CHAPTER 1

Introduction

With the ever increasing complexities of manufacture and discoveries of newer and better techniques of manufacturing, there has been a remarkable need for changing the "look" and "character" of modern machine tools. By the terms "look" and "character" we mean the aesthetic quality and functional characteristics respectively. These functional characteristics are enriched by higher spindle speeds to reduce the machining time, greater rigidity, increased power output and higher efficiency of metal removal.

The accuracy of manufacturing close-to-form and close-to-tolerance jobs, uniformity in manufactured parts, minimum losses in friction in the various kinematic parts of the machine tool- require certain changes in the orthodox machine tools particularly in their drives and controlling units. The uses of different cutting tools (to mention in particular mineral ceramic tools in lathe and milling machine) require the spindle to be provided with suitable bearings capable of accepting increased power transmission and able to maintain its rigidity even under the cases of unavoidable temperature rise with the life long accuracy.

Remarkable advance has been made all over the world in the field of design and development of machine tools. This will be clear by a mere critical comparison between a machine tool built today and the same machine tool built nearly a decade ago. The directions towards which all these developments have taken place are innumerous. Gone are the days when the safety factor of four was considered essential in designing for the sections of the beds and box details of the machine tools. Designers of today are more careful in considering weight-to-rigidity ratio as an important factor of aesthetism and finer functioning rather than relying on the methods of rule of thumb evolved by mere experience and intuition. The evolution in the field of

plastics and synthetic material has made possible the substitution of orthodox materials thereby reducing the time and money involved.

The study of dynamics of machine tools – a subject of comparatively recent origin enabled us to design machines which could minimize the machining errors that are liable to creep into the job under the dynamic condition, viz. deflection error, positional error, error due to vibrational instability etc.

1.1 The Fields of Development

Machine tools are nothing but instruments which have been created for the purpose of manufacturing wider range of products of all categories. Their designs therefore are variable functions dependent on time, obsolescence, technological changes, etc.

Every year more and more machines with newer and better accessories are being marketed. The production of all such machines is the outcome of specialized demand from the various engineering industries. In the manufacturing of their products, these machines are instrumental. The all - round developments in machine tool engineering can be very aptly-illustrated by Figure 1.1.

1.2 Classification of Machine Tools

Broad classification of machine tools was done by Schlesinger [2] and later on emphasized by N.S.Acherkan [1] et. al. in their book based on the functions they could perform. Such functional groupings of traditional lines was spread over distinct groups such as:

Group 1: Turning (Centre Lathe, Turret, Capstan, Semi-automatic, Automatic)

Group 2: Drilling (Horizontal, Vertical, Radial, Pillar, Multi-spindle, Jig Boring)

Group 3: Grinding & Polishing

Group 4: Gear tooth and Thread grinding

Group 5: Milling (Universal, Vertical, Surface, Horizontal, End etc.)

Group 6: Planning & shaping machines

Group 7: Sawing & cutting machines

Group 8: Miscellaneous

The broad groups of machine tools ; as given here are on the basis of functions. Other system of classification, as advocated by more and more

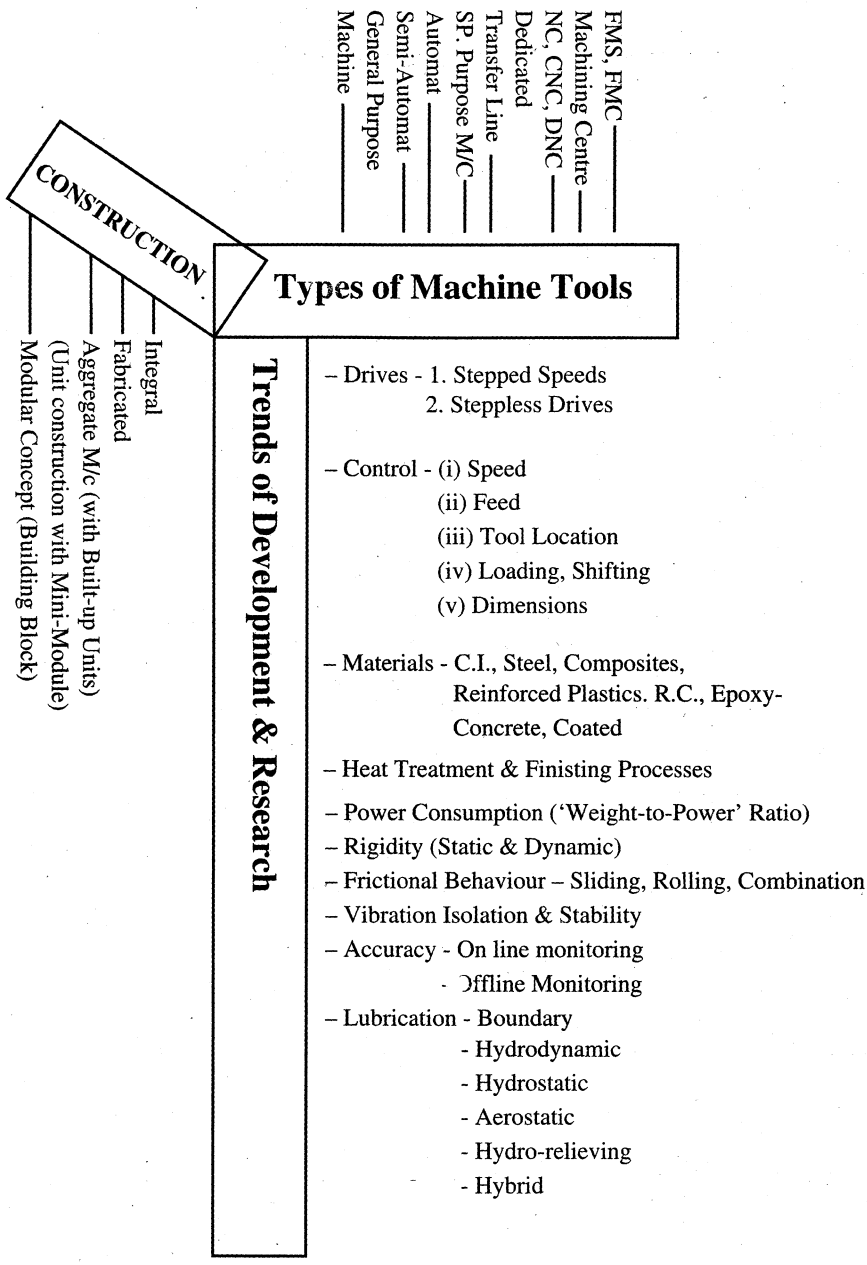

Figure 1.1 Trends in the development of Machine Tools.

authors and machine tool professionals including the manufacturers are somewhat exhaustive as shown in Figure 1.2.

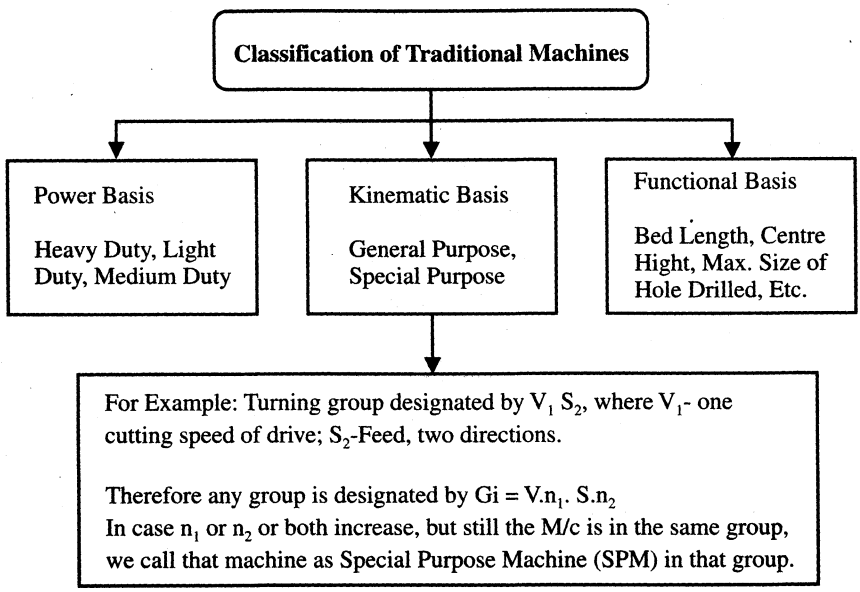

Figure 1.2 Present day method of classification.

But the classification of NC, CNC machines are little different from the traditional system of grouping & classification as given in Figure 1.3.

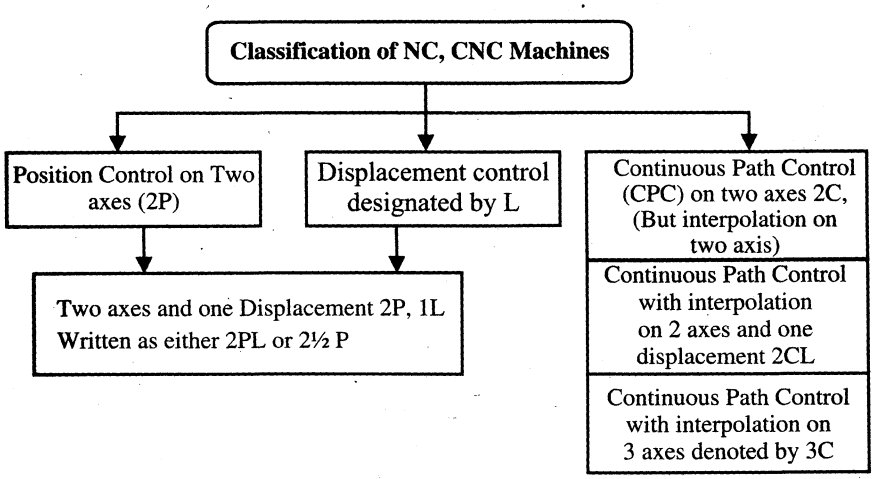

Figure 1.3 Designating the Numerical & Computer Numerical Control machines.

The NC, CNC, DNC and CNC machining centres are mainly distinguished by

(i) Positional control of various axes of operation (nP)
(ii) Displacement control (L)
(iii) Continuous path control (nC)

Where P, L, C stands for positional, displacement and continuous controls respectively and '*n*' stands for number of axes respectively as shown in Figure 1.3.

In many heavy machine tools there is a wide scope of R& D activities in the field of welded structure, plasma assisted machining, concrete filled bed, etc.

The trend of R & D in metal cutting machines is towards:

(i) Unit head construction – to some extent based on building block concept;
(ii) Development of automatic control system with or without feedback;
(iii) Design of elements including bearings, spindles, beds, etc.;
(iv) Use of adhesives for joining elements;
(v) Design and tribological consideration for life and dynamic stability;
(vi) Types and tribological characteristics of materials used , including composites, metal matrix composites;
(vii) Lubrication system including hydrostatic, hydrodynamic, aerodynamic or hybrid systems of lubrication, like aerostatic-cum-aerodynamic or hydrostatic- cum-hydrodynamic etc.

In the field of machine tool drives we are more and more drifting towards individual drive, that is to say each machine being driven by a separate motor. Every buyer of machine tools will like to have as many number of speeds as possible on his machine, even though the workers will be using only a few until and unless under strict supervision. This tendency has a natural leaning towards stepless regulation. Of course, to save machining time every machine tool should be provided with stepless regulation. The stepless regulation can be effected by friction and pressure variators, electro-mechanical regulation, hydraulic, pneumatic and electronic systems. Friction and pressure variators can give stepless regulation only to a limited range. Similarly electro-mechanical regulation gives us only a near approach to stepless regulation. Controlling of speeds can be done by three ways, namely simple, selective and pre-selective. In pre'selective control we can change a speed without going through any intermediate change or without completely stopping the machine during major manipulation. The controlling levers can be arranged best by taking into account the principle of

ergonomics ; that is to say the controls should be located within the easy reach of the operator. Depending on this we can have centralized control or decentralized control.

Modernization of machine should be done from the point of view of increasing the speed of working and power consumption. There is practically no limitation of power required for a machine tool except the economic consideration. With the increase in technological possibilities the modernization of machine tools must be directed towards reducing the number of accessories and simplifying the problem of servicing.

Machine tools are nothing but instruments for production of some kind or other and therefore when we buy machines, in reality we buy production. In order to increase the level of production and thereby reduce the human labour spent on the same, we must try to automatize the technological processes. Automation is only one of the fundamental steps in all-round technological developments of our country. For the purpose of automation, it is absolutely necessary to put in energy to the executive organ of the machine tool to overcome the force due to cutting, friction, etc. and to provide certain information in some form or other depending upon the configuration of the job to be made.

Copy turning lathes manufactured by the Ordzonikidze factory in Moscow work on hydroservomechanism for the control of microfeed and microdisplacement of the tool dependent on the tracer movement. In copying lathes machining time can be shortened by using multitool for machining on the principle of single tool. The designs of these machines are so compact that in no case they occupy more space on the shop floor than an ordinary machine of the same power.

Most of such copying machines, when used for machining antifriction bearing races or universal joint crosses, are provided with special automatic loader. The copying lathe has many features which favour individual automation. Out of these the following features are worth mentioning:

(a) automatization of turning process by copying from a template;
(b) automatization of work cycle with automatic multicut recycling device;
(c) automatization of the extended work cycle by automatic spindle speed change and automatic programme control.

Progress of Machine Tool Building

Flow production using transfer mechanisms and "inline" transfer machine, rationalization of industry and standardization of- components-are but a few essentialities of the technically advanced countries like Russia ENIMS (the

Institute for Experimental and Scientific Investigation in Machine Tools) in Moscow is one of the many research institutes that Russia is proud of. Staffed with well-trained scientists and engineers, the institute is carrying out work in all possible fields of development of machine tools. The factory "Stankokonstruksia" in the name of Lenin is also associated with this research institute. Stankokonstruksia is engaged in manufacturing mostly gear cutting, thread grinding machines, etc. Side by side the factory is also engaged in manufacturing experimental prototype machine designed by ENIMS. This research institute is divided into various sections, viz. general investigation in machine tools, electrical equipments of machine tools, metal cutting section, grinding machines section, programme control section, hydraulic control section, pneumatic equipment section, prototype section, etc.

Apart from ENIMS, various other firms are also engaged in research, design and construction of new types of machine tools. Automatically controlled drum type turret lathe designed and constructed by Gorky Automatic Machine Tool Factory in Kiev is undoubtedly a new one incorporating modern accessories. Kolomna Machine Tool Works which specializes in the manufacture of heavy duty vertical lathes and boring mills is situated only a few miles from Moscow. In the research laboratory attached to this factory considerable work has been done in the field of hydrodynamic lubrication under the leadership of M.N. Tsirlin, G.A. Levit and others. In the Institute of Automatics, Kiev, considerable researches in the fields of various control systems, servo-mechanisms and micro-displacement etc. are being carried out.

More and more uses are being made now-a-days of plastic guides. Such guides have been used so far in heavy duty planing and vertical boring machines.

Plastic materials bonded to the cast iron surfaces of the table V-guides have been used in Butler No. 8A spiral-electric planing machine. In many heavy duty machines of U.S.S.R. such plastic guides have been used. But in U.S.S.R. the mostly used plastic is textolite metallurgical variety B. In ENIMS considerable research work has been carried out into the characteristic behaviours of the plastic guides by A.S. Lapiduce, G.A. Levit and U.N. Sokolov ajid others.

Concurrently *t* tremendous amount of researches have been carried at Cincinnati Milacron, in the field of adaptive control, numerical control and computer numerical machines. Various machining centres and 'in-line' transfer machines developed in various places are the ultimate fruits of such researches. In the University of Berlin under Dr. G. Spurr, a large volume of

work had been done in the field Computer Aided Design (CAD) and computer aided manufacture (CAM).

In the Production Engineering Research Association, Melton Mowbray, U.K., work is being carried with great success, in automatic transfer of jobs in transfer machines and use of computer controlled robots for almost universal 'work in the field of metal processing. Progress in the application of robots to interact with sophisticated manufacturing processes has been made possible by the developments in microprocessor technology allowing large increases in the capability of robot control systems to deal with variability. This work was done under the able guidance of

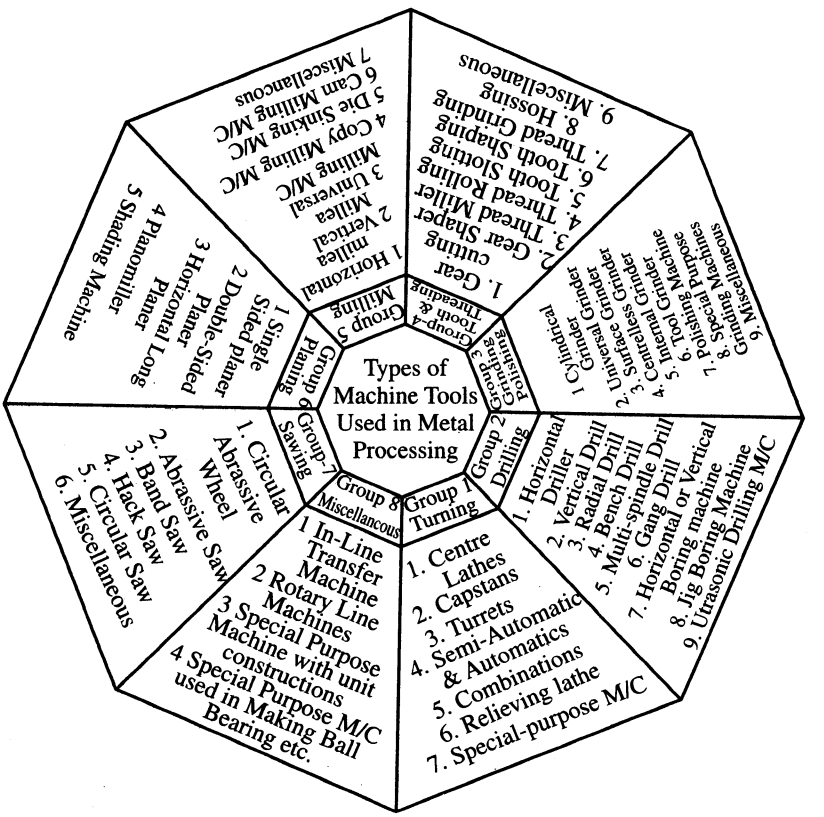

Figure 1.4 General Classification of Machine Tools.

W.B. Heginbotham, Director General of PERA. Readers may like to refer to the publication of Heginbotham, published in the proceedings of the 9th AIMTDR Conference held at IIT, Kanpur in December, 1980.

Progress of Machine Building

To overcome the shortage of skilled operators in an expanding technological sphere, the evolution of computer controlled machines is a general outcome. Manufacture of defence goods requires more and more precision and uniformity of the manufactured parts and we all believe that such demand will only increase with the passage of time. All over the world there is a trend towards manufacture and uses of computers numerical control (CNC) machine. There are firms now specialising in the development of computer controlled machining centres, and transfer machines with centrally controlled systems.

In the field of dynamic acceptance tests and stability of machine tools, the work done in the University of Birmingham under the leadership of Dr. S.A. Tobias is worth mentioning. Prof. Tobias had been doing valuable work in the field of machine tool vibrations.

Concurrently a large volume of work has been done all over the world in the field of metal cutting. The new concept of metal cutting and the basic scientific ideas connected with it have considerably influenced the design of a modern machine tool.

Hydrodynamic and hydrostatic slides are now-a-days commonly used in heavy duty machine tools. Researches are being carried out to obtain high speed air bearings (with one lakh r.p.m.) to be used in precision machine tools. Synthetic bearings and bi- or tri-metallic bearings are also finding increasing use in machine tools.

Dynamic Data System (DDS) advocated by Prof. S.M. Wu had almost revolutionised the field of condition monitoring using dynamic data for determining the malfunction or functional characteristics of system consisting of multiple subsystems. This indicates the growing use of stochastic processes in production engineering. It is a modelling technique using dynamic data in the form of a 'time series' to develop physically meaningful stochastic, difference and or differential equation. This system, which is based on time dependent data, can be used for universal application in all fields of engineering.

Machine Tools in India

Though manufacture of machine tools in India dates back to early twentieth century, planned production of the same started only after independence when the giant public sector undertaking Hindustan Machine Tools at Bangalore came into existence. Amongst the pioneers in the field, it is

Mysore Kirloskar that produced conepulley lathe in 1941. Subsequently considerable emphasis was laid on the production of the indigenous machine tools during our first five year plan and the target production of machine tools in subsequent plans. In effect there was a rapid progress in building 'mother machines' which could serve as infrastructure for manufacturing engineering and other commodities. The programme was launched with the slogan 'Build machines, Build India'. Today the Hindustan Machine Tools which is the biggest machine tools complex in India has opened up a new promise in the field of building indigenous precision machine tools in diversified field with up-to-date technological knowhow.

Though during the last 10 years considerable amount of developmental activities have taken place, the amount of export of machine tools has also gone up, as is evident from available statistics indicating the import of machine tools during the said period. This is because our R&D efforts in some specific areas of machine tools could not match with sophisticated technological know-how available in advanced countries. This, is particularly noticeable in the field of heavy machine tools wherein import of machine tools had to be done to meet the latest available technology. But this import of know-how in some cases has also helped us in developing our expertise for absorbing the associated technology, enlightening ourselves, and for effecting further imjrrovement in our developmental activities for producing indigenous machines.

Import of know-how in the form of foreign collaboration is normally characterised by a slower rate of assimilation by the recipient, thereby rendering the know-how obsolete or ineffective after a short time. The only means of combating this technological obsolescence may be 'in-house' R&D, so that assimilation of imported technology and innovative work go hand in hand.

Our Central Machine Tools Institute at Bangalore, Central Mechanical Engineering Research Institute, Durgapur, Machine Tools Laboratories at various IITs and in house R&D facilities attached to various major machine tools industries provide excellent infrastructural facilities for absorption of sophisticated technology, development of newer and better technology– appropriate to the requirement of the country, as well as development of quality products which could stand in the competition at home or in the export market.

Infrastructural facilities available in our country for research, design and development of machine tools, at present, provide an excellent opportunity to lay more emphasis on quality and ingenuity in design thereby resulting in self-reliance in R&D activities.

Under special requests from the Government of India, UNDP and UNIDO have agreed to set-up, in co-operation with CMTI, a modern NC training-cum-administration centre at Bangalore. The CMTI has already initiated its work on the developmental activities in the field of CNC machine tools during the last few years.

The R&D activities are now more focussed on the following machinery:

(1) Metal cutting machine-general purpose and special purpose including precision machine tools;
(2) Heavy machine tools;
(3) Metal forming machinery etc.; and
(4) Plastic processing machinery and foundry machinery etc.

In addition to this, development work in the other field of 'com-petence-oriented-machine-tools' is also under progress, in non-conventional machines such as EDM, ECM, NC and F.M.S., CNC machining centres, auto-tool exchanger etc. though such activities are still now limited and in some cases suffer due to technology gap.

Though India has made rapid stride in manufacturing machine tools, many of our machine tools have bold leap to take due to either design being back-dated, or obsolete, lacking in precision and not incorporating essential features of control and monitoring. Constant pressure grinding machines, machines with adaptive control are yet to be developed indigenously.

In metal forming, Hindustan Machine Tools at Hyderabad, Godrej, Scotish India Machine Tools, etc. are producing some medium and heavy machines. In the forming machines category Hindustan Machine Tools exhibited in IMTEX 79 newly developed high speed press, flow forming lathe, while Godrej and Boyce Manufacturing Company exhibited pneumatic press brake, high efficiency transfer press, etc. In many heavy machine tools there is a wide scope for R&D activities in the field of welded structure, plasma assisted machining, concrete filled bed, etc.

The trend of R&D in metal cutting machines is towards:

(i) unit head construction—to some extent based on building block concept;
(ii) development of automatic control system with or without feed back;
(iii) design of elements including bearings, spindles, beds, etc.;
(iv) use of adhesives for joining elements; and
(v) design and tribological consideration for life and dynamic stability.

Machine Tools Development Council, through various subgroups have already finalised sectoral technology report for metal forming machines, heavy machine tools, precision machine tools with modular constructions. All these reports show up-to-date demand assessment, indicate the technological gap and identify technologies requiring to be updated.

Modular concept, as stated above, is useful for building general purpose machine. A few self-contained units (unit heads) are so designed that they may be arranged in different combinations to suit the machining requirements of particular component. Thus thc requirement of a special purpose machine might be largely eliminated. This gives flexibility in design and in most cases shows techno-economic viability, with particular reference to their uses in small scale sector.

The growth in the computer technology indigenously has provided a basic support structure essential for development of good numerical control machine tools. Such technological development undoubtedly help us consolidate our path of self-reliance in the field of machine tools and effects development of indigenous know-how. Though self-reliance is essential to a great extent in machine tool R&D, 100 per cent self-reliance, which no country in the world has achieved, is not needed. In cases where requirement of some machines is negligibly small, it may be economic to import technology, rather than justify heavy expenditure on R&D.

Since machine tools industries is one of the basic industries on which depends the economic upliftment of the country, it has become necessary today to pay more attention to some of the vital points which almost challenge our existence in tne technologically competitive market.

Machine Tools Exhibition held in 1975 (IMTEX 75) which exhibited 500 machine tools and 5000 allied equipments, lend a tremendous boost to Indian machine tools industries. IMTEX now, held regularly, show further progress of the machine tools industries and explore new possibilities of export. It is really needed that we should occupy a respectable position in the export market and this requires rethinking in our export strategies to some extent.

In the field of high precision machines, the technology of manufacture calls for special plant and equipment, viz, Jig Boring, Jig Grinding and other super finishing machines, since the extent of precision in terms of dimensional tolerance varies in the range of IT-2 to IT-6.

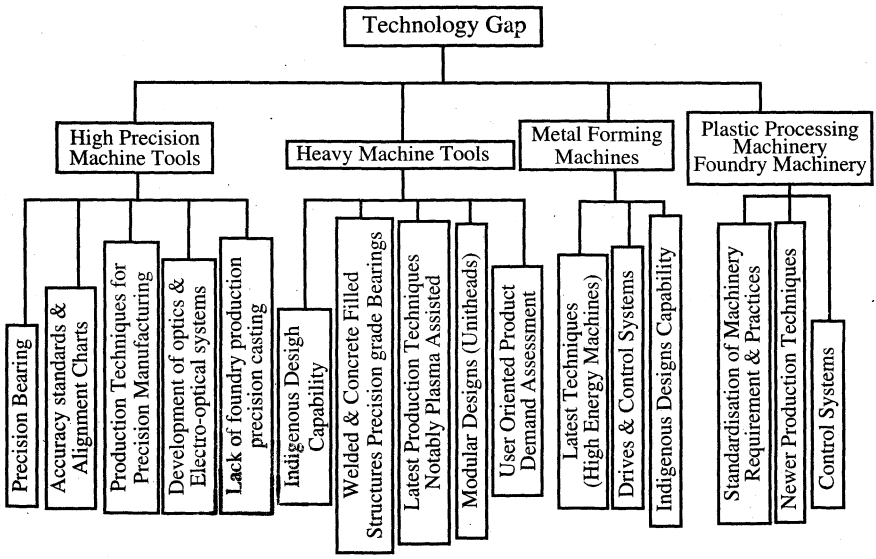

Figure 1.5 Technological gap in some areas of machine tools.

Central Manufacturing Technology Institute (CMTI) has established Acedemy of Excellence fot study & research in advanced manufacturing technology in Bangalore, where in addition to scheduled training programmes, it conducts other programmes, as well as, 'on-site' programmes at 'customer's premises, and corporate training programmes etc.

Similarly, there is a need for Research Centre for heavy machine tools, apart from promoting 'in-house' R&D in various heavy industries. This is essentially to bridge the technology gap, assimilate sophisticated technology-appropriate to our requirement, make technoeconomic viability study and to project our futuristic trend. To a limited scale foreign technical collaboration is also needed, particularly in certain areas of heavy machine tools.

For plastic processing machinery, indigenous design capability is available to a large extent. What is morereeded is researches into the production processes and their impact on newer design. Standardisation of units, and control system is also an essential need. CIPET, the Institute set up for the purpose, is already proceeding with this task with a view to achieving self-sufficiency.

It is necessary for CIPET to build up expertise in design and standardisation of toolings, moulds etc, since many users of plastic processing machinery are still not in a position to reduce the already existing technology gap, be it in small scale or medium scale sector.

Central Mechanical Engineering Research Institute has also been considerably helping manufactures to design special-purpose machines.

Establishing and Expansion of Machine Tools Industry

These developments have now brought us to a stage where our further course of action with regard to technological developments and marketing at home and abroad has to be concentrated on following points:

(a) We should put all our efforts and concentrations to produce goods primarily for the Indian market. Many of our machine tools may not be saleable in the industrially advanced countries. For example most of the lathes manufactured in India uses simple geared head-stock with lower horse power which are practically unsaleable in developed countries where the requirement is more for machines having more horse power, being more rugged in construction and easy to maintain, on account of high labour costs. Adaption of such technology is not difficult at all, but requires a considerable judgement in regard to value and economic viability.

(b) We should concentrate on setting up of factories in the developing countries in partnership with local entrepreneurs on the basis of technical know-how fee and royalty.

(c) Government of India, through its agencies like Planning Commission and Department of Science and Technology, should concentrate more in giving aids in the form of pilot projects etc. on the basis of the technological know-how deve-loped at national laboratories, to its neighbouring countries and least developed countries.

(d) We should participate more and more in world trade fairs. This is justified for boosting up our image in foreign market and exploring further directions of export possibilities. We had experienced quite an impressive boost after our participation in Hannover Industrial Trade Fair as early as in 1973.

(e) Such participation helps our engineers and designers to have an opportunity for expert comments and feedback of information related to their work from foreign users. They are also exposed to up-to-date or latest designs marketed by our competitors.

(f) For the more developed countries of Europe, America and Japan, in order to upgrade our technology we should aim at
   (i) manufacturing machines either complete (for fitment of advanced control systems, or
   (ii) manufacturing machines, partly machined and assembled (PMA) for final assembly abroad.

(g) So far as export of machinery or technical know-how, we should have stronger link with the least developing countries (LDCs). This will help us utilise the already developed technical know-how in regard to sophisticated machine and thereby gradually build up our own expertise.

(h) Value Engineering and Ergonomics study is absolutely essential. Not much work has been done in this field till now. But to survive in global competition, we must regard this as an important strategy.

(i) User's education: User should be taught to use simple machine with added functional performance and not 'anything sophisticated' machine, with all the gadgets on.

(j) Probabilistic method of determining the size and capacity range should be adopted before modernising our existing machines.

(k) Reliability and maintainability criteria should be primary consideration in developing precision machines.

(l) Design of special purpose machine/general purpose machine should be based on building block concept.

(m) Technology deal with LDCs or within our country between laboratories and industries must be completed as a package deal.

(n) In developing industries in the least developing countries, the manufacture of machine tools may profitably be carried out through a number of small scale industries, specialising in components, arranged in "a cellular structure feeding the centralised factory assembling the main product. This is needed essentially to develop captive ancillary units or small industries complex.

(o) For the positive growth of machine tool industries, information relating to these forms a vital segment of total informations required viz, technical enquiry regarding product, new information, compilation of state of art and trend reports, technoeconoinic data etc. National Information Centre for Machine Tools and Production Engineering (NICMAP) recently set up at CMTI, Bangalore, as a part of National Information System for Science and Technology (NISSAT) is a welcome step in dissemination of knowledge. It is certainly going to help transfer of technology.

There are large number of Indian agents representing Indian as well as foreign firms manufacturing machine tools and accessories. In such cases NICMAP supplements the process of exchange of information and guidance leading to transfer of technology.

Conclusion

The industrial image of a country depends to a large extent on the reputation and quality of the capital goods which it manufactures and exports.

Therefore the indirect benefit consequent on our improvement in the image of the country will greatly enhance the export of all manufacturers especially in the field of metal working engineering goods.

We should adopt a special strategy for export to the ESCAP (Economic and Social Council for Asia and Pacific) region and to other developing countries, where the technological advancement and skill are not at the same level as found in India. Now our growth has certainly reached an adequate high stage of technology, as has been seen from the research and development work done in our various National laboratories and Research Institutes and In-house application oriented researches in various industries.

That India had the potential to assist LDCs in this field is clear from UNIDO meeting held at Tbilisi-USSR as early as in October 1974, wherein it was felt that India having reached intermediate stage of technology should seriously consider assisting LDCs, in the development of machine tool technology.

Jyoti CNC Automoation Ltd., Gujarat, produces a wide range of CNC machines for any of metal cutting application. Milling machines produced by Bharat Fritz Warner Ltd. (BFW) continue to play a key role in the Jet-set age of machining across the country. During the period spread over last 25 years, in particular, in the field of CNC turning, Milling & Grinding Machines. All Micromatic groups have been making high quality machines with indigenous technology. In the field of ECM, EDM manufacture, the role played by Technofour Ltd. is remarkable. Indian Machine Tool Manufactures Association offers training programmes for machine tool design & manufacture for the benefit of the prospective young intreseted engineering. Such courses offer hands-on-session in tune with application-oriented as well as Industry endorsed curriculum. Apart from the brief informations put up here, these are a large number of small and medium scale industries catering to the needs of manufactures demands for special purpose machines as well as well as machines with NC, CNC systems.