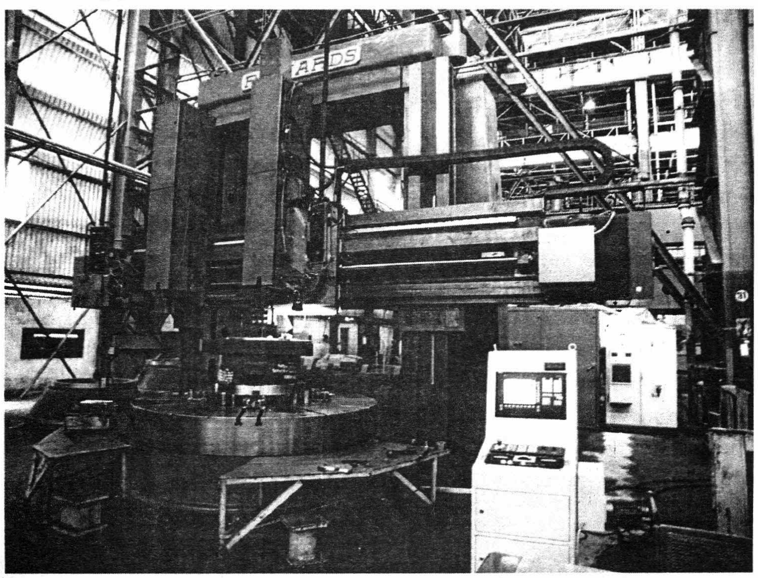
- A new lease of life to the machine through cost effective modernization.
- Capacity enhancement.
- Addition of extra Facilities.
- Restoration of accuracy / /better accuracy.
- Quality improvement.

• Productivity improvement upto 100- 200%.
• Cycle time reduction.
• Reduction in rework/ rejection.
• Rejection in down time.
• Flexibility of operation and programming.

Retrofitting is done for addition of extra feature / facilities to a machine tools which includes-

• Complete reconditioning of the machine.
• The state of art CNC control with PLC.
• AC/DC Digital / Analog servo feed drives for individual axis and spindles.
• Linear I Rotary position feed back system.
• Backlash free recalculating ball, screw and nuts.
• Complete rewiring anal cable drag chains.
• Automatic tools turret! changers.
• Hydraulic power pack, chuck and tail stock.
• Automatic centralized lubrication system and coolant.
• Chip disposal system and machine guard and telescopic covers

RETROFITTED VERTICAL BORING MACHINE



The major factors which are necessary for enhancing the productivity and utility of machines are as follows:-

1. Reduction in ideal time.
2. Increase in (cutting) material removal time during operation.
3. Effective programming operation and maintenance.

Most of the above factors are essential part of a CNC machine operation technology as described above. However maintenance of a machine is an important part of the life cycle of any machine.

MAINTENANCE MANAGEMENT

MAINTENANCE is an important part of the life-cycle of Machine Tools a Plants, and must be considered from the design stage through the end-of-life stage of the system. Maintenance covers two aspects of systems — operation and performance. Maintenance is generally performed in anticipation of, or in reaction to, a failure. Maintenance is performed to ensure or restore system performance to specified levels. A systematic and structured approach to system maintenance, starting during the design process, is necessary to ensure proper and cost-effective maintenance.

Maintenance operations have been categorized based on their frequency and their motivating factors. Four of the most common designations are described Predictive, Preventative, Corrective and Fault-finding.

TYPE OF MAINTENANCE

PREDICTIVE MAINTENANCE

Predictive maintenance involves a series of steps prior to actually performing maintenance. It begins with sampling physical data over time, such as vibration or particulate matter in oil. Analysis is then performed on the collected data to create an appropriate maintenance schedule, and maintenance is performed according to the schedule. This type of maintenance analysis works well for mechanical systems because the failure modes are well understood. Additionally there is historical data useful for creating and validating performance and maintenance models for mechanical systems.

PREVENTATIVE MAINTENANCE

Preventative maintenance refers to maintenance performed when a system is functioning properly to prevent a later failure. Generally, it is performed on a regular basis and the maintenance will be performed regardless of whether functionality or performance is degraded. The frequency of the maintenance is generally constant, and is usually based on the expected life of the components being maintained, but there is not necessarily any monitoring occurring at the same time (as there would be in predictive maintenance).

CORRECTIVEMAINTENANCE

Corrective maintenance refers to maintenance done to correct a problem when something has failed, or is failing. The need for corrective maintenance can be beneficial or detrimental depending on the product and the profit model used during the design phase of the product. On the most obvious level, corrective maintenance is detrimental to operation because it means that something failed, and the system is (probably) not available during the time needed to perform the maintenance.

FAILURE-FINDING MAINTENANCE

Failure-finding maintenance-involves checking a (quiescent) part of a system to see if it is still working. This is most often performed on portions of a system dedicated to safety — protective devices. This is an important type of maintenance check to perform because failures in safety systems can have more catastrophic effects, if other parts of the system fail.

STRATEGIC PLANNING

Due to ageing of machines the component of machines get detoriated. The electronic spare of machines get obsolete, the Mechanical accuracy of machines get decrease & due to non standardized spare it is very difficult to procure all spare of machines.

To resolve these problems Strategic Planning to be needed. For the improvement of the mechanical accuracy machine to be reconditioned completely.

OEE (OVERALL EFFECTIVENESS OF MACHINES)

OEE (Overall Effectiveness of Machines) is the measurement of the equipment efficiency.

Definition of OEE: Overall Equipment Effectiveness

• The overall performance of a single piece of equipment or even an entire factory, will always be governed by the cumulative impact of the three OEE factors: Availability, Performance Rate and Quality Rate.

• OEE is a percentage derived by multiplication of the three ratios for the factors mentioned above. The OEE percentage is used for analysis and benchmarking.

DEFINITION

• Availability· Measures the percent of equipment uptime divided by the time equipment can be used.

• Performance Rate· Percent of actual parts produced per time frame as against the technology rate.

• Quality Rate- Percent of good sellable parts out of total parts produced per time frame.

Note: The Quality rate takes into account parts rejected or rework done.

• Example: SO% Availability (O.S) × 70% Performance Rate (0.7) × 90% Quality Rate (0.9) = 50% OEE.

The beginning of the current era is selected as 1950 to correspond roughly with the beginning of the use of computers in operation management. At present the CNC machining centre appears to be the most capable and versatile automatic machine tool that can perform various operations such as drilling, milling, turning, boring, reaming and tapping etc. The general objective behind the development of NC machine continuous to remain the deduction in cost of production by reducing the operation time. The performance of a variety of machining operations on the same machining centre eliminates non productive waiting time that occurs if such operations or performed on different machines.

The enhancement in productivity technology is very vast there are many indications where technology will be going. Availability of the funds, support of the organization and knowledge to strive for more upgradation of machines will make the future of the organization for better productivity. Reconditioning and retrofitting of machines will go a long way in upgradation of machine to achieve better standards and optimum use of machine. Always the accuracy of machines has to be kept in mind for which effective maintenance management procedures have to be followed.

CNC Technology is the need of the day. Predictions of computers are difficult except that their power will increase. Winner of the competitive race will be the one that can combine hardware, software and people, who makes a product for reasonable price and market it around the world.

Production Engineering 2.0

Dr Sowmyanarayanan Sadagopan

Director, IIIT, Bangalore
s.sadagopan@gmail.com

It is common these days for people to refer to social media as Web 2.0. When the World Wide Web (WWW) started in mid nineties, many organizations built their web sites and made tons of useful information available to millions of users globally on a 24×7 basis. It was truly an "information revolution" unprecedented in human history. By making global reach available to the street comer shop as well as a mighty MNC, WWW "democratized" information access. After a decade of widespread use of WWW, "interaction revolution" started with services like Facebook and Twitter, with the user base dominated by the younger generation (Gen Next). This is generally referred to as Web 2.0. While WWW users could access information "any time, any where", they typically did several times in a month; but Web 2.0 users access their devices (typically smart phones) several times a day! Naturally, Web 2.0 has democratized interaction, once again unprecedented in human history. A positive news like Modi Election or World Cup results or a negative news like rape incident or Malaysian Airplane crash reaches billions of users in hours and minutes!

According to Wikipedia Production engineering "encompasses the application of castings, machining, processing, joining processes, metal cutting & tool design, metrology, machine tools, machining systems, automation, jigs and fixtures, and die and mould design and material science and design of automobile parts and machine designing and manufacturing". Over the past two centuries, production engineering has contributed to significant improvement in the quality of our lives by way of better kitchens, better homes, better cars / buses / trains / airplanes, better offices /airports /playgrounds and even better hospitals. But the overall improvement has been in efficiency and steady; we are about to see a transformational improvement in manufacturing too.

Computers and information technology (IT) in the past two decades have been transforming industries, for example, telecom, office automation, photography, printing, cinematography, TV, banking, travel, retail, banking, government and trading. Such transformations are referred to "electron-ification" or what IBM decided to call as "e-business". Even consumers in India have benefited enormously from e-ticketing (Indian Railways train booking), e-banking (SBI core banking), e-Trade (NSE Trade), e-retail (Flipkart) or e-Certificates (Bangalore One). Manufacturing too is currently going through such a transformation in the form of "additive manufacturing" (generally realized through 3D printing)

Manufacturing dominated production engineering until recently used "depletive removal" heavily; typically, a stock of metallic piece is "machined" by removing some portion by "cutting" so that a desired shape is realized. Machining processes improved dramatically over the decades to produce superior quality surface finish, control systems evolved to get much higher precision, efficiency improved to bring down costs. Newer materials, particularly engineering plastics, brought in novelty and convenience; alloys brought phenomenal improvements in strength. Unlike "depletive removal" one does a series of additive materials deposition using very sophisticated control to produce manufactured parts with phenomenal agility unprecedented in human history. That is referred to as "additive manufacturing".

Use of computers in manufacturing is not new. CAD (Computer Aided Design) and CAM (Computer Aided Manufacturing) are not new, but they represent Ver. 1.0 of the use of computers, the way WWW was Ver. 1.0 in the use of Internet. CAD / CAM did not truly transform manufacturing, but brought about phenomenal efficiency to manufacturing. At the core of CAD / CAM is "digitization" where the engineering drawing and machining instructions (NC machine codes) could be "digitized" so that the drafting could be done on the computer screen with much more flexibility and NC Machines could imbibe far more flexibility in their functioning. However, cost of manufacturing could not be brought down as the first generation of computers and NC machines were more expensive. What 3D printing promises is "democratization of manufacturing", with the following benefits.

- End users equipped with simple tools can make sophisticated parts
- The sophisticated parts could be "made to order"
- Manufacturing of sophisticated parts too can be done "just in time"

• Manufacturing can shift to "customer premise" rather than in huge factories

• Manufacturing in "small quantities can be economically viable"

On the face of it, 3D printing appears to be "too good to be true", but the past two decades of IT revolution has proved that the promise of 3D printing is realizable in the next two decades. Already popular media talks of 3D printing, producing fashion goods to medical equipment! While the many claims are far fetched at this moment, we are not far removed from reality. 3D Printing service of small parts is possible even in small Institutes like IIITB. There are services available in India where one can order 3D produced parts; right now, they are used for prototype development. Just as EDA (Electronic Design automation) permitted electronic design (typically IC / Chip / SoC / Embedded system) to be realized in "software", that could be "downloaded" to a Fab for prototype production, 3D printing permits mechanical design to be realized in physical form in "all digital" life cycle. Just as full-blown semiconductor Fabs rake the "all digital" idea to complete production, specialized 3D printers might take "all digital" idea to full-blown production. Already a giant 3D printing facility in China talks of 3D printing affordable homes! 3D Printing will change production engineering the way of EDA changed electronic manufacturing. That is a challenge production engineers today must get ready to face. It will provide huge opportunities in automotive, defence, biotech, footwear, jewelry and fashion industry. With India's IT prowess, one can hope to get a leadership position in production engineering 2.0 also. My very best wishes to tomorrow's production engineers who can benefit from Production engineering 2.0.

Achieving Green Manufacturing through Improved Technology

Prof Uday S Dixit

IIT Guwahati

I am honored to deliver a talk on green manufacturing in the memory of Late Professor Gopal Chandra Sen. Professor Sen graduated in Mechanical Engineering from College of Engineering and Technology Jadavpur in 1933. After working for two years in industry, he joined National Council of Education, Bengal as an instructor. In 1940, he became a lecturer. In 1946, he went abroad for higher studies and got an MS from University of Michigan. He became Professor at Jadavpur University in 1952. In 1969, he became the Dean of the Faculty of Engineering and in 1970, he became the Vice-Chancellor of Jadavpur University.

Prof. Sen has contributed a lot to the growth of education and research of Production Engineering in India. His books on Principles of Machine Tools and Principles of Metal Cutting are still very popular reference books. He has produced a number of outstanding students at Jadavpur University.

Green Engineering and Manufacturing

Manufacturing is a part of engineering with distinct and unique features. It acts like a backbone of engineering industry and economy. Since the times immemorial, engineering has been utilizing the natural resources for providing comfort to the human society. Engineers have been using natural resources such as wood, fossil fuels and minerals. As the human population and technology grew, the world faced two side-effects of technological development. One is the depletion of natural resources and other is the pollution. While it is debatable how much time the fossil fuels on earth will last considering the exponential growth in per capita use of energy and growing population, it is easy to understand the impact of over-harvesting the forest resources on the ecological-system. Green Engineering is a broad term for drawing attention towards sustaining the environment along with technological growth. Green engineering is the design, commercialization, and use of processes and products, which are feasible and economical while minimizing (a) generation of pollution at the source and (b) risk to human health and the environment. In the conference of "Green Engineering: Defining the Principles" held in Sandestin, Florida in May 2003, more than 65 engineers and scientists developed the "Principles of Green Engineering which are as follows:

1. Engineer processes and products holistically, use systems analysis, and integrate environmental impact assessment tools.
2. Conserve and improve natural ecosystems while protecting human health and well-being.
3. Use life-cycle thinking in all engineering activities.
4. Ensure that all material and energy inputs and outputs are as inherently safe and benign as possible.
5. Minimize depletion of natural resources.
6. Strive to prevent waste.
7. Develop and apply engineering solutions, while being cognizant of local geography, aspirations, and cultures.
8. Create engineering solutions beyond current or dominant technologies; improve, innovate, and invent (technologies) to achieve sustainability.
9. Actively engage communities and stakeholders in development of engineering solutions.

Anastas and Zimmerman (2003) have presented "12 principles of Green Engineering". In a concise form, they can be expressed as follows:

1. All material and energy inputs and outputs should be as inherently nonhazardous as possible.
2. Waste should be minimized.
3. Energy consumption and use of materials should be minimized.
4. Efficiency of mass, energy, space and time should be maximized.

5. Products, processes, and systems should be "output pulled" rather than "input pushed". Just in time (JIT) production system is one example.
6. Embedded entropy and complexity must be viewed as an investment when making design choices on recycle, reuse, or beneficial disposition. It is better to make modular and upgradable design.
7. Targeted durability, not immortality, should be a design goal. Products should be easily disposable once they become obsolete.
8. Design for unnecessary capacity or capability (e.g., "one size fits all") solutions should be considered a design flaw. This implies the importance of customized production.
9. Minimize material diversity.
10. Design of products, processes, and systems must include integration and interconnectivity with available energy and materials flows.
11. Products, processes, and systems should be designed for performance in a commercial "afterlife".
12. Material and energy inputs should be renewable rather than depleting.

All the above principles are applicable for green manufacturing. In this lecture, I shall be presenting a brief state of the art on green manufacturing initiatives in different type of manufacturing processes. I shall also present some research directions in green manufacturing field.

Green Manufacturing in Machining

Machining is a widely used manufacturing process. It is classified under subtractive manufacturing processes. Inherently, it wastes a lot of material in the form of chips. However, for precision manufacturing of small lot size components, it is often the most convenient process. Following elements of machining are the major sources of environmental problems:

1. Cutting fluid: A lot of heat is generated during machining. This raises the temperature of the cutting tool and in turn its wear rate. In order to cool the tool and also to reduce the friction between cutting tool and workpiece, often a cutting fluid is used during the machining. Petroleum based cutting fluids are very common. Cutting fluid may cause asthma, respiratory irritation, pneumonia, skin disease and sometimes even cancer to the operator (https://www.osha.gov/SLTC/metalworkingfluids/metalworkingfluids_manual.html). Apart from it, the disposal of cutting fluid is a big problem. Waste cutting fluids pollute soil and water and also may affect agricultural produce. It is essential to either minimize the conventional cutting fluids or substitute them by harmless cutting fluids.

2. Cutting tool: Cutting tools use a variety of materials and coatings. A lot of material and energy resource is used in manufacturing the cutting tools. They also have to be disposed. Thus, it is essential to optimize the use of cutting tools. According to one study (Armarego et al., 1996), "In USA, the correct cutting tool is selected 50% of the time, the tool is used at the rated cutting speed only 58% of the time and only 38% of the tools are used up to their full tool life capability". This depicts the extent of resource wastage in the machining processes.

3. Energy requirement: A lot of energy is consumed in machining processes. Most of the time the efficiency of machine tool is about 30%, as they run idle and are underutilized. The machining processes should be optimized to reduce the energy consumption. There is also a need to carry out design modifications in machine tools for making them inherently energy efficient.

4. Chips: The disposal of chips is very important in machining processes. In many modern machine tools, the chip disposal is being made automatic. The disposed chips can be reprocessed. However, the conventional methods of reprocessing the chips are energy and materials intensive. It is better to search for alternative uses of the waste chips. For example, they can be embedded in the epoxy matrix for making various types of particulate composites.

For reducing the consumption of cutting fluid, mist lubrication is being employed (Kelly, and Cotterell, 2002). However, mist is also harmful for the health. The permissible exposure level of the mist is 5 mg/m^3 (https://www.osha.gov/dts/chemicalsampling/data/CH_258700.html). In coming days, this limit may be reduced to 0.5 mg/m^3. Other method is to supply the coolant internally to the tool. Recently, minimum quantity lubrication (MQL) is gaining importance (Dhar et al., 2006). In MQL, the consumption of cutting fluid is only 50 to 500 ml/h. The key point is that the cutting fluid should be injected at appropriate places with proper pressure. There have been some attempts to employ heat pipe and thermoelectric refrigeration. Cryogenic cooling is another area that has been researched. All these techniques are still not very popular due to lack of proper cost-benefit analysis and awareness in industry.

One of the most prominent ways of achieving lubrication in dry machining is to use soft coatings on the cutting tools. These coatings are called self lubricating coatings (Weinert et al., 2004). A typical self-lubricating coating is MoS_2, which is applied on a hard coating using direct current (DC) sputtering technique. Koshy (2008) deposited multilayer films of CrN and Mo_2N, where the Mo_2N forms a sacrificial oxide that lubricates at high temperature. The reduction of friction at high temperature points to a thermally activated self lubricating mechanism in operation. As the coating wears the multilayer arrangement ensures the constant supply of lubricating oxides (from the Mo_2N layer) at the sliding interface. Many researchers have incorporated solid lubricants in the ceramic matrix to develop the self-lubricating ceramic composites. Self-lubricating ceramic composites consists of a supporting ceramic matrix surrounding the dispersed pockets of one or more softer lubricating species. Partially stabilized zirconia (PSZ) with a thin film (about 50 nanometers) of CuO can make a good self-lubricating tool.

Many methods for proper chip handling have been introduced. This includes appropriate modification of cutting tool. For example, the milling cutter with large tooth spacing will remove chips easily. Wherever possible, instead of drilling, a trepanning process should be preferred. Trepanning produces a solid scrap instead of a lot of chips, which is easier to remove. Many computer numerical control (CNC) machines use chip conveyor and exhaust system for the proper disposal of the chips.

Gas cooled machining

Cutting fluids pose the problem of disposal. The gas cooled machining can be carried out. Commonly used gases are N_2, CO_2, Ar, air, water vapor and oxygen. These are used in the compressed form. Among these, compressed air is a better option. Often the compressed air is available on the shop floor. Sarma and Dixit (2007) has employed compressed air in turning of cast iron and steel. In the study TiN coated carbide, CBN and ceramic tools were employed. It is observed that air-cooling always provides better machining performance. For example, Fig. 1 shows the drastic reduction in the flank wear while machining of grey cast iron with ceramic tools. To further enhance, the convective heat transfer coefficient, the cooler air can be used. An energy efficient way is to employ vortex tube for cooling.

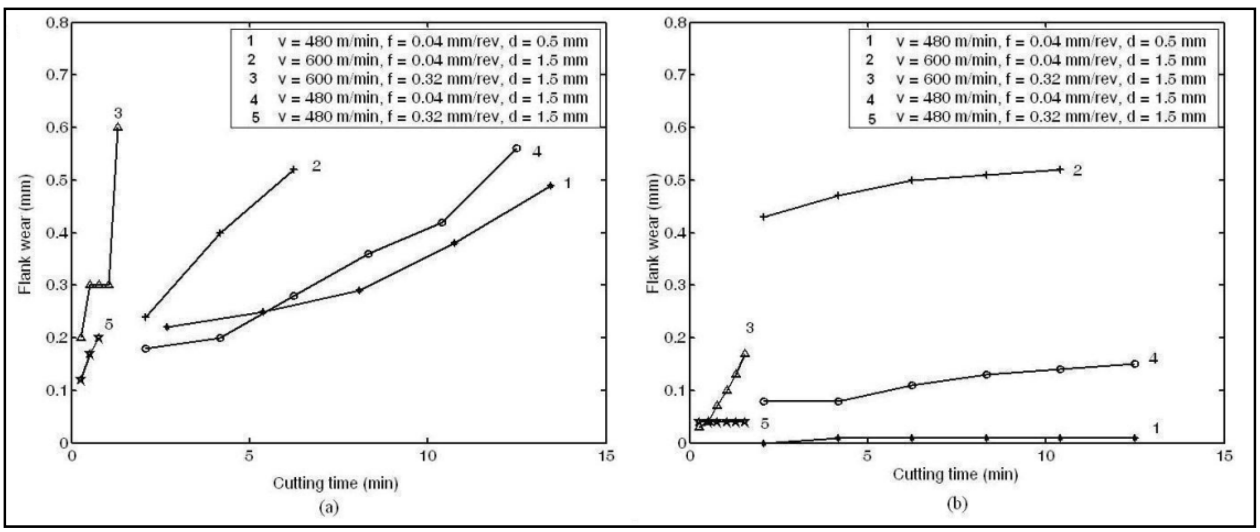


Figure 1: Progression of tool flank wear with cutting time: (a) dry turning (b) air-cooled turning of grey cast iron with ceramic tool at high cutting speed. With permission from Sarma and Dixit (2007). Copyright (2007) Elsevier.

Optimization of machining processes

Research on the optimization of machining process started since 1950 (Gilbert, 1950). Most of the time, the objectives have been the minimizing the cost of machining, maximizing the production rate or maximizing the profit rate. Most of the researchers did not consider the cutting fluid related costs. From green manufacturing perspective, considering the cost of cutting fluid as well as its disposal is very much essential.

Although thousands of the papers have been published on the optimization of machining processes, there is hardly any actual shop floor application. Even now most of the time industry relies on its operator or process planner's intuition. One reason is the lack of proper machining data and modeling methods. In his book, Shaw commented that it is next to impossible to predict the performance of machining process (Shaw, 2005). The challenges are two-folds. First, the physics of the process is still poorly understood. Second, even if a reliable model could be developed, there will be difficulty in getting proper input data for the model. Soft computing can be used to model the process provided sufficient training data is available. Cloud computing can also be used for getting the machining data (Chandrasekaran et al., 2013).

In nutshell, there is a lot of scope for applying green manufacturing practices in machining. As present, machining is largely dominated by empirical rules and intuitive understanding. Awareness should be created in the industry for reducing the consumption of cutting fluids, tools and energy. Figure 2 schematically depicts some of the attempts for reducing or totally eliminating the toxic cutting fluids, thus contributing to the goal of green manufacturing. Further details are available in a monograph authored by Dixit et al. (2012).

Green Metal Forming Processes

Concerns in green metal forming are similar to machining. Metal forming has got one advantage that the material is not wasted. Hence, chip disposal is not a problem. However, the metal forming processes use lubricants, which may pose health hazard. Proper selection of tool and process parameters is very important in metal forming. Optimization plays a vital role in metal forming too.

There is a need to develop innovative environmentally benign processes. Recently, one thermal autofrettage process has been developed at Indian Institute of Technology Guwahati (Kamal and Dixit, 2015). Hydraulic, mechanical and explosive autofrettage processes have been in vogue in industry. These processes produce compressive residual stresses on the inner surface of the pressure vessels. Among them hydraulic autofrettage process is the most widely used process. However, hydraulic oil and the sound generated by hydraulic power pack are detrimental for environment. Moreover, all the above mentioned processes consume a large amount of energy. The thermal autofrettage is much simpler compared to these processes. Here, a thermal gradient is produced to cause non-homogeneous plastic deformation. The removal of the thermal gradient causes the residual stresses. The outer surface is heated by a heater and inner surface is cooled by flowing water to produce appropriate thermal gradient. Figure 3 shows an experimental setup for the thermal autofrettage of cylinders.

Incremental forming can also be very efficient process for fabricating large sized structures. For many materials, laser forming or laser assisted forming can be energy efficient. At the same time, it minimizes the cost for fabricating special setups and dies etc.

Green Joining

Welding of metals by arc or gas has been carried out since long. The fumes produced in welding are harmful for the operator and environment. Moreover, the radiation produced during welding is harmful for the operator. One green manufacturing practice will be to provide the operators with the protective eye-shield and mask. The processes like submerged arc welding protect the operator from the harmful effect of the arc. They also are energy efficient and produce the better quality weld. Green electrodes can also be used, which avoid harmful elements.

Friction based welding processes viz. friction welding (Vairis and Frost, 1998) and friction stir welding (Thomas and Nicholas, 1997) have the following advantages from the environment point of view: (1) These processes do not produce harmful radiation, (2) they do not use any flux material and (3) they do not generate harmful fumes. Wherever possible, the adhesive binding may be preferred to welding. The process of adhesive bonding may be made energy efficient. There is a less amount of wastage of adhesive.

3D Printing Processes

Three-D printing processes are additive manufacturing processes that manufacture a three dimensional object layer by layer (Vaezi et al., 2013). They are called additive manufacturing processes. In these processes, there is very little wastage of material. There is no need to make dies and fixtures. This in turn minimizes resources including energy. Also, one machine may be enough for making a variety of products. This helps in space minimization. One good three-D printing machine may act as a factory. Often the need for assembly is eliminated.

At present, a number of processes are popular that process a variety of materials by various ways. Fused deposition modeling (FDM) heats a thermoplastic material above its glass transition temperature and deposits it layer by layer. Its application is limited because of its inability to make the products of high melting point materials. In Stereo lithography (SL), a computer controlled laser beam is used to draw the object layer by layer on a liquid polymer that hardens when struck by laser. Selective laser sintering (SLS) builds a three-dimensional object by using a laser beam to selectively sinter (heat and fuse) a powdered material. Laminated Object Manufacturing (LOM) uses a continuous sheet of material (plastic, paper or even metal) that is drawn across a platform by a system of feed rollers. Plastic and paper sheets are coated with adhesive. To form an object, a heated roller is pressed over the sheet on the platform. Adhesive melts and joins the sheets. A computer controller laser beam or blade cuts the material in the desired pattern. Shape deposition manufacturing (SDM) is a 3D printing process in which assembly is carried out simultaneously. The SDM cycle consists of shaping of layers and embedding other parts for example, sensors and actuators.

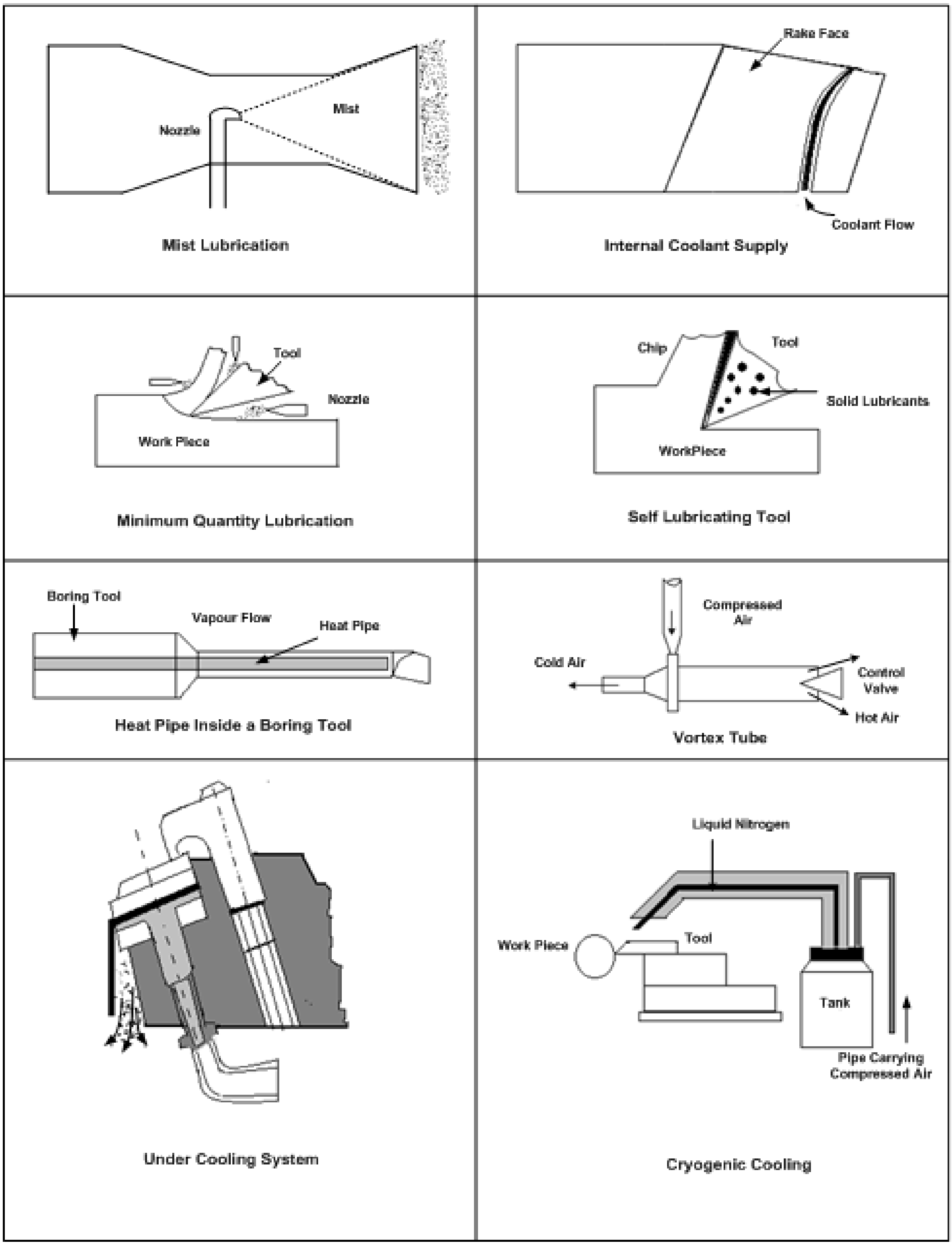


Figure 2: Some techniques for reducing or eliminating cutting fluids in machining

Figure 3: An experimental setup for thermal autofrettage of cylinders

Miniature Manufacturing

Miniaturized products have a number of advantages. They involve low material and energy consumption. They are light weight and due to it they are easily portable. They have high performance to cost ratio. Research on the micromanufacturing is drawing the attention of a number of researchers across the globe (Jain et al., 2014a, 2014b). Micromanufacturing refers to the manufacturing of a component or feature whose one orthographic view can be contained in a square of 1 mm size. Although the micro and nano components may proved to be high energy efficient during operation, often their manufacturing requires a large amount of energy. Due to size effect in micromanufacturing, the friction is tremendously increased and lubricants are required. Moreover, many micromanufacturing processes are non-traditional and are not very efficient. For example CO_2 laser has efficiency of the order of 10–15%. The efficiency of Nd-YAG laser is in single digit. It is essential to consider green aspects in developing micro and nano technologies.

Concluding Remarks

Green manufacturing refers to the activities that are environmentally friendly. Waste minimization and energy efficiency is very important for green manufacturing. Manufacturing processes should avoid using harmful chemicals. To achieve the goal of green manufacturing, process selection should be carried out judicially. For example, if a part can be manufactured easily and conveniently by a metal forming process, then it should be produces by machining, which wastes a lot of material. Although green manufacturing includes good manufacturing practices on existing technologies, it is essential to invent green manufacturing technologies. In the last two decades, a number of green technologies have been developed, but they are not popular in industries. Awareness and fine tuning is required in order to popularize these technologies.

Acknowledgements

Support from the Engineering and Physical Sciences Research Council (UK) through grant EP/K028316/1 and Department of Science and Technology (India) through grant DST/RC-UK/14-AM/2012, project Modeling of Advanced Materials for Simulation of Transformative Manufacturing Processes (MAST) is gratefully acknowledged.

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Applied Research at University to Enhance Manufacturability

Dr P Aravindan, *PhD*, *FIE, FIIPE*

Principal Director Research, Dr. M.G.R. University, Chennai

The R&D work on solid fuel rocket motor production had been sponsored recently by DRDO, Government of India and its outcome to enhance the manufacturability of rocket motor had been given as an example of applied research work.

1. Introduction

Applied research deals with gathering of contemporary knowledge and generation of ideas through innovation and creativity with the goal of producing useful materials or devices to meet the specific needs. In carrying out R&D work, the new engineering practice of product development is used considering nonlinear behaviour of parameters causing problems which are solved through high performance computational techniques and validated by simulation.

2. DRDO: Design of Collapsible Mandrel System

2.1 Aim

Research and design of Collapsible mandrel system (CMS) which is reliable, safe and accurate for casting propellant in solid rocket motors having intricate port configuration.

2.2 Objectives

Achieve the complex propellant grain port configuration using a reusable collapsible mandrel.

Remote decoring process without causing any friction, buildup of static charge and damage to the grain shape.

Machining should be negligible, if not avoided.

The collapsible mandrel system has to ensure safety, reliability, accuracy and repeatability.

2.3 Milestones

Milestone 1: Systematic Study of Casting Solid Propellants in Rocket Motors

Milestone 2: Evolving various Design concepts of Collapsible Mandrel

Milestone 3: System improvements & simplification and Critical Design Review

Milestone 4: Detailed Design / Material Selection / Lab work Preparation/

Submission of Final Design drawings and report

2.4 Project Deliverables

CMS Assembly & Part Drawings

Assembly and Decoring Unit (ADU) Assembly & Decoring programme

Bought out items, Test Reports and IS 2063 NC Test Code

2.5 Present Practice

DRDO currently produces plain internal cylindrical bore in cast solid propellant of rocket motors by using solid plain mandrel. Then, the required complex circumferential slots configuration is achieved by machining the cured solid propellant of the rocket motor. This machining process takes nearly 40 days for 6 slot motor and 25 days for 2 slot motor. The machining is done very cautiously using special purpose cutting tools without causing any explosion of the propellant due to tool friction and this is a very time consuming, risky, hazardous and unsafe operation for shaping the complex port configuration. Elaborate arrangements have to be made to remove the machined propellant chips away from the cutting zone by the vacuum suction and special chip collection system. Thus, there is a need to develop a new system of casting solid propellant rocket motor with circumferential slot configuration, eliminating the laborious, unsafe machining practice and loss of time due to such operation.

The present practice of achieving intricate shaped propellant grain with circumferential slots, Figure 2.1 is explained below:

Step1: Plain solid cylindrical mandrel is used for casting propellant

Step2: After casting, curing and de-coring of cylindrical mandrel, plain internal cylindrical bore is achieved for the propellant grain.

Step3: Circumferential slots are machined to achieve the required propellant grain configuration.

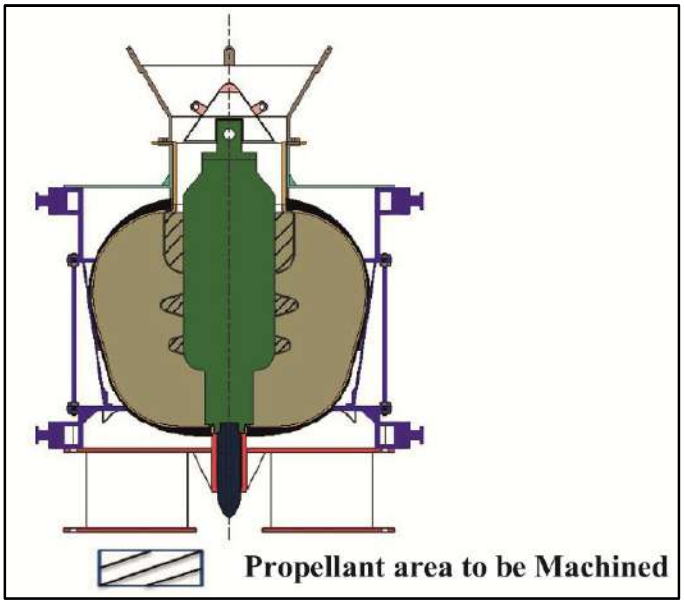

Figure 2.1: Solid propellant casting of rocket motors by using solid plain mandrel

Limitations of the present practice

1. When many units of solid rocket motor are to be manufactured, machining costs per unit can be prohibitively high.

2. Additional problems associated with machining slots are that, such operations produce undesirable quantities of propellant machining waste.

3. Slots must be radiographically inspected both before and after machining.

4. Machining of solid propellant carries a danger of accidental ignition because of the heat associated with machining friction and accidental contact of cutting tools with the hard material of the case.

It was therefore decided to research and develop a collapsible mandrel system for a 2 slot motors to eliminate all the above limitations.

2.6 Literature survey

Extensive literature survey was carried out on state of the art of casting solid propellant Rocket motors of missiles / launch vehicles used in different countries requiring complex port configuration with intricate shapes for enhancing the burning efficiency and meeting the mission requirements. These complex shapes of solid propellant grains had been achieved in defence organization of advanced countries, such as US, Russia and France by using different methods as observed, in the detailed literature survey carried out by Dr. M.G.R. Educational and Research Institute.

2.7 Conceptual Design Evolution

This project aimed by Dr. M.G.R. Educational and Research Institute, Chennai to design a new casting system to reduce the requirement of machining, if not eliminate and also meet all the functional requirements were enumerated. This new system is developed for its implementation at DRDO.

This new casting system development includes conceptualizing, designing and manufacturing of collapsible mandrel for rocket motors. The new system will enable casting of solid propellant in rocket motor with complex port configuration safely and accurately with minimal machining, which ensures faster production rate of rocket motors.

A total of eleven conceptual designs of collapsible mandrel, as evolved at Advanced Research Institute (ARI of Dr. M.G.R. Educational and Research Institute for the casting of solid propellant of rocket motors with intricate inner cavities had been presented at various stages to scientists for their reviews and comments.

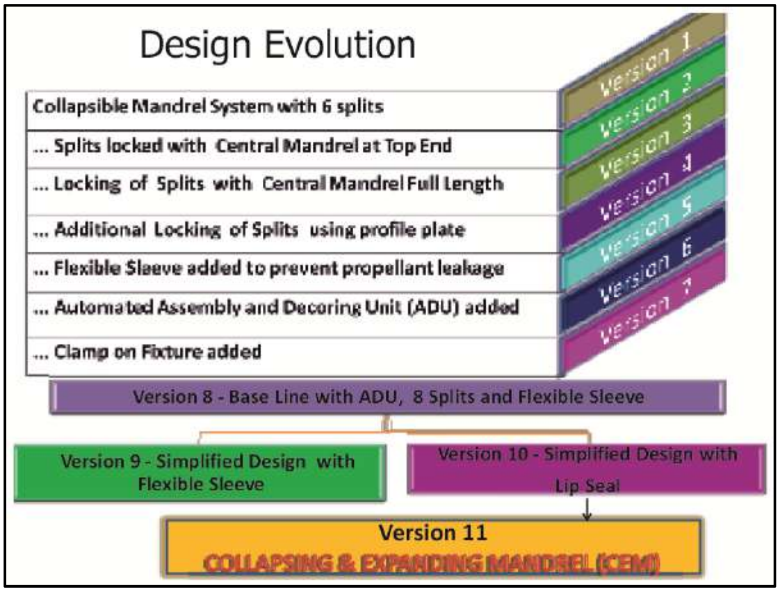

Figure 2.2: Collapsible Mandrel Concept Design Evolutions

2.8 Collapsible and Expandable Central Mandrel (CEM) Version-11

To overcome the limitations of the previous version-10, Collapsible and expandable mandrel (CEM) is newly designed to ensure uniform radial pressure across the entire length of the split joints. The lip seal design is also modified for preventing the leak of solid propellant slurry through the split joints all along its port grain profile spread from its top end of splits down to the bottom end which are placed on mandrel bottom. The same lip seal arrangement has also been selected for sealing split base joints along the peripheral cup lip surface of the mandrel bottom on which all eight splits rest. Details of collapsible and expanding mandrel (CEM) are given in figure 2.3 & figure 2.4.

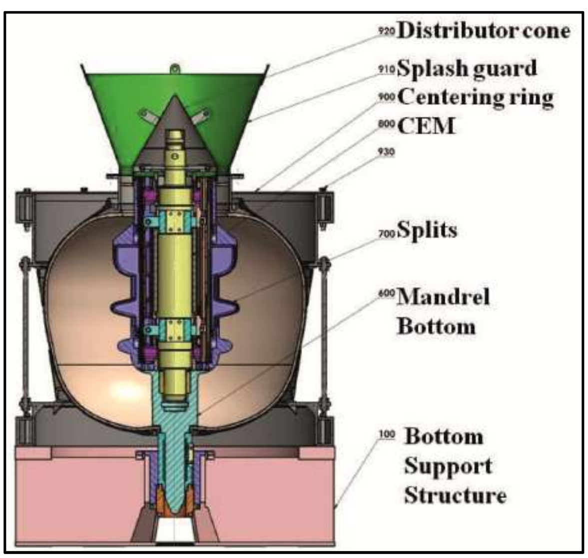

Figure 2.3: Sectional view of CEM

Figure 2.4: Exploded View of CEM

2.8.1 Lip Seal of splits

The function of the seal is derived from the asymmetric geometry of the split joints. The seal is designed to provide a fairly sharp seal lip that contacts the split joints. The flexibility of the seal is governed by the lip profile and its chemical formulation.

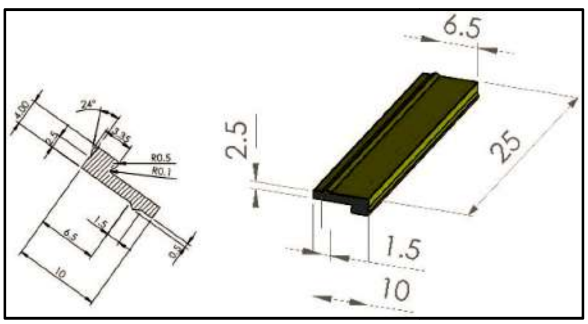

Figure 2.5: Lip seal

The lip seal design as shown in figure 2.5 is carefully developed for sealing the split joints all along its port grain profile spread from its top end down to the bottom end resting on mandrel bottom.

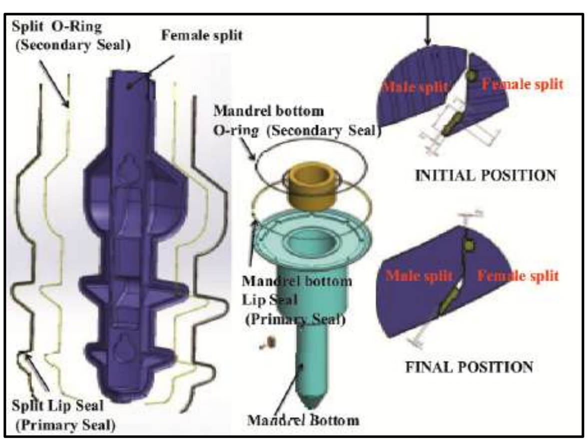

Figure 2.6: Split fixed with Lip seal and "O" ring

The mandrel bottom circular parting line mark is also so designed with protruding line mark of 0.3 mm × 0.3 mm maximum around the mandrel bottom lip seal whose thickness of 3mm is compressed by 0.9 mm at the loaded condition of CEM. The figure 2.6 shows the splits with lip seal and “O” ring.

2.8.2 Male and Female Splits

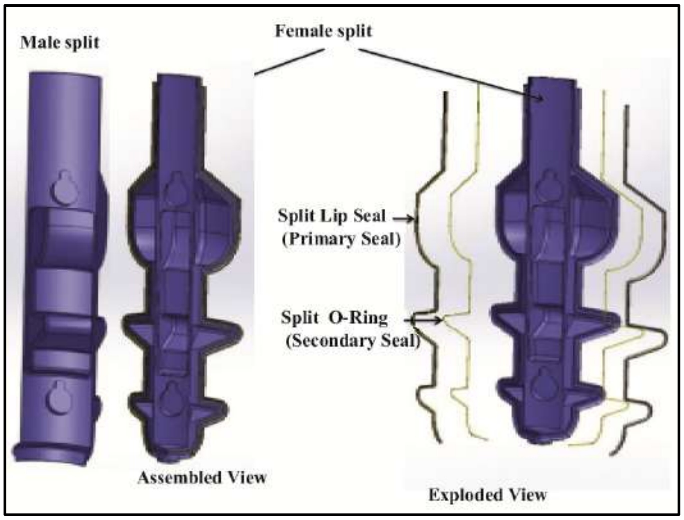

Figure 2.7: Exploded View of Male & Female Splits

3. Conclusion

Research is a continual process of reasoning based on theories and findings augmented by dynamic interplay among methods. Innovations and creativity support research and development in rendering useful services. It builds understanding in the form of models or theories that can be tested. The R&D work had resulted in a new design of a collapsible mandrel system which ensures manufacturability of solid rocket motor with complex port configuration.

Jute Geotextiles and its Applications in Geotechnical Fields

Dr Pradip Kr Choudhury, *FIE*

Principal Technologist
National Jute Board, Govt. of India

BRIEF TEXT

India produces about 1.7 million ton of jute per annum and employ more than 4.5 lac people in cultivation, manufacture, trading etc. Jute, the oldest agro based industry in India has been catering the demand worldwide particularly in packaging sector since 1856. With the passage of time demand of diversified jute products have been generated which have been developed, manufactured indigenously in most successful manner. Among the diversified jute products, technical textiles like, jute geotextiles deserve special mention. Application of geotextile for mitigating soil related problems in civil engineering is a well-tried and accepted concept worldwide. Large scale application of Jute Geotextile (JGT) in this field has started since three decades though its use was documented as early as in 1920 in Scottland and latter in 1933 at Kolkata for road construction work.

Jute Geotextile is a natural permeable textile made from 100% jute fibre having required physical, mechanical and hydraulic properties suitable for geotechnical applications. When applied in or on soil it improves the engineering properties of soil by performing the functions like separation, filtration & drainage, reinforcement and erosion control.

Some intrinsic properties of jute like, high initial tensile strength, moisture absorption capacity, unique drapability etc. had prompted scientists / technologists for development and application of JGT in civil engineering fields. The work was initially started in India by the R & D organizations during 1980s. Varieties of product developed, number of experiments and field applications were conducted with success in association with reputed organizations like, Central Road Research Institute, Canfield University of UK etc. Efficacy of the products has been established in the areas like, road construction, river bank protection, slope protection, erosion control, reinforcement of earthen embankment, control of railway track settlement, mine spoil stabilization, afforestation in semi-arid zone, growth of sapling, weed control etc. Findings of these studies have been well documented.

Various types of JGT have already established their efficacy as highly potential material for geotechnical applications. In India alone more than 280 field applications have been done successfully. Sub-grade CBR value of road has been found to increase by more than double, erosion of river bank has been checked and vulnerable slopes has been stabilized as a measure of bioengineering support. Environment consciousness among the people around the world also demanding a natural biodegradable and eco-friendly material for use in this field where jute-products fit well. Govt. of India, like other developed countries is now preferring to use this technoeconomically viable material in number of infrastructure projects in the country. The manufacturing process of JGT, properties, their function along with few successful field applications are presented.

Advanced Coatings for High Speed Machining

Dr Ajay Kumar Chattopadhyay

Professor
School of Mechanical Engineering, IIT Kharagpur

The cutting tool material, cutting tool geometry and the cutting parameters directly influence the productivity in a manufacturing industry. The development in formulation of new tool materials and the processing of the same is advancing rapidly with a view to enhancing the working life of a cutting tool which in turn increases the capability of the same for high speed machining, dry machining and machining of difficult to machine materials at higher material removal rate. Though tool life is influenced by the geometry of cutting tool, cutting parameters and cutting environment, it is governed mainly by the properties of cutting tool material i.e. physical, mechanical, thermal and chemical properties. The improvement in cutting tool material can be realized by enhancing its strength, toughness, hardness and wear resistance specially at elevated temperature to cope up with failure by mechanical breakage, plastic deformation and rapid and excessive wear. After attaining adequate strength, toughness and resistance to plastic deformation, the gradual wear on face or flank of the tool appears to be major cause of tool failure. Therefore, control rate of growth of tool wear becomes obviously focal point in the development of modern cutting tool material. The cutting tool should ideally possess high resistance to brittle fracture and plastic deformation but extraordinary resistance to wear. Hardly-one can find a material having ideal combination of properties as required by a cutting tool. Thus, the concept of cutting tool material with dual property has emerged i.e. core property along with precisely tailored surface property according to the requirement of machining.

The technology of surface coating has a pivotal role to play in fine tuning the surface properties of the cutting tool like wear resistance, anti-welding and chemical inertness. Cutting tool wear is not only influenced by the cutting velocity or the environment. The work material properties can have an overriding influence. The coating materials need to be finely tailored to offer remarkable resistance against a work material. Various CVD (chemical vapour deposition) and PVD (physical vapour deposition) techniques are industrially available and advanced technologies are currently under development aiming at deposition of multilayer coating, multi component coating, superlattice coating, superhard coating and composite coatings. The effectiveness of coating technology may be assessed by its ability to coat cutting tools with nanocrystalline structure, high density, improved adhesion, low residual stress, low deposition temperature, improved smoothness of the coating and last but not the least with high yield. Uniform coating on the cutting edge and on the complex geometry of the cutting tool is another challenge for the coating technology.CVD technology has been highly effective and commercially successful in synthesizing hard coatings like TiC, TiN, Ti(CN), Al_2O_3 etc. for cutting tools. These coatings already proved their capability in retarding tool wear in machining of carbon and alloy steels at high cutting speed in comparison to uncoated tools. Being a high temperature process, CVD technology was restricted to only cemented carbide substrate. However, with advent of plasma assisted CVD and use organic source materials the deposition temperature could have been reduced substantially and moderate temperature CVD could be scaled up for TiN and Ti(CN) coating.

The top functional layer of Al_2O_3 laid over a layer of TiC deposited on the cemented carbide substrate outperforms other hard coatings in high speed machining of ferrous materials. Remarkable chemical stability of Al_2O_3 and retention of coating hardness are the key factors in elevating its cutting capability. However, synthesis of Al_2O_3 on the cemented carbide substrate may not be that easy because of passive nature of aluminium oxide. Surface chemistry of the substrate requires modification and this is done with a base layer of TiC directly on the substrate. However, thickness of Al_2O_3 has to be restricted to 1- 2 urn. The wide difference in thermal expansion coefficient and modulus of elasticity between the coating and the substrate results in high coating-substrate interfacial residual stress leading to separation of the coating from the substrate if the thickness is too high. However, the problem can be greatly minimized by alternating a less hard coating between two layers of Al_2O_3. This may reduce the risk of crack formation and propagation in the hard coating because of discontinuity at hard and soft layer interface. Thus a composite coating architecture can be built with thickness as high as 10 µm. Thus, thicker hard coating can give longer service life than the thinner coating.

The role of the substrate at high speed machining associated with high cutting temperature is also found to be quite important. The coating protects the substrate. The substrate on the other hand provides support to the functional coating. Measures should be taken so that the substrate does not undergo plastic deformation. This will ensure mechanical stability of the coating. In this regard a heat insulating layer may act as a thermal barrier and minimize the chance rise of substrate temperature substantially. The heat shielding layer can be deposited on the adhesion layer which is attached to the substrate. Al_2O_3 being a very effective insulating material may provide additional benefit in holding form stability of the substrate.

Emergence of PVD technology has also opened up new opportunities in the field of cutting tools. The most important feature of the process is the low temperature deposition capability thus, allowing use of HSS (high speed steel) as the tool substrate along with cemented carbide. One of the most successful product of PVD technology happens to be TiN coating. The process can be done either by vacuum evaporation or sputtering route. In early days electron beam gun was used as the heating source in the evaporation system. However, presently arc evaporation is routinely used in industry for coating of the cutting tool. Arc technology has shown its strength in terms of yield and adhesion of the coating. However the coating lacks the smoothness as required for the sharp cutting edge. Deposition of coating material in the form of droplets followed by its condensation on the tool surface is not uncommon in arc deposition process. This makes coating rough and uneven and unsuitable for many machining applications. Sputtering technology on the other hand has many variants like DC, pulsed DC and RF (radiofrequency). Magnetron has been incorporated in the M system to obtain different modes of sputtering like balanced magnetron, unbalanced magnetron, mirror field unbalanced magnetron, closed field unbalanced magnetron sputtering (CFUBMS). The CFUBMS in pulsed DC mode has shown tremendous potential for deposition of advance coating for cutting tool application. A smoother coating can be produced by pulsed DC CFUBMS in comparison to what can be obtained by arc evaporation process. However, sputtering technology still faces stiff challenge from arc technology so far as yield and adhesion of the coating is concerned.

In recent years emergence of HiPIMS process (High Power Impulse Magnetron Sputtering) has completely changed the scenario in the field PVD technology. This new technology has already demonstrated its potential in synthesizing nitride coatings like (Ti, Al)N, (Ti, Cr)N, (T, Al, Cr)N, (T, Al, Cr, Si)N with microhardness exceeding 35 GPa. In a way it combines the advantages of both arc and sputtering technology. It requires even lower deposition temperature than what is needed for arc deposition process. Interestingly, high density coating with exceptionally high hardness, adhesion and smoothness can be obtained. Low residual stress in the coating also, allows one to make even a thicker coating. This upcoming deposition technology can offer many coating solutions for cutting tools aiming at dry and high speed machining and machining of difficult to machine materials.

Manufacturing Technology Trends of 2019 & 2020s

Dr L Karunamoorthy

Chairman of Faculty of Mechanical Engineering, Anna University, Chennai, India

Ladies and Gentlemen,

Vanakkam!

I would like to express my heartfelt gratitude to the organizing committee of the Institution of Engineers - India, for extending this opportunity to me to deliver this lecture in memory of Professor G C Sen, one of India's most distinguished professors, to whom teaching was a dedication not just a profession.

Let me also extend word of gratitude to N Rajasekaran, Convenor -Technical Committee- NCPE 2019,for his efforts in bringing the legacy of Professor G C Sen to the current generation, which will provide best guidance and mentorship.

It is fortunate that his dedication is not forgotten and his revolutionary works being continued by good hearts like Institution of Engineers, helping us get a glimpse into the professional life of this legendary engineering professor GC Sen.

I know about some of the many contributions of the popular Vice Chancellor of Jadavpur University and now it is time to know more about him and spread his messages to young engineers.

As Dr. A. P. J. Abdul Kalam said, Teaching is a very noble profession that shapes the character, calibre and future of an Individual, If the people remember me as a good teacher, that will be the biggest honour for me.

Professor Sen was an active personnel of production engineering and contributed to a great extent towards changes in manufacturing. In his honour and remembrance I have hence selected manufacturing as my field of lecture. Yes we are now going to expose the "Manufacturing Technology Trends of 2019 and 2020s".

INTRODUCTION

The next decade will be wrought with technological change across the manufacturing industry. How painful or pleasurable that is depends on what you decide to invest time and energy on today.

No manufacturer wants to look at 2020 in hindsight full of regret about what could have been done differently. To prepare for all the critical transformations besetting the industry in the coming decade, which are not only poised to restructure your business, but the very nature of modern society, you have to know all (be major technologies at play.

III today's fast-paced global economy, manufacturers are facing demands like never before. Their customers expect products that are more customized to their individual needs, the speed of innovation and new product releases continues to accelerate and the tolerance for error has become razor-thin.

And if that was not enough pressure, the Internet now provides buyers with more options than ever before; to thrive, manufacturers must deliver excellence. They must accelerate product introduction, create more agile shop floors, and improve order fulfillment through intelligent connected operations.

Industry 4.0, the fourth Industrial revolution, is revolutionizing manufacturing by providing manufacturers with the opportunity to utilize advanced manufacturing capabilities and information technology (IT) throughout the product lifecycle.

As a result, manufacturers are benefitting from increased visibility into operations, substantial cost savings, faster production times and the ability to provide excellent customer support.

The only way manufacturers can stay ahead of competitors and win market share in today's quickly morphing environment is to embrace change. Those who wish to thrive and not just survive are leveraging the latest in growth-inducing Industry 4.0 technologies.

INTERNET OF THINGS

The Internet of Things (IoT) k having a major impact on manufacturing, giving manufacturers more visibility into their operations, enabling predictive maintenance on their machines, and allowing them to provide remote support to their customers.

Manufacturers are increasingly leveraging the Internet of Things (IoT), which involves the interconnection of unique devices within an existing Internet infrastructure, to achieve a variety of goals including cost reduction, increased. efficiency, improved safely, meeting compliance requirements, and product innovation.

IoT's existence is primarily due to three factors: widely available Internet access, smaller sensors, and cloud computing. Which means that more devices sometimes including unfinished products will be enriched with embedded computing. This will allow field devices to communicate and interact both with one another and with more centralized controllers, as necessary. It will also decentralize analytics and decision making, enabling real-tune responses.

"IoT and predictive analytics are having a major impact on manufacturing, offering exciting new opportunities for connecting operations and transforming business processes," said Michael Strand, Senior Vice President at Hitachi Solutions America. "Innovation is driving business growth, and technology is enabling manufacturers to evolve with an increasingly digital-first business landscape."

A recent Gartner study projected that by 2020,

• There will be nearly 20.8 billion devices on tile IoT by 2020.

• 41% of manufacturing organizations use sensor data frequently

PREDICTIVE MAINTENANCE IS KEEPING PRODUCTION ON TRACK

A breakdown in critical equipment is costly to manufacturers both in terms of repairs as well as downtime and loss of productivity. According to Information Technology Intelligence. Consulting, 98% of organizations say a single hour of downtime costs over $100,000. Ensuring that all equipment is functioning optimally therefore remains a key priority for manufacturers, many of whom are turning to predictive maintenance technology to do so.

Predictive vs. Preventative Maintenance

Unlike preventative maintenance which seeks to decrease the likelihood of a machine's failure through regular maintenance, predictive maintenance relies on data to determine a machine's likelihood of failure before that failure occurs. Widespread adoption of predictive maintenance technologies could reduce companies' maintenance costs by 20%, reduce unplanned outages by 50% and extend machinery life by years according to management consulting firm McKinsey & Company.

Predictive maintenance programs monitor equipment using any number or performance metrics. By automating the data collection process through the use of IoT technology, manufacturers can develop a better understanding of bow systems work and when they will fail. This allows manufacturers to move from a repair and replace model to a predict and fix maintenance model using predictive analysis which relies on data, statistics, machine learning, artificial intelligence and modelling to make predictions about future outcomes.

SIMULATION, VIRTUAL MODELS AND DIGITAL TWINS

Simulations will be used more extensively in plant operations to leverage real-time data and mirror the physical world in a virtual model, which can include machines, products, and humans. This will allow operators to test and optimize the machine settings for the next product in line in the virtual world before the physical changeover, thereby driving down machine setup times and increasing quality.

E.g.: A digital twin of the machine could be use the real time data and predict the remaining service life of the parts and order it on time or summon the maintenance team before the failure occurs. It could be used to simulate the machine under various real time parameters and arrive at an optimal performance of the machine with help of AI.

Autonomous vehicles will dramatically shift maintenance, with smart sensors, machinery will be able to self-diagnose potential maintenance issues, while autonomous devices will be able to visually confirm the issue, determine a solution, assemble the correct tools and parts, and perform the fix. This will be especially useful in places where maintenance is difficult to perform, like cell towers and bridges. This type of predictive maintenance will help manufacturers increase the speed of doing business, reducing down time and costs.

VR AND AR ARE CONTINUING TO FORGE WINNING PARTNERSIDPS BETWEEN MAN AND MACHINE

Assistive technologies, such as augmented reality (AR) and virtual reality (VR), will continue to create mutually beneficial partnerships between man and machine that positively impact manufacturers.

Due to VR software interlacing seamlessly with computer-aided designs, product developers can use VR to quickly make modifications and additions to products during the product design stage before they go into modeling and manufacturing processes.

AR devices such as electronic glasses or goggles, place computer-generated graphics in a worker's field of vision that provide him with real-time help when it comes to performing a task. AR technology can also be used with cameras and sensors for training. Workers can be shown how to perform a task and use the data feed to correct mistakes, which makes it possible to quickly and effectively train unskilled workers for highvalue work.

Augmented Reality based systems support a variety of services, such as selecting parts in a warehouse and sending repair instructions over mobile devices. These systems are currently in their infancy, but in the future, companies will Blake much broader use of augmented reality to provide workers with real-time information to improve decision making and work procedures.

SHIFTING FOCUS FROM B2B TO B2B2C

Brands are trying to manage growing customer expectations by taking greater control over their value chain, from R&D to delivery. This is forcing manufacturers to shift from B2B to B2B2C businesses, placing a greater emphasis on tile end user's needs and experience.

There are benefits and risks — financial, social, security, emotional- involved in every consumer purchase decision. When consumers make a purchase, they are not just buying a product, they are buying an experience, This experience includes their experience with a product, but it, also extends to the complexity of purchasing, how they tee) in-store, the packaging the ease of setup and their confidence in getting the support they need should an issue arise. "How much stress is this going to cause me?" "What will my friends think?" "What are the chances this mil break?"

B2B businesses need to be more end-consume focused. They can no longer simply focus on their customers' needs, they must now consider their customers' needs.

This transition has turned B2B businesses into B2B2C businesses, causing manufacturers to reassess their products and services based on these evolving demands.

To effectively sell direct to consumers you will need to select a platform for your e-commerce operations that supports both your B2B and B2C sales platforms. It will have to deliver on order fulfillment and tracking, secure payments, customer service management, and sales and marketing activity tracking while providing a 3600 view of all your B2B and B2C customer interactions.

• Increased customer demands are forcing businesses to take greater control of their value chain.

• Manufacturers need to be more transparent and end-customer focused.

• 87% of global consumers consider CSR when making a purchase decision.

• Today, one third of manufacturers classify their degree of digitization in their value chain as high and more than 80% expect to have digitized their value chain within five years.

LEVERAGING SUPPLY CHAIN FOR COMPETITIVE ADVANTAGE

Manufacturers are evolving their value chain to provide a stronger focus on customer experience, better support, and more transparency. The evolving value chain, in conjunction with new technology like 3D printing, has created new business opportunities for manufacturers, starting with the ability to personalize. Manufacturers are already starting to offer manufacturing services that an mere akin to the "on-demand" ordering (often referred to as "real-time demand fulfillment") than traditional manufacturing, and its impact is starting to be felt. Twenty nine percent of businesses reported that personalized service through technology was already disrupting their market.18 Personalized products are already emerging in impactful ways, including personalized medical devices and customized pharmaceuticals, as well as more playful applications like personalized toys. Technology is enabling these services both from a manufacturing perspective, as well as from an operations and logistics perspective.

The growth of the Internet of Things (IoT) has also played a large role in developing manufacturing as a service. With the added ability to monitor products after they have been sold, manufacturers can gather usage data and use predictive analysis to offer preventative maintenance. This will absolutely revolutionize the service industry in the next few years.

Drivers will no longer need to bring their cars in for cheek-ups. Instead, their car will self-diagnose problems and report when maintenance is needed. Manufacturers can send any needed parts to the autoshop in advance, and the mechanic performing any work will be able to view a diagnostic report before their customer even shows up.

The movement towards smart-manufacturing facilities and digitalized value chains is having a major impact on manufacturing businesses. Today, one third of manufacturers classify their degree of digitization in their value chain as high and more than 80% expect to have digitized their value chain within five years. And while the opportunities are great, the cost of purchasing smart machines and digitizing is expensive.

With Industry 4.0, companies, departments, functions, and capabilities will become much more cohesive, as cross company, universal data integration networks evolve and enable truly automated value chains.

• 64% of companies surveyed said that their ability to negotiate and collaborate with alue chain partners will become more important.

• 29% of businesses reported that personalized service through technology was already disrupting their market.

• 59% of manufacturers already use robotics technology,

ERP SYSTEMS ARE CONTINUING TO STREAMUNE PROCESSES

Small to medium sized manufacturing companies are increasingly recognizing that an enterprise resource planning (ERP) system is key to creating a lean and competitive advantage.

ERP systems offer two key benefits:

• They streamline processes by automating all business operations and providing accurate, real-time information.

• By providing accurate real-time information, administrative and operational costs are reduced. The end result is that manufacturers can proactively manage operations, prevent disruptions and delays, break up information roadblocks and help users make quicker decisions.

The lengthy implementation of traditional ERP systems can be frustrating for manufacturers. Now, however, you have the option to choose a rapid implementation ERP system, which can be up and running much faster and more affordable than traditional ERP systems.

GREATER VISIBILITY INTO BIG DATA IS HELPING MANUFACTURERS ACHIEVE MORE

With better data collection and cloud-enabled analytics platforms, manufacturers have greater visibility into their businesses and operations than ever before.

One of the biggest challenges for big data has been managing the volume and speed. While faster, more reliable data is a stride in the right direction for big data, it also creates new challenges, what IBM bas coined, "The Four V's of Big Data." The four V's include volume (scale of data), velocity (analysis of streaming data), variety (different forms of data), and veracity (uncertainty of data).

Manufacturers are now relying on a new breed of analytics tools designed to make big data more easily accessible, including machine learning, predictive analytics, and automation tools. Big data, in and of itself, is not useful; it becomes useful when it can provide knowledge, make processes more efficient, and allow manufacturers to operate more efficiently. These tools help manufacturers with detection, classification, probability, and optimization.

Big data analytics refers to the collection and comprehensive evaluation of data from many different sources of production equipment as well as enterprise and customer management systems. IoT transforming almost every surface into a sensor for data collection and providing real-time insights for manufacturers. This ability to collect data from so many sources combined with increasingly powerful cloud computing is finally making big data usable. The enables them to improve production, optimize operations, and address issues before problems arise. They may become standard to support real-time decision making.

• 45% of organizations said that gaining access to data from different areas of the business was a top pressure driving their need for analytics.

• 47% of global businesses feel they have insufficient access to the data they need.

• SMAC-stack (Social, Mobile, Analytics, and Cloud) is changing the way manufacturers do business.

In the SMAC-stack, social capabilities, empowered by the cloud, enable businesses to share data more efficiently, improving collaboration. Not only do these social capabilities provide better internal communication, they also improve communication between suppliers and other vendors in the supply chain.

EMRRGING TECHNOLOGY

Technology has always been a driver of innovation in manufacturing and today's emerging technologies are no different. From 3D printing to nanotechnology, these cutting edge tools and techniques are changing how products are made.

3D printing

3D printing is one of the most exciting emerging technologies in business and manufacturing today. Through an additive layering process, it allows manufacturers to print virtually any 3D digitally rendered Image in physical form. This growth has been driven by technological improvements that have resulted in lower machine and material costs, as well as faster printing times. While 3D printing is not new, these improvements have made 3D printing much more practical for a larger set of manufacturers. In fad, 3D printing adoption among small companies is quickly catching up to that among large companies, 59% compared with 75% respectively, and the gap is closing.

The applications for 3D printing is expansive, including customized medical devices, personalized products and packaging, and printed replacement parts that allow ships to make repairs while at sea. Uses have already emerged allowing users to print their own beauty products in custom shades, and pharmaceutical companies are .testing 3D printing technology as a way to produce more customized medicines for patients. In manufacturing today, 3D printing is primarily being used for prototyping. Thirty-four percent of manufacturers report using 3D printing for prototyping, 28.9% say they are still experimenting with how to apply it, and 2.6% report using 3D printing to build products that cannot be made from traditional methods. As 3D printing technology becomes faster and less expensive, it will inevitably enable new applications for manufacturers.

On-demand manufacturing

On-demand manufacturing — largely aided by advancements in 3D printing — will drastically change some businesses. Imagine a part breaks on a washing machine. Instead of finding the part online and ordering it, a customer could simply print out a bar code, take it to a local store, and have the part printed for them there. Or better yet, it could be delivered via autonomous drone. Speed and convenience aside, this evolving model will have large implications for manufacturers, including a diminished need for high volume manufacturing facilitates. It would also allow manufacturers to reduce inventory demands, as well as simplify logistics for fulfillment and delivery.

Hyper-weal on-demand manufacturing — like a customer ordering a part online, printing a barcode, then using that barcode to have the part 3D printed at a local store — will not only help customers get products faster, it will reduce shop Door demands, as well as simplify inventory management.

• 66.7% of U.S. manufacturers have deployed 3D printers in some capacity.

• 3D printing adoption among small companies is quickly catching up to that among large companies, 59% compared with 75% respectively, and the gap is closing

THE MICRO-MANUFACTURER

The growing demand for artisan goods has sparked an increase in "micro-manufacturers," very low volume manufacturers. But beyond the demand for hand crafted goods, several other variables are adding to the micro-manufacturing trend. While new technology Is making manufacturing less expensive for big manufacturers, it has also reduced the cost of entry for new manufacturers. High quality 3D printers can be purchased for just a few thousand dollars; CAD software that once cost thousands of dollars to license only costs a few hundred dollars now, and it no longer requires expensive specialty machines to run; many of the processes that once required expertise and (raining have been automated; and the Internet has given individual easier access to less expensive materials.

While a person with a 3D printer in their garage might not be competing directly with large manufacturers, at scale, the growth in micro-manufacturing is already having an effect on manufacturing. And with the growth of the sharing economy, there is a real potential for a network of privately owned 3D printers to turn into a major force for manufacturing goods.

Additionally, the growth of e-commerce has helped resolve one of the largest challenges of manufacturing: distribution. From Amazon to Alibaba to Etsy to Foodoro, there are now dozens of marketplaces large and small, for micro-manufacturers to distribute and sell their products.

AUTONOMOUS DEVICES

While autonomous devices, like self-driving cars and drones, may seem like a fantasy of the future, the truth is that these devices are already here. Many automakers, including Mercedes Benz and Tesla have already rolled out cars with autonomous capabilities, and in a recent interview. Tesla CEO Elon Musk predicted that self-driving cars would be the norm in 20 years. Perhaps the biggest hurdle will come in the form of regulation rather than the technology itself. The total number of published patents for robotics and autonomous systems has grown 264% from 2004 to 2013. Robots have been commonplace in manufacturing for a long time — probably more pervasive than in any ether industry — but a new generation of artificially intelligent autonomous devices is primed to change the manufacturing landscape in three major areas: production, operations, and maintenance. Like robots of the past, robot-assisted production 10 the future will continue to help make tasks more efficient and will continue to do things that humans are incapable of doing such as lifting heavy materials, but the addition of artificial intelligence and autonomy allows these machines to operate more independently.

AGILE MANUFACTURING

Many manufacturers are moving towards an agile manufacturing approach to stay responsive to evolving customer demands and to meet the need for greater product customization.

• Product release cycles are decreasing across many industries.

• Many businesses are moving from larger releases to smaller, iterative updates.

• Speed-to-market was the top motivation for manufacturers to collaborate on innovation (25%).

As the speed of doing business continues to accelerate, manufacturers must become more agile to meet new demands, and technology paired with agile processes is enabling them to do just that.

Agile shop floor execution

Manufacturers are facing significant skills shortages on the shop floor, and yet are expected to produce more product variants with shorter ramp up times. It is your workforce that has to operate and fill the gaps between machines.

Manage your production floor with workspaces, task guides, and work instructions tailored for operators and supervisors, that can adapt to the display on any device, enhancing local productivity and global visibility with operational insights.

MODERN DAY WORKFORCE NEEDS TO UPGRADE WITH THE ADVANCEMENT IN TECHNOLOGY

Knowing today, what jobs will be in demand tomorrow is difficult. Two centuries ago the vast majority of workers were farmers. Today only 1% of the workforce is in developed countries' farms, yet they produce significantly more than their predecessors ever could dream of. Manufacturing jobs that existed a century ago did not exist the century before they did. Similarly in the world today, manufacturers are much faster than capitalists a century ago, could have ever imagined.

A century from today, the jobs of today will be replaced by entirely new ones. The jobs that were done by labourers, then by workers using machines, and today increasingly by machines themselves, will, grow fewer.

According to one estimate, 5 million jobs existing today will be lost by 2020. However, those who are skilled in "computational thinking" and skilled in using software to "spot patterns In massive amounts of data" will be in ever greater demand. Marketing professionals working in the domains of Market Research and Marketing, with skill in using "big data Information", will be highly valued by several companies.

Yet workers must learn to upgrade with the use of new emerging technologies such as Big Data and Artificial Intelligence and use the same in their fields if they do not want to be left behind and replaced by automation or a better-skilled worker.

Small is the new big

Advancements in manufacturing technology, lower cost of entry, a need for speed, and the demand for more customized products is leading to growth in smaller more localized manufacturing.

• The top reason for localizing manufacturing was to shorten Supply chains (79 %).

• The artisan trend is impacting many industries.

• A lower cost of entry is enabling a tier of small scale, low volume manufacturers

Since the Industrial Revolution, manufacturing bas largely sought efficiency - "lean" - which has led to optimizing processes within larger, centralized facilities. For the rust time in 250 years, this is starting to shift. Improvements in manufacturing technology and transportation have helped reduce the cost of manufacturing, diminishing the value of large, centralized manufacturing plants. It has also reduced the cost of entry, making more room for small and mid-sized manufacturers that may not have been able to secure enough capital to open a shop in the past.

INTELLIGENT ORDER FULFILLMENT

Even if you have invested in the latest intelligent automation and digital manufacturing on the shop Door, supply and demand exceptions can threaten your ability to meet promised delivery dates to customers. With global visibility of inventory, manufacturing and logistics, and a role tailored workspace accessed anywhere, on any device, your customer service representatives can proactively explore production, warehouse and transportation remediation options for your customers.

INDUSTRY-UNIVERSITIES COLLABORATIONS

There has long been an. understanding of the value of industry/University collaborations, however, until recently this was limited to a few select partnerships. In 2019, Jinks between industry and academia will continue to strengthen as both sides seek to use the resources and expertise of the other to enhance their own. offerings and increase their understanding of the theoretical and practical applications of new technologies.

• Product release cycles are decreasing across many industries.

• Many businesses are moving from larger releases to smaller, iterative updates.

• Speed-to-market was the top motivation for manufacturers to collaborate on innovation (25%).

To conclude, manufacturing has seen not only rapid growth through the years but has also evolved and still evolving, employing newer means and methods as manufacturers have realised that the only way to slay ahead of competitors and win market share is to embrace change.

I thank the Institution of Engineers, Tiruchirappalli Local Chapter, Bharat Heavy Electricals Limited, National Institute of Technology, Anna University, BIT Campus, Tiruchirappalli.

I wish all participants the very best in all their future endeavours.

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About Production Engineering Division Board

The Production Engineering Division of The Institution of Engineers (India) was constituted in the year 1984. This Division consists of quite a large number of corporate members from Government, Public, Private Sectors, Academia and R&D Organizations.

Various types of technical activities organized under the aegis of Production Engineering Division, which include All India Seminars, All India Workshops, Lectures, Panel Discussions etc., held at various State/Local Centres of the Institution. Apart from these, National Convention of Production 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 '**F W Taylor**' and '**G C Sen**', doyens in the field of Production Engineering, which are delivered simultaneously by the experts in this field.

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

- Lean Manufacturing
- Cellular Manufacturing
- Rapid Prototyping
- Nano-technology for Industrial Applications
- Micro Finishing and Allied Operations
- Bio Inspired Manufacturing
- Process Optimization and Control
- Sustainable Manufacturing
- Green Manufacturing
- Digital Manufacturing
- Surface Engineering and Micro-machining
- Micro and Nano Robotics
- Online Multi Sensor Condition Monitoring
- Fractal, Bionic and Holonic Manufacturing

In order to promote the research and developmental work in the field of Production Engineering, the Institution also publishes **Journal of The Institution of Engineers (India): Series C** in collaboration with M/S Springer which is an internationally peer reviewed 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