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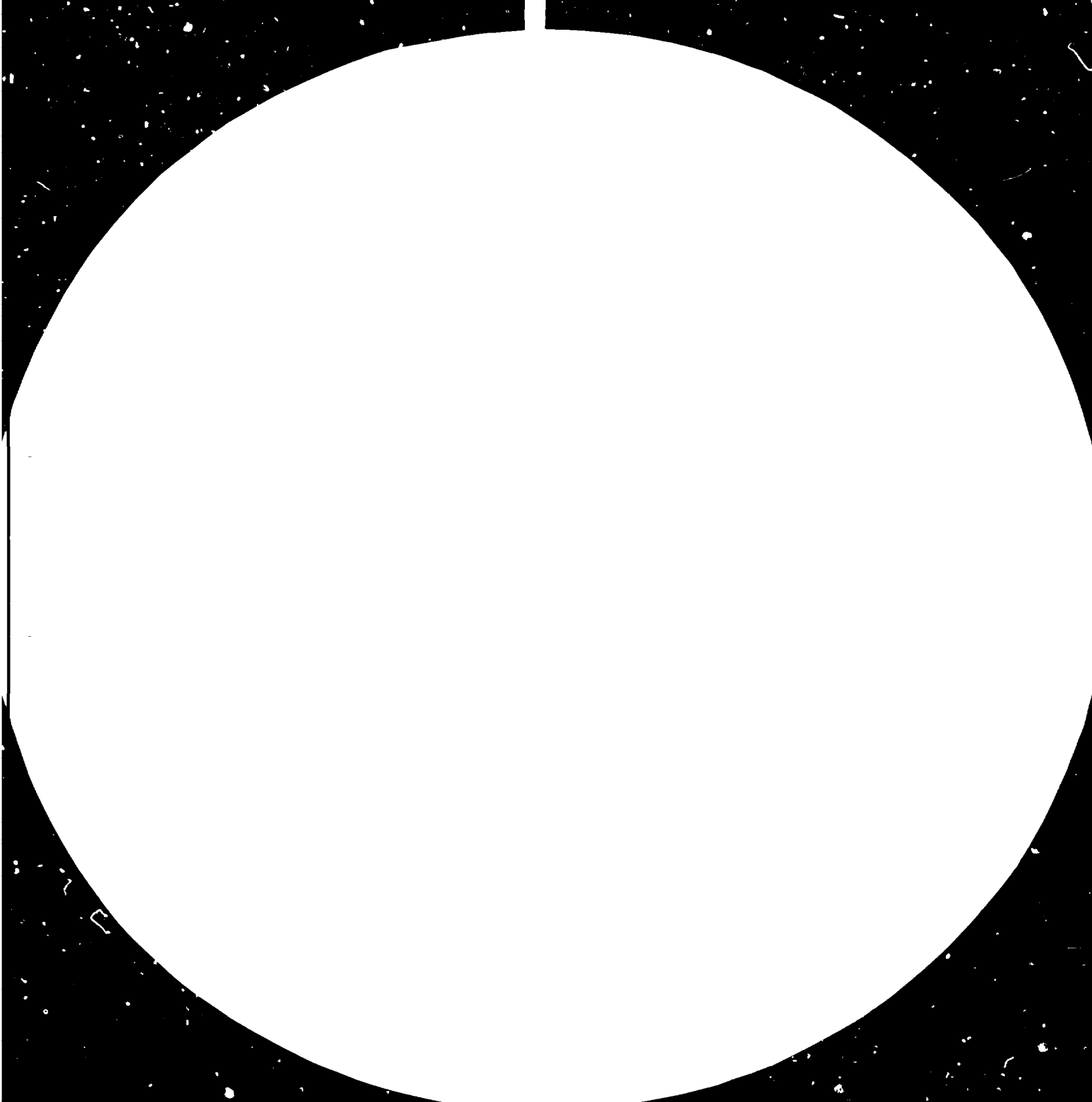

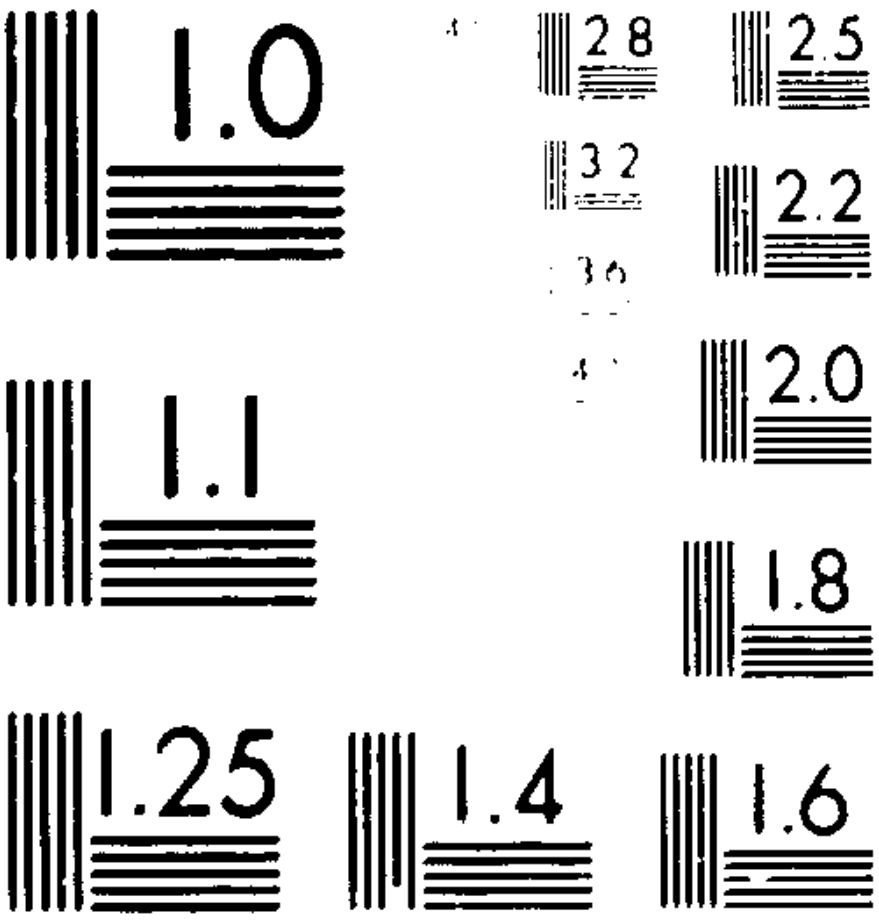

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T E C H N O L O G Y

A N D

E Q U I P M E N T M A R K E T S*

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INTRODUCTION

Technological developments exert a profound influence on the equipment and its manufacturing industry and consequently on the equipment market dynamics. The process is rather complex and the effects are far reaching particularly in the case of basic capital goods industries. The subject paper presents a case study in the machine tool industry, and discusses the technological developments in the machine tool industry in the coming two decades, their influence on the equipment, the share of the new equipment that is expected and the structural shifts that are anticipated in the markets. In the light of this process, recommendations are given for the development of the machine tool industry in the developing countries.

With the advent of the Numerical Control and computer technology, the nature of the equipment, namely the machine tools, has witnessed unprecedented changes. The present trends of computer numerical control, direct computer control and the industrial robots, are pointing to complete automation of the production processes leading to automatic factories. The machine tool manufacturing industry in the developed countries is fast giving up the production of the conventional general purpose machine tools. But since this equipment is expected to remain in application, although in an ever decreasing quantity, the market demand continues. However, in order to compete with the high productive NC machines and machining centres, the conventional machine tools are designed with higher productivity. The construction is also expected to change to modular unit type machines in order to lend them suitable for manufacture on the automatic flexible manufacturing systems based on group technology.

With the projected total production of machine tools in the developed countries exceeding 25 billion dollars by 1990 and 35 billion by the year 2000 (at current prices) and the share of the sophisticated computer controlled machine tools and systems reaching 35% by 1990 and 50% by 2000; the planned 50 to 60% exports during the 1980s and perhaps higher in the 1990s, would have to find the necessary markets.

The conventional machine tools that are being produced in some of the more advanced developing countries would face stiff competition, both in price and quality, in the face of the high precision, high productivity modern design general purpose machines, that are emerging in the market from the developed countries. The machine tool industry in the developing countries has to be geared up to the situation. This would also become necessarey to find the markets for the sophisticated equipment of the coming years.

CHAPTER 1

TECHNOLOGICAL DEVELOPMENTS IN THE MACHINE TOOL INDUSTRY - A CASE STUDY

For the sake of clarity and completeness, the past evolutionary stages in general and the present state-of-art and the tendencies in the field of machine tool technology are presented below in brief.

1.1 METAL WORKING

Metal working developed into two distinct processes namely the metal-cutting and the metal-forming, employing two different categories of equipment, the metal-cutting machine tools and the metal-forming machine tools. In order to transform the metal into a part of a required shape, size and finish, the metal cutting process utilizes mechanical energy to 'cut' the metal in solid state at normal temperature by means of a tool of harder material, (with the exception of certain processes where local heating in the cutting zone is applied); and the metal forming process utilizes mechanical and heat energies on the metal in solid state either at normal temperature (stamping, cold forging, cold drawing, cold extrusion) or at elevated temperatures (hot forging, drawing, extrusion), and in liquid state, naturally at elevated temperature, (casting, pressure die-casting) and also in powder or granular form making use of forms, dies and moulds of materials of higher hardness and/or higher thermal stability. There are other special processes utilizing electrical energy (electro-erosion, electro-discharge) chemical energy (chemical machining), sound energy (ultrasonic-machining) and light energy (Laser beam machining) used in a limited application.

1.2 METAL CUTTING MACHINE TOOLS

In the case of metal cutting process, to generate different surfaces in the required configuration and the specified dimensional accuracy, a vaiety of operations are performed by different machine tools namely the lathes, milling, drilling, boring, shaping, planning, slotting and grinding machines using single point, multipoint cutting tools and abrasive grinding wheels.

The basic structure of the machine tools has changed very little over the years. But with the ever increasing cutting speeds and the demand for higher working accuracies, substantial advances have been made in the design of machine tools to increase the geometrical accuracy, the static rigidity and the dynamic and the thermal stabilities of the machine tools. Progress has also been achieved in the materials that are used for the construction of the elements of the machines. Considerable developments have been made in raising the productivity of each machine by mechanical and electrical programming and also by the automatic transfer lines for the large series production of components.

1.3 THE CUTTING TOOL

In the area of cutting tools, new and harder materials and wear-resistance coatings have been developed. The gradual development, from high speed steels, of harder cutting tool materials such as cemented carbides, the ceramics has brought up the cutting speeds on constructional steels up to 600 metres/minute, increasing the productivity by 4 to 5 times. Wear resistance coatings on high speed steels and cemented carbides have increased the tool life by 2 to 3 times, similarly in the case of grinding speeds beyond 100 metres per second have been reached and together with improoved methods of keeping the cutting surface of the wheel clean, the productivity is raised up to 3 to 4 times.

1.4 NUMERICAL CONTROL

The most significant technological developments have taken place in the area of control of machine tools with the advent of the numerical control concept in the early 1950s, and revolutionised the whole production process. The numerical control (NC) is the operation of machine tools by a series of coded instructions. The control commands range from the positive positioning of the tool in relation to the workpiece to other auxilary functions such as selection of tool/tool station and controlling the speed and direction of the tool or workpiece rotation and other secondary functtions. The commands are logically organized comprising a programme to direct the machine tool to perform a sequence of operations and thereby accomplish the specific task of machining a workpiece.

1.4.1. THE MACHINING CENTRE

The NC led to certain developments in the machine tool. The conventional machine tools have been redesigned to suit the NC operation. Several operations like drilling, boring, milling, etc. have been combined in a machine with considerable time saving in set-up times. The most important development had been the concept of the machining centre, where a number of different machining operations are performed in a single setup, on several surfaces of the workpiece; with the ability to automatically select the required tool from a tool magazine, insert it into the spindle, and remove after the operation and return it to the magazine.

1.4.2 COMPUTER NUMERICAL CONTROL

The programme is prepared with or without the assistance of a computer and is put in a suitable medium, which is mostly a perforated tape; and the machine control unit, which is the bridge between the programmer and the machine tool, converts the programme commands into signals for the electrical or hydraulic servomechanisms of the machine tool to obtain the actual motions of the various elements of the machine tool. The machine control unit witnessed the most rapid evolutionary development from the bulky tube type units of the early 1950's to the present day computer Numerical Control (CNC) making use of the microprocessor technology. It was in the late 1970's the full CNC concept has emerged.

The Computer (Computerised) Numerical Control (CNC) is a numerical control system wherein a dedicated, stored programme computer is used to perform some or all of the basic numerical control functions in accordance with control programmes stored in the computer's memory. The computer usually a mini-computer is dedicated to one specific machine tool or two or three simple machines. The computer is not utilized for work-piece programme generation, but a programme that is already generated is stored in the computer and is read in the execution of the programme to machine a work-piece. The executive programme can be modified at anytime and new operations introduced by simply reading them into the executive position of the control unit computer. This is usually done with a punched tape. With manual data entry is also possible to make changes in the programme that is stored in the computer, without involving the original programme tape.

1.4.3. THE ADAPTIVE CONTROL

The speeds and feeds for a machining operation are normally determined by the programmer, in accordance with the material, tool and the machine para-metres, together with certain factors of safety against unexpected adverse cutting conditions. These speeds and feeds may not always result in the optimum productivity and accuracy due to variable factors of static and dynamic rigidities, thermal stability of the machine. The concept of Adaptive Control is developing, to change the speeds, feeds and depths of cut in order to compensate for the variable system para-metres affecting the productivity and accuracy, by sensing torque, deflection, vibration and thermal deformations during the actual cutting process and giving feed-back singals for the appropriate changes in the machining parametres.

1.4.4 DIRECT NUMERICAL CONTROL (DNC)

The present day growing phenomenon in the numerical control is the extensive use of computer control, ranging from the control of a simple two-axis machine to an entire factory involving complex machining centres. The Direct Numerical Control (DNC) is a system connecting a set of numerically controlled machines to a common memory for part programme or machine programme storage with provision for on-demand distribution of data. The direct computer control system may actually be in three different levels. A large central computer, at the first level, capable of handling programming several hundred machines, hierarchies of smaller computers, at the second level, to interpret and disseminate the logic from the central computer and capable of handling groups of lines of machines and then the individual mini-computors dedicated to individual machines, with provision for remote communication with the central computer.

1.4.5 FLEXIBLE MANUFACTURING SYSTEMS

In the area of organization of the production process, the technological development is in the direction of complete automation. For the automation in small and medium batch production, in order to accommodate frequent changes in the product component, Flexible Manufacturing System (FMS) with the direct computer control are presently being developed. The system consists of a group of machine tools on CNC, with automatic

feeding and transportation of the workpiece from point to point and the system is capable of programming the sequence of operations, selection of the machine tool stations, selection of tools, selection of optimum cutting speeds and feeds, inprocess dimensional control. The auxilary operations are automated by robots.

1.5 COMPUTER AIDED MANUFACTURING (CAM)

The direct computer control in concept represents the very frontiers of manufacturing technology. The real breakthrough in manufacturing is emerging - the completely computer aided manufacturing (CAM). The concept would apply not only to manufacturing but to the interrelated processes of product design (computer aided design : CAD) and marketing. In computer aided manufacturing, the computer control would be applied to all the functions in a manufacturing process, such as inventory, tooling, production planning, scheduling, machine control, inspection, quality control, storage and so on; leading to completely automatic factories. The interrelated production functions and processes will be controlled in such a way that any action in one function, affecting any other will be sensed and corrective actions taken resulting in an optimum operation of the whole process.

1.6 METAL-FORMING MACHINE TOOLS

In the case of metal forming, in order to bring the metal into the required shape and size a variety of operations are performed by different machines. These are punching, cold forging, rolling, drawing, extrusion, hot forging,rolling, drawing; die casting, powder metallurgy, etc. on different presses and machines making use of particular types of dies, moulds and forms.

The essential features in metal forming may be said to be its high productivity and minimal metal consumption. The forming techniques are being developed as finishing operations replacing a number of conventional metal cutting operations and thereby reducing the number of metal cutting machine tools required in a production process, cold rolling for bearing races, gears, etc, cold forging and stamping of a variety of components in the automobile and agricultural machinery industries and die casting in a number of industries are coming out as more economical and productive technologies, producing higher quality workpieces.

Over the past two decades the construction of the presses has not experienced any basic changes. The principal directions of their development are: increased productivity by rationalising and automatising the auxilary operations of loading and unloading or feeding of the work material, change of dies, and simplification of setting, etc; increased speeds of operation, enhanced safety with a number of interlocks, diagnostic systems, etc. The most important technological development is the NC control of the presses and completely automatic lines, integration into production lines together with metal cutting machine tools, computer controlled production lines, etc.

1.7 METAL WORKING INDUSTRY - APPLICATION OF TECHNOLOGY

It needs no elucidation to recognize the fact that the metal working machine tools play the most important role in the metal working industry and consequently, in all the industrial sectors in general. The overall productivity of the metal working industry is a function of the productivity of the machine tools used and the quality of the product directly depends upon the quality of the machine tools employed. They also determine the level of the mechanization and automation in the industry and bear a relationship to the skills required of the labour.

1.7.1 FACTORS AFFECTING THE APPLICATION

The developments in the machine tool technology and their application in the industry, to a large extent, are determined by various factors such as the industrial sector where the machine tools are used, the product, the type of the process and the manufacturing technology employed, the production technology and the quantities involved, the nature of the raw materials that are to be worked, etc. Each one of the above factors or a combination of them demand different and specific types of machine tools: for example, heavy engineering equipment industry requires heavy and unique and specialised machine tools, the instrument industry needs high precision machine tools, generally smaller in size, bearing industry high precision, and automatic lines, and similarly the automobile, tractor industries demand special purpose, automatic lines.

1.7.2 THE TYPE OF INDUSTRY

The application of NC technology is varied in different industries, each characteristic of a certain type of production technology. For example in the automobile industry, where mass production and very large series production is employed, the advantage of the NC over other means of automation is not appreciable. In the industrialized countries of the world, NC machines found most of their application in the general machine building and aviation industries, particularly in the industries producing machine tools, internal combustion engines, turbines, etc.

1.7.3 THE MANUFACTURING TECHNOLOGY OF THE INDUSTRY

The manufacturing process exerts a great influence on the type of machine tools required. Developments in the process technologies and changing over to new processes lead to major shifts in the requirement of machine tools. Some of the developments such as die casting of parts both in non-ferrous and ferrous metals and powder metallurgy have led to certain overall reductions in the demand for conventional metal cutting machine tools. Similarly introduction of cold rolling and forging of ball bearing races, certain gear wheels, etc; pressing, stamping, hot and cold forging of a variety of parts in the automobile and related industries have, either eliminated or reduced to a minimum, a number of metal cutting operations and the machine tools required for them.

1.7.4 THE PRODUCTION TECHNOLOGY OF THE INDUSTRY

It is worthwhile dwelling briefly on the influence of the production technology employed in an industry in order to assess the application of the various technological developments in the machine tools individually and in their organization for increasing the productivity.

Automation in its early stages was essentially developed for the mass production of components. Machines were developed to perform single operations and the workpieces were transposted by mechanized means from point to point and together with the necessary automatic control of dimensions, formed complete automatic lines.

Small batch production, involving a variety of components and frequent change in the product require different means of production employing semi-automatic, automatic multiposition, multitool, special purpose, unit machines, NC machines, in semiautomatic or fully automatic production line, including metal forming presses where required. These lines are capable of change over from one component to another. The machining centres can constitute the basic elements of such automatic lines. The workpieces are fixed on to pallettes and moved from point to point.

The utilization of these automatic lines, in practice, may often be below their capacity due to various factors related to the organisation of the production process. The computer control of such automatic lines vastly improves the utilization.

The difficulty in the automation of auxilary operations, particularly in the batch production, is successfully solved by employing industrial robots with computer controls and considerable improvements in productivity have been achieved. The ease of operation with robots leads to complete automation of production lines for batch production.

1.7.5 THE MATERIAL TO BE WORKED

More and more different metals and materials are being used for a variety of equipment operating on extreme working conditions. Metals that withstand very high temperatures are used in the construction of gas turbines, rockets, space craft, nuclear energy equipment, etc., similarly high tensile, heat-resistant metals are used in making dies employed in high pressures, impacts and temperatures. These items often require extremely complicated shapes to be generated and high precision machining to be performed. These machining operations tend to be either impossible with, or lend themselves to be impracticable on the conventional machine tools. It is in these areas the electro-physical, electro-chemical and laser beam machining are employed.

CHAPTER 2

THE EFFECT OF TECHNOLOGICAL DEVELOPMENTS ON THE MACHINE TOOL MARKETS

The technological developments in the field of machine tools have greatly influenced the markets. The nature of these influences can be ascribed to different aspects of the technological developments and are prompted by a number of reasons. Some of these effects on the market, as they are happening in the industry are presented in the following paragraphs.

2.1 The effects, on the market, of the developments in process technology

2.1.1 Process technology related to materials for products

With the increasing use of new constructional materials such as zinc based alloys, aluminium alloys and plastics in a variety of products from household gadgets to automobiles, the production processes as applied to the processing of these materials are taking over the conventional metal working operations and consequently the demand for the machine tools in such areas is either decreasing or shifting to other types. 1/

Similarly in the automobile industry, it is a known fact, that the content of aluminium parts which was hardly about 5 kg by weight in an automobile in the 1940s has increased to more than 50 kg in the present day, a tenfold increase; and is expected to exceed a 100 kg towards the end of the 1980s. The content of plastics, which was about 10 kg in the 1950s has presently reached more than 80 kg and is on the increase up to 200 kg towards 1990. 2/ The components in aluminium and zinc alloys are made by die casting and those in plastics by plastic injection moulding and other plastics processing equipment, displacing in increasing proportions, the machine tools used for processing the conventional metals in the automobile industry.

1/ For example the Singer Company has reduced the metal cutting operations by about a quarter by a change-over to die casting, powder metallurgy and plastic injection moulding of some of the parts of the sewing machines of their new series.

2/ "American Machinist", January 1978.

Another area related to the materials is the increasing application of new metals and materials in equipment working at high temperatures such as gas turbines, rockets, space vehicles, nuclear energy equipment etc. and at very high pressures and impacts such as forming tools and a variety of other special applications, new machining processes like electro-physical, electro-chemical and laser beam machining are employed requiring entirely different types of machine tools.

2.1.2 Process technology as influenced by shifts between metal cutting and metal forming

Cold forming techniques developed to produce components required in the mass production industries are influencing a shift from metal cutting to metal (cold) forming methods eliminating a number of metal cutting operations and consequently the metal cutting machine tools employed earlier for these operations.

The economy of metal consumption and the higher quality, by way of increased wear resistance, strength and life of the parts produced by the chipless forming methods are other reasons prompting the use of these methods. Cold rolling of bearing races, cold forming of fine module gear wheels are proving to be high productive methods resulting in improved quality. Similarly in the automobile and agricultural machinery industry cold forging and stamping techniques are increasingly used for a number of parts required in large quantities. In the Soviet Union cold forming methods for the production of straight and involute spline shafts, among others, have been developed. The parts are completely finished and do not require any final finish grinding as in the normal methods. The accuracies obtained are in the order of 0.02 mm. The forming tools have a life of 150,000 pieces. One machine replaces 15 to 20 spline hobbing machines.

The chipless forming, without further machining or with minimum machining has led to considerable shifts in the application of other conventional metal cutting machine tools. But, however, this is limited

to certain components that lend themselves for such forming and would be, in general, applied for parts required in the automobile, tractor and similar industries. It is expected that in the next two decades the shares would reach: 25 per cent metal forming and 75 per cent metal cutting.

Within the metal forming techniques the cold forming is gaining in application. In view of considerable loss of metal in hot forming and the energy expended on it, the cold forming is more economical from the point of energy saving. It is expected that, towards 1990 the cold forming methods would have a share of 50 per cent of the hot forming operations in the 1970s.

2.2 Market effects due to development in the machine tool

The most significant development in the machine tool field had been the concept of the numerical control. The advent of NC has set off an unprecedented series of developments in the machine tools and is responsible for the remarkable and far-reaching effects that are experienced in the market and seems destined to bring about in future equally profound changes, together with the developments in the computer technology.

2.2.1 The displacement in production of general purpose machines by the numerically controlled

In the 1970s, as the production of NC machines increased, the machine tool manufacturers in the developed countries have been progressively giving up the manufacture of general purpose universal machine tools with conventional controls. 1/ Several factors are responsible: the GPMs of the traditional designs are less productive than the NC machines, they face severe competition from manufacturers that concentrate on GPMs, the demand for the NC machines with their ultimate economies tends to rise etc.

1/ As production of NC machines increased, over the period 1972 to 1976 M/S Cincinnati Milacron have dropped 32 models of conventional machines.

2.2.2 The displacement in GPMs due to developments in NC machines

With further developments in the design of NC machines, for example, the machining centres that combine operations such as milling, drilling and boring etc, the production of conventional machine tools in the milling, drilling and boring machine groups has fallen. This has resulted in another phenomenon, namely, the increase in the productivity of these machines. The manufacturers that produce exclusively these machines have increased the productivity and versatility by means of additional accessories and also by introducing numerical controls and a new set of modern, high productive machines are on the market.

At the same time, the production of turning machines, high productive machines like single-spindle and multi-spindle automatic machines, with automatic cycles and with NC have gone up in production.

2.3 Effects on the market due to developments in production technology

2.3.1 Effects of the production technology in the manufacture of the machine tools

In order to rationalize the production technology in the manufacture of machine tools, the variety of the GPMs is being reduced and more specialized multioperational GPMs are produced with machine construction modified to lend themselves for production on automatic lines. The designs are being rationalized to be in modular construction such that the unit elements can be assembled to form different variants by specification.

The concept of standardization of the unit elements of machine tools including the NC machines is expected to develop extensively. This would make possible the manufacture of the machine tools on completely automatic flexible manufacturing systems with overall economy.

2.3.2 The effects of the production technology as applied in the user industries

As already mentioned in the previous chapter in the industries such as the automobile, tractor and other similar industries, where large batch or mass production technologies are employed, the manufacturing lines are completely automatic, specially set for a particular product and were rather 'rigid'. In the small and medium batch production, as is the case with a variety of small and medium scale industries, the production lines have to be 'flexible' to accommodate a large variety of components, characteristic of a wide range of cutting parameters and composite operations. This requirement has led to the creation of flexible manufacturing systems capable of quick and easy resetting. The NC machining centres constitute the basic elements of the system and is controlled by a computer for process optimization . The difficulty in the automation of the auxilary operations is resolved by employing automatic industrial robots. The concept of the flexible manufacturing system is being introduced even in the large batch production industries.

CHAPTER 3

THE DYNAMICS OF THE MACHINE TOOL MARKET IN THE COMING DECADES

An analysis of the general present day utilization of the various technologies in the industry and the present trends would reveal the broad future tendencies and the technological perspectives and help assess the implications for the developing countries.

3.1 THE SHARE OF NC

Although the rate of increase in the utilization of NC machines in the 1970s is considered to be high, the percentage of absolute numbers of these machines in the total park of machine tools in various countries at present, is relatively very small: in Japan 1.4 per cent, USA 1.3 per cent, UK 1.1 per cent, FRG 0.6 per cent. Numbers do not convey the share, as one NC machine is equivalent to 3 to 8 and one NC machining centre is equivalent to 8 to 10 conventional machines, a more appropriate index would be the share by productive capacity. The present share in the total productive capacity is approximately: USA 10-13 per cent, Japan 9-10 per cent, UK 7-9 per cent and FRG 4-5 per cent. 1/

By the machine tool census of various developed countries, there was about 100,000 total NC machine park in 1977, with an average rate of increase of about 19 per cent per annum over the period of 1967 to 1977 2/

1/ Source: A.C. Kosminin, "The capitalist market of metal working equipment and prospects for its growth"; Bulletin of Foreign Commercial Information, No.1, 1980; USSR Market Research Institute (VNIIKI), Moscow.

2/ Source: "L'Usine Nouvelle", 15 December 1974, "Machine Outil", May 1976, "Metal Working Production", 1976, "Il Parco Machine Utensile nell' industria Italiana", 1975, "Statistical Year Book" of the USSR, 1980.

The statistical data is presented in table 3.[1/] Therefore, by very approximate extrapolation for the purposes of orientation, it may be said that the share of NC machine tools by productive capacity might be expected to be about 23 to 25% by 1990 and 67 to 70 percent by 2000 year. This indicates that by 1990, still 75 percent of the metal working would be done by conventional machines. However, by 2000 year, the share would be reduced to 30 percent.

The total production of machine tools in the developed countries in 1978 was approximately 16 billion Dollars growing at an average annual rate of about 10% over the period of 1960 to 1978. Rough projections indicate that the production will exceed 25 billion dollars by 1990, 35 billion dollars by 2000 year. The statistical data is brought out in table 4. The production figures of NC machines by some of the developed countries is given in the table 5. Judging by these figures a very approximate indication may be made that the production of NC machines would have a 35% share by value by 1990, and 50% by 2000 in the total machine tool production. (Annexure 1-A and 1-B)

Table 3

NC MACHINE PARK
(pieces)

	1976	1970	1975	1976	1977	Average rate of Annual Growth (%)
USA	12,000	20,376	36,000	40,000	45,000	14
JAPAN	500	800	8,560	12,000	15,500	38
U.K.	1,500	3,100	7,000	9,500	11,500	22
FRG	730	2,200	6,800	8,000	10,000	30
ITALY	160	848	3,290	3,960	4,780	36
FRANCE	630	1,050	2,950	3,500	4,000	23
Total:	15,510	28,376	64,600	75,960	90,780	19

1/ Source: "l'Usine Nouvelle" 15 Dec. 1974, "Machine Outil", May 1976, "Metal Working Production", 1976, "11 Parco Machine Utensile nell' industria Italiana", 1975, "Statistical Year Book" of the USSR, 1980.

Table 4

PRODUCTION OF MACHINE TOOLS IN DEVELOPED COUNTRIES *

(Million Dollars)

	1960	1965	1970	1975	1977	1978	Average rate of Annual growth(%)
FRG	582.9	851.0	1,479.0	2,349.0	2,635.8	3,287.4	10.7
USA	777.7	1,457.7	1,443.1	2,406.1	2,426.9	3,050.0	8.4
USSR	608.0	887.8	1,360.0	1,931.1	2,768.0	3,020.0	9.3
JAPAN	74.1	289.7	1,109.4	1,098.2	1,608.8	2,330.0	22.5
ITALY	109.6	112.0	433.6	748.0	878.6	980.0	13.7
SWITZERLAND	106.3	153.5	240.0	540.0	581.9	790.0	12.5
U.K.	265.7	395.6	476.9	723.0	587.8	760.0	6.4
FRANCE	158.6	226.5	316.5	554.0	591.6	716.0	9.3
SPAIN	14.5	58.1	90.2	212.0	193.1	220.0	17.3
SWEDEN	31.6	48.7	66.0	146.0	146.3	135.0	8.9
BELGIUM	17.7	27.2	33.1	91.0	106.4	124.0	12.1
OTHERS	102.3	200.0	261.4	402.7	607.8	552.6	10.4
Total:	2,849.0	4,708.0	7,310.0	11,201.0	13,133.0	15,965.0	10.0

Table 5

NC MACHINE PRODUCTION IN SOME DEVELOPED COUNTRIES* (METAL CUTTING)

(Million Dollars)

	1965	1970	1975	1976	1977	Average rate of Annual growth (%)
USA	136.6	190.1	504.7	501.0	496.7	12.4
JAPAN	1.1	78.7	134.1	173.2	301.6	35.0
U.K.	11.8	37.7	50.8	45.8	58.7	15.7
ITALY	3.0	-	-	102.3	129.0	35.0
FRANCE	1.4	10.9	91.2	81.6	93.7	35.0

* Source: Calculated from industrial statistics of the countries.

It is expected that in the early 1980's completely automatic machine tools and flexible manufacturing systems with computer control and process optimisation will be used; and in the late 1980's they will constitute about 35% by value of the total production of machine tools and executing 25% of the metal working operations. In the early 1990's completely automatic factories with robots would be operating. The share of all the systems reaching 50% by value of the total production and contributing 70% of the metal working capacity by the year 2000.

3.2 STRUCTURAL SHIFTS WITH NC MACHINES

As the production of NC machines increases and that of general purpose decreases, with a view to rationalize the technological manufacturing processes, the latter would be modified more towards unitised modular construction to lend them for manufacture on special purpose automatic lines based on group technology and they would fall some where between universal and special purpose machines.

As the production of machining centres increases, that of the conventional machines of the milling, drilling and boring families will be reduced, but their productivity and versatility will be greatly enhanced, (as it had already started happening). Their configuration would also be modified to make them suitable for operation with robots.

With the increase in production of the NC machines, that of the turning group has also increased to a considerable extent, particularly in the turret, single and multispindle automats. High productive and high precision turning machines will be produced. Universal machines for roughing operations will drastically fall.

In view of the above, it is expected that the future universal machines will be high productive, high precision, versatile machines in modular construction

The NC machines will further develop in their construction. As individual machine tools, they will develop into large size machine for machining large and complicated workpieces and as small, compact and inexpensive machines for simpler operations on smaller workpieces. The

past years have indicated the development mainly into machining centres and turning machines. The NC turning machines will further develope in their versatility combining more operations other than turning.

As elements of flexible manufacturing systems and completely automatic factories, the NC machines will be developed into unit modular construction as the production of such systems will reach 50% of the total. It is expected that about 75% of the total manufacturing technology would be based on group technology by early 1990's.

The application of industrial robots for the automation of auxilary operations and assembly operations, in the completely automatic manufacturing systems and factories, would be extensive.

It is likely that industrial sectors like the automobile industry may also apply flexible manufacturing systems.

CHAPTER 4

THE IMPLICATIONS FOR THE DEVELOPING COUNTRIES

With the exception of some of the developing countries in Europe and Brazil, India, Argentina and Mexico amongst the rest and a few others; the machine tool industry is in a very low level of development. The existing machine tool park is mostly of obsolete design, very old and of low productivity. The metal working industry is in general oriented for repair and maintenance work for other equipment in transport and agriculture and partly for the manufacture of spare parts for the same. The public sector and the organized and unorganized private sector firms engaged in the manufacture of engineering equipment and machinery are acquiring considerable skills in metal working. The economic development plans of the developing countries in general stress the importance of the metal working and machine tool industries as the sector for the development of other sectors and for the overall economic development. Presently, the most part of the required machine tools are imported. The indigenous development of machine tool industry to a large extent would depend on the capital goods and engineering industries, in particular those for the manufacture of automobile and other transport equipment, agricultural machinery, household goods, construction equipment, earth moving equipment, mining and metallurgical equipment.

Machine tool industry is the basic industry for the development of all engineering industries and other basic industrial sectors. The developing countries therefore should develop this industry on a sound and firm basis.

Some of the more developed countries among the developing have made appreciable progress in the field of machine tools. The production of machine tools in Brazil, India and Argentina is given in table 6. Over the period 1965 to 1978, the average rate of annual growth was: Brazil 14.1%, India 6.1% and Argentina 7%. In relation to the machine tool industry, the developing countries may be divided into two groups, the one having a machine tool industry base and the others that have yet to develop it.

Table 6

MACHINE TOOL PRODUCTION IN BRAZIL, INDIA AND ARGENTINA*
(Mill. Dollars)

	BRAZIL			INDIA			ARGENTINA		
	Total	Metal cutting	Metal forming	Total	Metal cutting	Metal forming	Total	Metal cutting	Metal forming
1965	30.0	30.0	-	53.0	34.0	19.0	25.8	15.5	10.3
1970	33.8	19.6	14.2	66.0	43.0	23.0	32.4	18.0	14.4
1975	137.0	95.0	42.0	93.0	70.0	23.0	42.0	21.0	21.0
1976	176.0	122.1	52.9	96.1	72.8	23.3	56.0	30.0	26.0
1977	132.0	92.4	39.6	89.5	68.7	20.8	60.0	32.0	28.0
1978	146.0	102.0	44.0	108.0	82.0	26.0	58.0	29.0	29.0

* Source: "American Machinist", January 16, 1967; January 24, 1972; February 1978; February 1979.

In the light of the technological developments in the coming two decades and taking into consideration the two groups of the developing countries, the implications may be viewed in two aspects, namely in meeting the domestic requirements by way of imports and establishing and developing their own machine tool production.

Considering the domestic requirements, in the initial period the need for simple general purpose universal machines would continue to grow, whereas the supply from the industrialized countries is either highly sophisticated automatic machines and systems or modern, highly production oriented, general purpose machines. This situation may be restored by the supplies from the more developed among the developing countries.

The more important aspect is the development of the machine tool industry in the developing countries.

The foremost question would be what type of machines the DCS should manufacture, whether the sophisticated machines or the GPMs. In view of the fact that GPMs will continue and are expected to enjoy a share by value of 60 to 70% and 50% by 1990 and 2000 respectively; The DCS should take up or continue to manufacture the GPMs.

The next point would be what type of GPMs they should prod ce, since the GPMs required and produced in the industrialized countries would be of high productive, advanced modular designs. Logically, they should go in for GPMs of high productive modern designs. But the process is not an easy one. For one reason, the designs may not be existing with them and it takes long time to develop them by themselves and secondly, they may not be readily made available to them from those that have them. There seem to be two approaches: the group one should go in for the production of the modern GPMs. The task would be easier and also difficult at the same time - easier because they already have a base for the manufacture of simple and conventional GPMs and for the same reason that they have the base, it would also be difficult since the manufacturing capacities are based on conventional production technology. However, it is necessary that they should gradually develop the modern machines, machines of modular designs; for, this would also help them in the production of special purpose machines (SPMs) that form the elements of transfer lines which would be any way required for mass and large batch production industries. For the second group of the developing countries, that do not have a manufacturing base for machine tools, the industry should be introduced. They may have to go through the same process of the three phase development of the 'technology induction' from outside sources by way of technical collaboration, 'technology assimilation' by consolidating the acquired technology and skills in the industry and then the 'technology development' on their own efforts; as some of the countries in the group one have successfully gone through. But with one exception that, in the present situation, the technology that is being introduced into these countries should be that as required for the modern GPM's. The process can be initiated with simpler machines. One important aspect that is to be borne in mind would be the simultaneous development of other industrial sectors such as the automobile, agricultural machinery, electrical machinery and other machine building industries that are interrelated and interdependent with the machine tool industry and are so essential for and instrumental in the development of the same. The

developed countries would be willing to share their technological know-how, or even it may become necessary, in order to create markets for their exports, that they aspire would reach 50 to 60% of their production in the 1980's [1/]

In the development process of the machine tool industry, for the production of GPM's, in the developing countries, those more advanced among the DCs, that have established the industry in an environment of investment and infrastructure constraints, would be better equipped to impart the necessary manufacturing skills and management abilities and introduce the culture of machine tool building by sharing their own experience. It may also be advantageous to take up a certain specialization in particular areas and types of machine tools for specific countries, instead of attempting development of all types of machines, particularly in the smaller countries and in the initial stages. To make the machine tool industry in the developing countries self-sustaining and for the sake of mutual benefit, the industrialized countries should be able to import the GPMs from the DCs.

Perhaps, it may be worthwhile to consider the possibility of international standardization of the design of basic general purpose machine tools according to types (operation wise), sizes, quality (classes of accuracy) tools and the accessories. Basing the desings on modular construction, it may even be possible to standardise the production processes and the equipment that is required for them. Basic machine tools are basic machine tools. They are required to perform basic machining operations. There is no reason why they should not be standardized. The concept is sound and has abundant common good to all. The designs, evolved through international co-operation, can be given to any country that wants to produce them.

1/ The total exports of the developed countries in 1978 was about 6.5 billion dollars. 50 to 60% of exports by 1990 would be approximately 13 to 16 billion dollars.

THE SOPHISTICATED TECHNOLOGY

The other important aspect is whether the DCs should take up the manufacture of sophisticated NC machine tools and computer controlled systems. From the view point of not perpetuating the technological gap between the developed and developing countries, and in order to make the DCs to partly meet their domestic requirement of the davanced and sophisticated machine tools and to establish a base for further development, it is necessary for them to take up the development and manufacture of the NC machines and other computer controlled manufacturing systems. In this area, it is evident that the technology transfer has to take place from the developed to the developing countries through technical collaboration. But acquisition of a technology for the sake of acquiring it, will have no consequence on the more important dimension of development. Similarly, mere assembly or manufacture of the machines with imported control systems, without initiating action for balanced growth in the other infrastructural support industries, particularly, in the electronics industry, can lead to another situation - perpetual imports, with limited effect on the development, limited to the manufacture of only the mechanical systems in the NC machines. Lack of internal demand in the industry can result in a dangerous situation of not enough domestic market, and not competitive in the export market as the prices can be high due to the heavy import content. Therefore, it is imperative that utmost caution has to be exercised and a judicious approach adopted to consider all these aspects.

The group one countries that have the necessary inputs can start or intensify their efforts in the development of the NC machines. Judging by the present and future development trends in the developed countries, the individual NC machines seem to be coming off essentially into two types, namely the NC lathes and the NC machining centres that combine milling, drilling and boring. In the case of flexible manufacturing systems, perhaps it is more suitable for the domestic industry to develop semi-automatic FMSs. The controls may be more advantageously based on microprocessor technology. Development activity should also be initiated on CAD/CAM.

The group two countries probably would need some time before they can embark on the development of NC. It may require initially about 10 to 15 years, depending on their present potential and the pace of development in a country to acquire and assimilate the machine tool technology as required for the manufacture of quality GPMs, as it had been the case with the group one countries. Towards the end of this period it would be the appropriate time to start the development of the more sophisticated NC machine tool technology.

In all the cases, constant R and D effort is essential. The sense of precision and productivity is important. Continuous development activity is needed in the areas of cutting tool materials, optimum machine tool designs with respect to stiffness, dynamic and thermal stabilities for high working accuracies, finishes and productivity, design of basic elements such as bearings, spindle units, guideways, etc. for higher accuracies, higher speeds and forces, automatic controls, new manufacturing processes, new production techniques and organization of the production processes.

The activity of development advocated for the DCs, in the foregoing paragraphs, constitutes a dual appraoch, a two pronged action namely simultaneous development of the common technology as well as the sophisticated. Both are needed. Both have their application in the relevant sectors of industry

This approach is also necessary for the mutual benefit of both the developing and the developed countries.

International co-operation is required in the spheres of standardisation, technology transfer, development of industrial infrastructure, trade; between developed and the developing countries and amongst the developing countries themselves, UNIDO's assistance in negotiation, technology transfer, development of infrastructure, establishment of production capacities and manpower development; and together with UNCTAD in trade, would continuously be needed.

CHAPTER 5

CONCLUSIONS

Following are the conclusions and projections.

1. New and high productive finish metal forming processes, particularly the cold forming techniques, are increasingly replacing metal cutting operations. It is expected that the metal forming will reach about 25 per cent of the total metal cutting operations by the year 2000; and the cold forming methods to take a share of 50 per cent of the present hot forming operations by 1990.

2. The general purpose machine tools would continue to be, but in modern high productive versatile designs and probably in modular unit construction to lend themselves for production on automatic flexible manufacturing systems based on group technology. By value they are expected to be approximately about 60 to 70 per cent and 50 per cent of the total machine tool production by 1990 and 2000 respectively. The total production in the developed countries is expected to exceed 25 and 35 billion Dollars by 1990 and 2000 respectively.

3. The numerically controlled machines, as individual units, would be on computer numerical control (CNC) based on micro-processor technology. Flexible manufacturing systems (FMS) under direct numerical control(DNC) and adaptive control (AC) for process optimization together with robots, for the automation of auxilary operations, will be increasingly used for the small and medium batch production industries, that are characteristic of frequent product change. By 1985 it is expected that about 30 per cent by value of the total metal cutting machine tools produced in the developed countries would be NC machines out of which 35 per cent would be computer controlled. The 1980s would bring in extensive use of FMS and the 1990s would herald the automatic factories.

4. Metal working methods such as electro-discharge, electro-chemical, ultrasonic, laser beam machining etc. would be applied in specific areas and for special materials and would reach about 1 to 2 per cent of the total metal working operations in the coming decade and perhaps would remain so in the next.

5. In the light of the technological developments in the field of machine tools, the developing countries should develop their machine tool industry both in the common technology of GPMs as well as in the sophisticated technology NC machines adopting a two pronged development strategy.

6. Machine tool industry is the basic industry for the development of all other industries. The machine tools are the essential equipment in the metal working industry. The technological developments indicate that the machine tools are going to be modern GPMs and automatic NC machines and computer controlled manufacturing systems. The developing countries should manufacture the GPMs for their small and medium scale industries and the NC machines for the large scale industries. The NC machines are also advantageous for the small and medium scale industries due to their overall economy, provided the initial investment is made possible. The machine tool industry in the developing countries should produce the machine tools required for specific industries like the agricultural machinery, the transportation equipment, and other specific industries, drawing from the technologies as developed in the field of machine tools and the equipment made available in the markets.

ANNEXURE 1-A

MACHINE TOOL PRODUCTION IN THE DEVELOPED COUNTRIES AND PROJECTIONS FOR 1990 AND 2000 YEARS
(Value : Million Dollars)

ITEM	1960	1965	1970	1975	1977	1978	1980	1985	1990	1995	2000
Machine tool production in Developed market economy countries	2,241.0	3,820.0	5,950.0	9,270.0	10,365.0	12,945.0	11,800.0 (1)		21,500.0 (1)		
Machine tool production in the USSR	814.0	1,265.0	1,478.0	2,412.0	2,548.0	2,560.0	2,645.0 (2)		4,860.0 (3)		
Tot. machine tool prod. in developed countries	3,055.0	4,085.0	7,428.0	11,682.0	12,913.0	15,505.0	14,445.0		26,360.0 (3)	31,000.0 (3)	35,500.0 (3)
NC machine tool production in developed market economy countries (metal cutting)	-	154.0	343.0	856.0	1,080.0	1,334.0					
NC machine tool production in the USSR (metal cutting)	-	4.0	178.0	677.0	726.0	816.0					
Total NC machine tool prod. in developed countries (metal cutting)	-	158.0	521.0	1,533.0	1,806.0	2,150.0		6,510.0 (4)	10,000.0 (3)	13,000.0 (3)	16,000.0 (3)
NC metal forming (approximate projection)									(1,000.0)		(2,000.0)

Sources: - Machine tool production and NC production figures are from published statistics of the developed countries for the period 1960 to 1978.

(1) Estimated production from A.C. Kosminian, "The capitalist market of metal working equipment and prospects of its growth", Buletin of Foreign Commercial Information: Vol. 1, 1980; The USSR Research Institute VNIIKI.

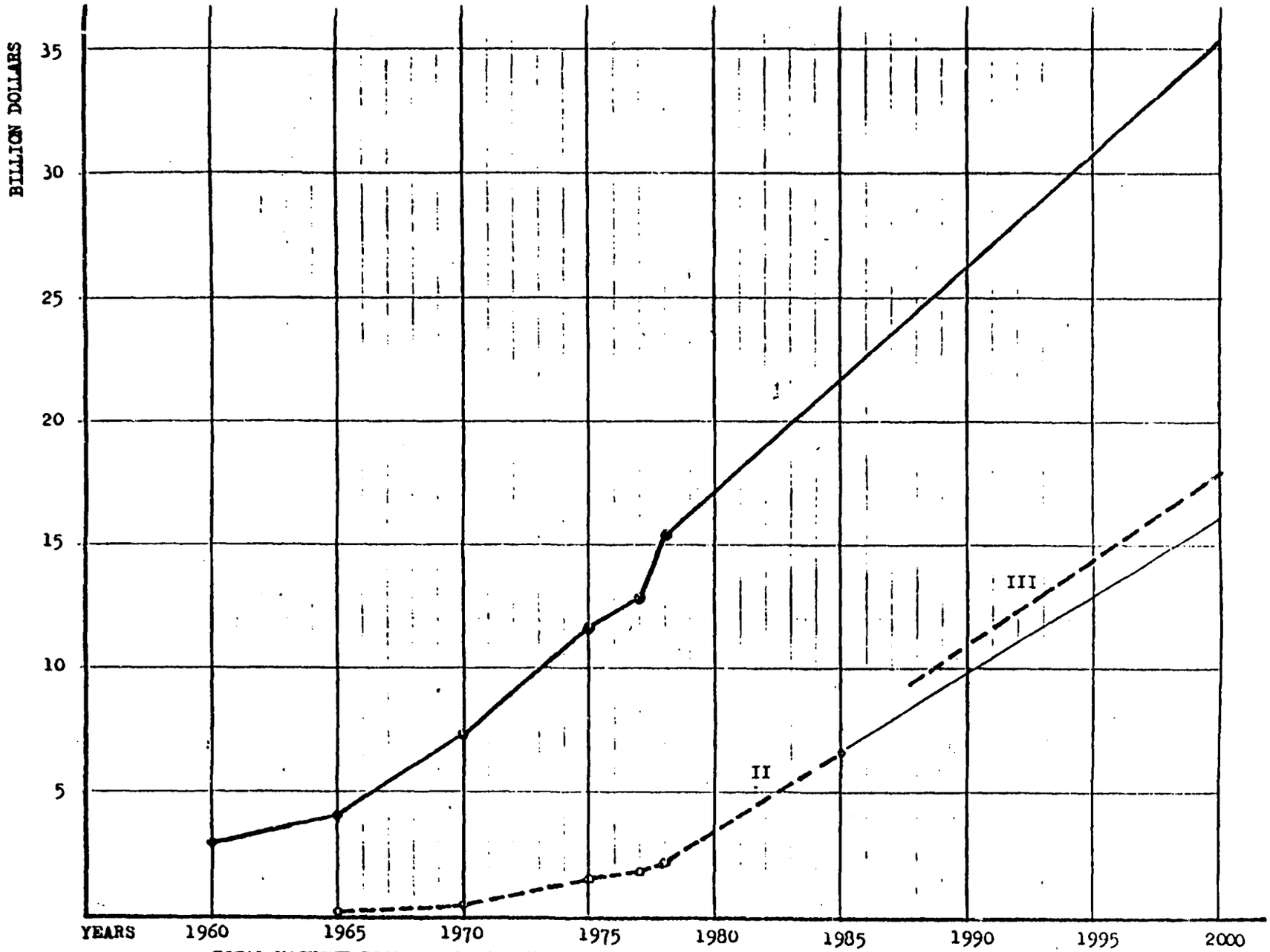
- Machine tool and NC production for the period 1960 to 1978 taken from the Statistical Year Book 1980: 'Peoples Economy of the USSR 1979'. Values calculated from corresponding prices in the developed countries of the market economy.

(2) Targets

(3) Projected by extra polation at current prices.

(4) Expert opinion

Annexure 1-B



TOTAL MACHINE TOOL AND NC MACHINE PRODUCTION AND PROJECTION IN DEVELOPED COUNTRIES

I TOTAL MACHINE TOOL PRODUCTION, II NC METAL CUTTING MACHINE TOOLS, III APPROXIMATE METAL FORMING NC INCLUDED.