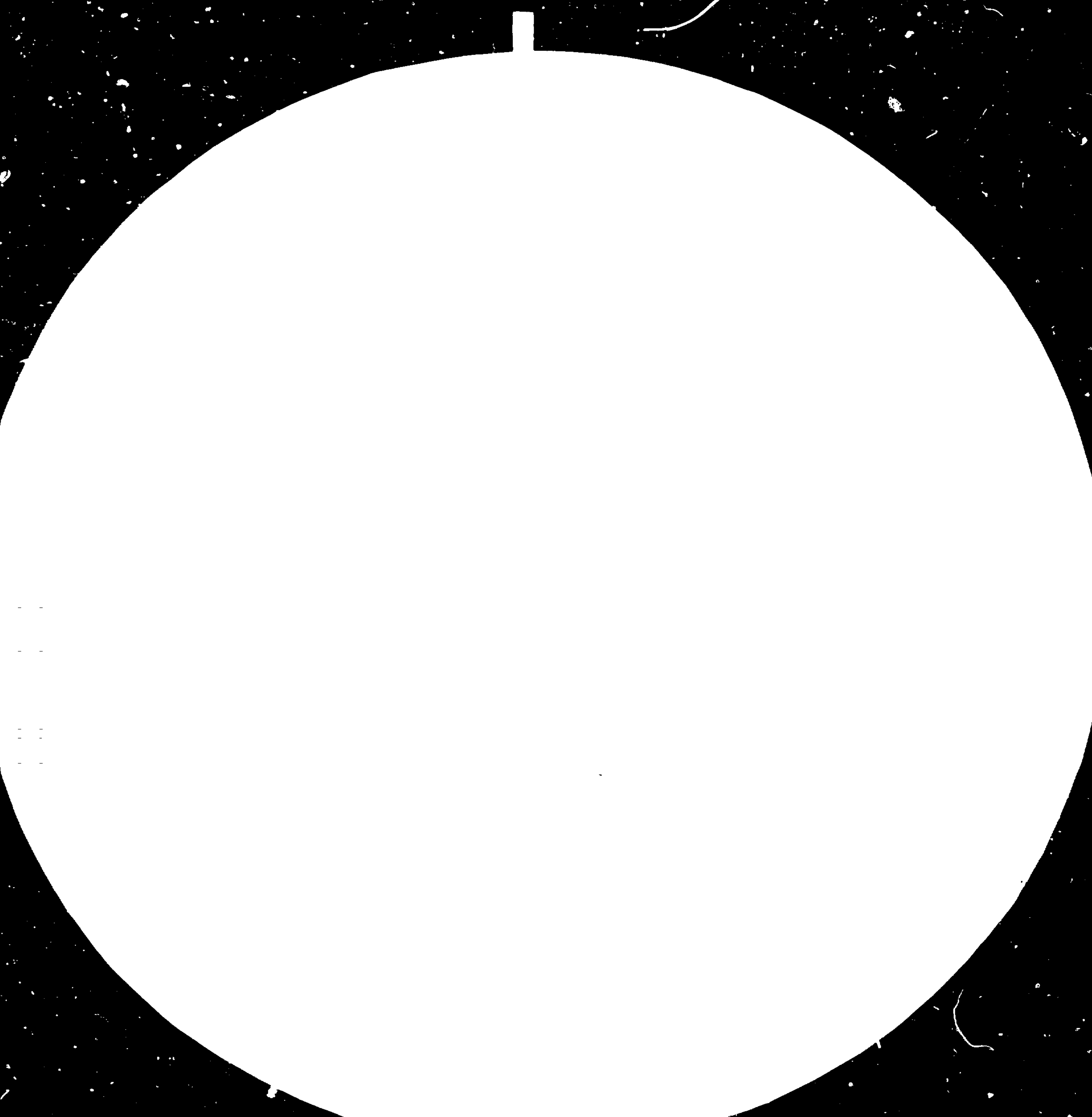
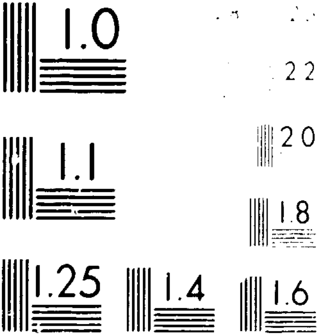
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org




1.0
2.2
2.0
1.1
1.8
1.25
1.4
1.6

11718

Distr.
LIMITED

UNIDO/IS.333/3
30 July 1982

ENGLISH

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

TECHNOLOGICAL PERSPECTIVES IN THE MACHINE TOOL INDUSTRY

AND

THEIR IMPLICATIONS FOR DEVELOPING COUNTRIES

PART III

The implications of technological developments in the machine tool industry for developing countries*

by

S.M. Patil

UNIDO Consultant

90..28

* This is an advance edition of a UNIDO publication to appear in the Development and Transfer of Technology Series. A summary has already been issued under UNIDO/IS.230.

This document has been reproduced without formal editing.

V.82-29244

EXPLANATORY NOTES

References to dollars ($) are to United States dollars, unless otherwise stated.

The views expressed in this document are those of the author and do not necessarily reflect the views of the secretariat of UNIDO.

The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Mention of firm names and commercial products does not imply the endorsement of the United Nations Industrial Development Organization (UNIDO).

References to rupees (Rs) are to Indian rupees. In 1980, the value of the rupee in relation to the dollar was $1 = Rs 7.95.

In addition to the common abbreviations, symbols and terms and those accepted by the International System of Units (SI), the following have been used in this study:

AJM	abrasive jet machining
ATC	automatic tool changer
BHN	Brinell Hardness Number
CAD	computer-aided design
CAM	computer-aided manufacture
CBN	cubic boron nitride
CHM	chemical machining
CIRP	International Institution for Production Engineering Research
CMEA	Council for Mutual Economic Assistance
CMTI	Central Machine Tool Institute
CNC	computer numerical control
CPU	central processing unit
CRT	cathode ray tube
CUPE	Cranfield Unit for Precision Engineering
dB	decibel
DC	direct current
DCs	developing countries
DCS	diagnostic communication systems
DNC	direct numerical control
DRO	digital readouts

EBM	electron beam machining
ECG	electrochemical grinding
ECM	electrochemical machining
EDM	electron discharge machining
EEC	European Economic Community
EMO	European Machine Tool Organization
ENIMS	Experimental Scientific Research Institute of Metal-cutting Machine Tools
EPROM	erasable and programmable read-only memory
FMS	flexible manufacturing systems
GM	General Motors
GPMs	general purpose machine tools
HIP	hot isotatic press
HMT	Hindustan Machine Tools Ltd.
IBM	ion beam machining
IC	integrated circuit
ICAM	integrated computer-aided manufacturing
IMTMA	Indian Machine Tool Manufacturers Association
LAFTA	Latin American Free Trade Association
LBM	laser beam machining
LSI	large-scale integration; large-scale integrated circuits
MDI	manual data input
MVA	megavolt-ampere
NC	numerical control; numerically controlled
NICs	newly industrializing countries
NMTBA	National Machine Tool Builders Association
OBI	open back inclinable presses
PAM	plasma arc machining
PC	programmable controllers
PM	powder metal(lurgy)
PROM	programmable read-only memory
PSI	pounds per square inch
PUMA	programmable universal machines for assembly
RAM	random access memory
R&D	research and development
ROM	read-only memory
rpm	revolutions per minute
SCFMO	Syndicat des Constructeurs Français de Machine-Outils
SCR	silicon-controlled rectifier

SIP	Société Genevoise d'Instruments de Physique
UAW	United Auto Workers
UCIMU	Unione Construttori Italiana Macchine Utensili
UMC	unmanned machining centre
UMS	unmanned manufacturing systems
USM	ultrasonic machining
VLSI	very large-scale integration; very large-scale integrated circuits
VUOSO	Research Institute of Machine Tools and Machining
WJC	water jet cutting
WJM	water jet machining

CONTENTS - PART ONE

A GLOBAL STUDY OF THE MACHINE TOOL INDUSTRY AND A CASE STUDY OF THE MACHINE TOOL INDUSTRY IN INDIA

CONTENTS - PART TWO

PROSPECTIVE TECHNOLOGICAL DEVELOPMENTS IN THE MACHINE TOOL INDUSTRY IN DEVELOPED COUNTRIES

CONTENTS - PART TWO, contd.

CONTENTS - PART THREE

THE IMPLICATIONS OF TECHNOLOGICAL DEVELOPMENTS IN THE MACHINE TOOL INDUSTRY FOR DEVELOPING COUNTRIES

Annexes

Tables

Part one

CONTENTS - PART THREE contd.

Tables

CONTENTS - PART THREE contd.

Figures

Preface

This study consists of three parts: Part I comprises a global review of the machine tool industry which includes a case study of the machine tool industry in India; Part II considers prospective technological developments in the machine tool industry of the developed countries and Part III discusses the implications for developing countries of technological developments in the machine tool industry and contains recommendations, annexes and a bibliography.

The study is based on replies to a questionnaire sent to leading machine tool manufacturers, designers, production engineers, machine tool technologists, researchers and teachers in production technology and machine tool users throughout the world. While preparing the study, the author attended the 30th General Assembly of the International Institution for Production Engineering (CIRP) held in Australia in September 1980 and he has drawn on the insights gained from discussions held with some of the members of the CIRP and from subsequent visits to machine tool research institutes. Annex I contains an extract from a report of the Technical Policy Board of the the Institution of Production Engineers, United Kingdom; the questionnaire referred to above is reproduced in Annex II and the names of the companies, institutes and individuals visited by the author are given in Annex III.

PART THREE

THE IMPLICATIONS OF TECHNOLOGICAL DEVELOPMENTS IN THE MACHINE TOOL INDUSTRY FOR DEVELOPING COUNTRIES

INTRODUCTION

To a discerning observer, it is evident that there has been a tremendous development in the industrialised countries over the past three decades in the machine tool industry and consequently in the production technology employed in the metalworking industry. Most spectacular are the foreseeable future trends in development in the industrialised nations which could carry the industry to such a high degree of automation/ sophistication that it is questionable whether such technological advancements could even cause harm and create social and human problems mainly due to a large number of unmanned machining operations and unmanned factories in the metalworking industry as a whole. No one can say with certainty what is going to be the scenario in the highly developed countries in the future but this much is clear. that such enormous technological advances would result in a so much wider technological gap that it might be more difficult than ever for the developing countries to cope with the advancements. Not only would the technological gap considerably widen, but such a situation could create a larger economic imbalance and greater disparity between the North and the South than at present.

However, the lack of technological development in machine tool production and the metalworking industry as a whole could be to some extent offset if the developing countries make determined efforts to push their respective programmes of industrial development in general, and the production of capital goods including machine tools in particular, in line with some of the latest and advanced technological developments taking place in the industrialised nations in this field.

In the following pages an attempt will be made to analyse the implications for developing countries on two major counts: technological and economic. Naturally, for the purposes of this study the technological implications will receive wider coverage although the economic aspects as well will be touched on briefly.

Due to the technology gap and the economic gap, the implications of the large-scale technological developments in machine tool and manufacturing methods, which are taking place in the highly industrialized countries, are each in their own way different but, nevertheless, interrelated.

The technology gap could most likely result in continued economic underdevelopment and consequent poverty in a greater part of the developing world. Even so, in this study attempts have been made to deal separately with the implications of the technological gap and the economic gap for the developing countries.

I. THE TECHNOLOGY GAP AND ITS IMPLICATIONS

Among the developing world, some of the newly industrialising countries (NICs), like Argentina, Brazil, China, India, Mexico, Portugal, the Republic of Korea and Singapore. have well-established machine tool industries of their own.
In the last three decades, some of them have been able to make significant progress in developing their respective machine tool industries mainly through acquiring designs and manufacturing technology from transnational corporations. The case study of the Indian machine tool industry, covered in Part I, section VI of this study, abundantly reveals this phenomenon. The Indian machine tool industry has been built primarily on the foundation of the transfer of machine tool technology which has taken place over the last three decades between machine tool manufacturers in the industrialised countries and Indian enterprises both in the public and private sectors. Up to 1979, as many as 113 major technical collaborations (licensing of designs and know-how and joint ventures) for the production of

several types of machine tools have taken place, viz. Czechoslovakia (4), Federal Republic of Germany (20), France (7), German Democratic Republic (7), Italy (6), Japan (7), Switzerland (5), United Kingdom (29), United States (14); the others were with countries like Belgium, Poland and Sweden. An almost similar pattern of development has taken place in the machine tool industry in the other NICs like Argentina, Brazil, Mexico and the Republic of Korea.

Besides, these countries have simultaneously striven hard to build their own capabilities in developing new designs of machine tools - mostly general purpose machine tools - and it can be said that many of them undoubtedly have become almost self-sufficient in their needs for general purpose machine tools. Some advanced types of machines like special purpose machines, some tyr transfer lines, single and multi-spind. automatics, certain types of gear cutting machines, horizontal and vertical boring mills, commonly-needed designs of grinding machines of cylindrical, internal and universal types are also being produced in these countries. The efforts made by the governments of the respective countries to develop the infrastructure needed for the machine tool industry and to give the industry high priority in the overall industrial plan of development and other financial and fiscal supports have been more or less on similar lines to what has happened in India. Some of the countries, like Mexico, which do not at present have institutes for R&D in machine tool design and technology have been seriously contemplating establishing these facilities as well on a priority basis.

The development and growth of the machine tool industry in these newly industrialising countries is satisfactory and they are today, able to export part of their production, varying from 5 to 30 per cent, not only to countries in Africa, Asia and the Middle East but also to highly developed areas like North America and Europe and countries like Australia, New Zealand and the United Kingdom. In fact these developing countries compete against each other on world markets and even face effectively the competition from developed countries like the Federal Republic of Germany, France, Italy and Spain.

Some of these countries, notably Brazil, India and the Republic of Korea, have also entered into the NC line of machine tools. They produce simple machining centres, turning centres and turret centres and MDI (Manual Data Input) controlled lathes, milling machines and drills. The technological level of the machine tool industry in some of these countries has been described in Part I of this study. From these details, it can be seen that the machine tool industry's technological progress in most of these countries has been more or less at the same level, though some of them like Brazil, India and the Republic of Korea are somewhat more advanced than others.

However, when these developments are compared with those taking place in the highly developed nations and particularly viewed against the background of the future technological development in machine tools and manufacturing methods in these developed economies, it is noticeable that that even the newly industrializing countries are far behind the highly developed nations

and there will always be a great disparity in the technological levels between the developed and developing nations. Even so. it is necessary and important for the developing countries to make efforts continuously in evolving new designs of machine tools required in the advanced production technology of their metalworking industry.

A careful look at the details of the machine tools being imported by the developing countries from year to year will reveal that in spite of the production showing a quantitative increase over the years, there exists a considerable gap both in the production range and machine tool technology between the developing countries and the industrially advanced countries.

The vast developments that are taking place in the realm of the metalworking and capital goods industries in the developed countries can be directly attributed to: (a) the evolution of modern machine tool mechanics and design; (b) cutting tool materials and tool geometry; (c) machine tool controls; (d) manufacturing systems. By comparison, the progress taking place in these areas in the newly industrializing countries is insignificant. In the least developed countries, with little manufacturing industry, the question does not arise at all.

(a) <u>Machine tool mechanics and design</u>. In the field of machine tool mechanics and design, developing countries lag far behind. The majority of the machine tools being produced in these countries have been licensed from transnational corporations. For one thing, it is not expected that these designs would, in all cases, be the latest designs because if the latest designs are the main export items of the developed countries, the licensors would not easily agree to transfer the designs and know-how to build them elsewhere. Even if it were possible to obtain the agreement of the licensors to grant manufacturing rights for some of these advanced designs of machine tools, it would certainly take a large amount of resources to be invested by the licensee by way of licence fees, royalties, production facilities like plant and machinery and above all, extensive training of technical and production personnel to be able to master the whole process of producing the sophisticated designs of the machines. More important is the fact that in the developing countries, a sufficiently large volume of demand cannot be expected currently for some of these highly sophisticated machines.

It should be noted that such highly advanced designs are developed to meet specific demands of the machine-tool-using industries. For example, most of the latest designs of machine tools have been developed by the machine tool manufacturers in the industrially advanced countries at the request of the user industries like the aerospace, aircraft, automobile, armaments and engineering industries, which sometimes even extend to machine tool manufacturers guarantees of purchasing economical numbers and paying adequate prices for the development endeavour in producing such advanced designs of special machine tools. In some cases, these could also be projects sponsored by the machine-tool-using industries.

In the absence of such growing and highly advanced machine-tool-using industries in the developing world, there could not be any sizeable demand for these highly complex and very costly machines and equipment. Furthermore, such advanced designs are continuously undergoing changes and before these get stabilised, close dialogue, co-operation and understanding is required between the producers and the users. In the developing countries the prevalence of similar situations on a large scale cannot be expected.

Many of the new design concepts have no relevance in the developing countries. The art of high-speed machining has yet to be learnt and mastered in these countries. Neither have they any need presently for such highly productive machine tools nor do their technicians and workers possess the required confidence in machining at very high rates of metal removal, using super high-speed heavy duty machine tools driven by high horsepower motors.

Although computer-aided design is catching up in some of the newly industrialising countries, it is restricted to certain applications like bed and column design calculations, gear drives and the design of main spindles. Computers are mainly employed for checking the designs of machine elements and unit assemblies after the prototypes have been built on empirical designs. Furthermore, facilities for such work are far too limited and perhaps available only at the machine tool research institutes and some of the universities teaching machine tool technology.

It may be concluded that the incentive for evolving new designs of advanced machine tools is dependent on the production technology employed by the main machine-tool-using industries, namely the metalworking and other engineering industries. Advancement in machine tool design *per se* has no advantage unless it is needed in the capital goods and other metalworking industries. Hence it is very necessary to update the manufacturing methods employed in the metalworking industries on the pattern of the industrialised countries so that there is sufficient incentive, scope and demand for developing more modern designs of machine tools, particularly the numerically controlled-electronic (NC) machines, machining centres etc., so that these could be integrated in the modern manufacturing systems in the metalworking industry.

It is also the experience of the developed world that improvements in the production technology of the metalworking industry take place if advanced types of machine tools are produced in the country which increase the production and improve the quality and bring competitiveness by reduction of costs of the end-products of the metalworking industry. In actual practice, however, both these things happen; namely, improvement in manufacturing systems takes place in the machine-tool-using industries through the availability of advanced and highly productive machine tools like NC machine tools, and also the advanced designs of machine too's are made available to the using industry if there is sufficient demand for them. Hence, the technological gap in the machine tool industry could narrow down if modernisation takes place in the production technology employed by the metalworking industry, which after all is the main customer for machine tools.

In sum, attempts at evolving original designs of advanced machine tools have just begun in NICs recently, particularly in the field of special purpose machine tools and transfer lines. New concepts in machine tool designs, suitable for NC and high precision work, are just being thought of in some of the developing countries. Through the process of acquiring imported designs and production know-how and the laborious process of modifying and adapting these to suit local conditions such as the kind of plant and machinery available externally-purchased items, raw materials and market needs, machine tool designers, technologists and production engineers. some of the developing countries have gained some experience to tackle complex problems associated with the development of original designs of modern machine tools.

All this however takes time and if the metalworking industry were given the correct incentive to grow modern and productive, the developing countries would in the course of time be able to narrow the technological gap in machine tool mechanics and designs to some extent. But taking into consideration the situation of the market and the resources available and above all the extraordinary advancement in technology taking place in the advanced world, it is to be expected that there would always be a technological gap in machine tool technology between the developing countries and the developed world which it would be difficult to bridge completely within the time horizon of the next two decades. However, attempts will have to be made by the developing countries to improve their machine tool mechanics and designs so that there is an appreciable advancement in the production technology of their metalworking and capital goods industry.

(b) Cutting tools. The extensive use of advanced types of hard and extra hard cutting tools depends on the designs and types of machine tools in operation in any country. It has been observed that some of the developing countries, mostly the newly industrialising countries, do use high production, high precision, high-speed and heavy powered machine tools for certain applications. In these instances, it is possible that these countries use many highly specialised tools like tungsten carbide, coated carbide tools, throw-away tip tools and diamond tools. Some of the well-known transnational companies manufacturing cutting tools, like Krupp WIDIA of the Federal Republic of Germany and Sandvik of Sweden, either have their own factories or joint ventures in some of the developing countries. Hence they are in a position to provide advanced types of tools like sintered carbide tools, tungsten carbide, coated carbide and throw-away carbide tip-tools for use in conjunction with some of the more advanced high-powered machine tools, many of them imported. In the aircraft, space, automobile and other metalworking engineering industries, these advanced types of cutting tools are extensively used in some of the developing countries.

However, ceramic tools, special tools needed for the tool changers for machining centres and high precision diamond tools are being imported since the use of these highly advanced types of tools is very much restricted in the developing countries.

Extensive use of high-speed tools, particularly for steel-bar work and machining of steel castings, is still a common feature of the metal-working industries in the developing countries. Carbide tools are primarily used for machining cast iron components. Even so, for certain applications, carbide tools and cutters for machining steel components and cast-steel items are used, due to the availability of appropriate and better types of carbide tip tools and milling cutters manufactured by the transnational companies operating locally in the developing countries.
For instance, tungsten carbide tools and cutters are commonly used in single and multi-spindle automatics, transfer lines and similar advanced designs of machine tools, even where steel components are being machined. Metalworking industries in the developing countries have started using

carbide tools, cutters and throw-away tip tools like T-Max for several applications.

However, due to various reasons mainly on account of the absence of fierce competition in the domestic market for capital goods and other products, and in some cases on account of a protected market and insufficient export trade, currently there appears to be less compulsion to exploit the full potential of such advanced types of cutting tools. Perhaps this is partly also due to the inexperience on the part of machine operators in developing countries.

(c) Machine tool controls. One of the most glaring technological gaps between the developed countries and the developing countries is in the area of micro-electronics. There has been some growth in the electronics industry in some of the developing countries but this has been mainly to meet the requirements of the consumer/entertainment sector and to some extent, communications and armament sectors. Though the use of computers for office purposes is comparatively well established in some of the developing countries, the industrial application of modern computer technology, however, is almost absent in these countries.

In the advanced nations, the main instrument of change is the electronic data processing machine, so tiny and yet possessing amazing capabilities. This remarkable device is the microcomputer, also known as 'computer-on chip'. In its configuration, it consists of just that: complex circuits on a chip of silicon about the size of a small shirt button. Yet even a medium strength microcomputer can perform 100,000 calculations per second. If there is any technological gap which is going to widen greatly between the industrialised and developing nations, it is perhaps in the area of computer science.

Some of the machine-tool-producing developing countries have also started producing NC machine tools but the controls belong to the older generation where coded tape is the heart of the NC which consists of the sequence of the machining operation, machine position, spindle speeds, feeds etc. But in the last 10 years in the industrially advanced countries, NC has undergone phenomenal changes. NC, guided and controlled by a computer, viz., CNC, is the heart of NC machines like machining centres extensively produced in the industrialised countries.

These types of controls including minicomputers are not manufactured in the developing countries, although some imported CNC controlled machining centres are used in some of the developing countries. These machines come with the executive programmes developed by the manufacturers in the form of standardised system designs. A knowledge of software design and systems integration is necessary in all new production/manufacturing systems. A good software designer will be able to maximise hardware utility and create flexible systems that others can repair and alter. Such personnel are rare to find in the developing countries and this in itself is a great hurdle for the further development of computer control of machine tools in the developing countries.

The manual data input (MDI) type of control systems which go beyond the digital readouts (DRO) are used in some of the developing countries like Brazil, India, the Republic of Korea and Singapore. Centre lathes, knee-type milling machines, drills etc. are provided with this control system which is in itself an advanced step to DRO. However, modern MDIs developed and employed extensively in the industrialised countries are microprocessor-based types, which eliminate the tape reader which is normally a source of trouble. Although there is a great scope for such types of MDI controls in the developing countries these are not produced by them at present.

The few encountered in these countries are imported and suffer from the inadequacy of the programmers.

(d) Manufacturing systems (production technology). The combined effects of technological underdevelopment in some of the above main areas like machine tool design, cutting tool technology and machine tool controls, as could be expected, result in considerable underdevelopment in manufacturing technology as a whole.

During the last three decades in some of the newly industrializing countries, there has been some progress achieved in the area of production engineering. In the first decade, many developing countries which initiated the production of capital goods and metalcutting and other engineering products did so primarily with an idea of import substitution to save foreign exchange. This gave the countries a certain degree of self-sufficiency and saved to a large extent foreign exchange resources as the latter had been the main bottle-neck in their economies. In the initial stages, the designs which were licensed and a few which developed indigenously were those which were being slowly phased-out by the developed nations. In the initial stage of development, costs, prices and to some extent even the quality of metalworking products did not receive adequate attention in the main drive to save foreign exchange through import substitution. These and other unfavourable conditions are not healthy for the sustained growth and modernisation of the metalworking industry. Since labour in most of these countries was plentifully available, the primary objective it appears had been to train and employ personnel wherever possible, thus making the production technology highly labour-intensive.

In the second phase, the main machine-tool-using industries viz., capital goods manufacturers of products like automobiles, locomotives, electric motors, power generators and diesel engines- in order to improve their designs, costs and competitiveness - started demanding modern highly productive machine tools so that these could be readily employed in the design and production technologies which they had imported from their collaborators in the industrialised countries. Thus to some extent conditions were created in some of the developing countries (mainly the newly industrialising countries) whereby machine tool customers became more productivity-conscious and demanded that the general purpose machine tools supplied by the manufacturers should be fully tooled-up or should be suitable when tooled-up for performing certain specific operations or for the production of certain components. Not only were quality standards rigidly insisted upon, but floor-to-floor timings for different operations were strictly stipulated. With this, there was some improvement in the performance of machine tools through better and modern designs and production technology. Also many of the machine tool manufacturers made arrangements with advanced countries for the licence to manufacture better and more modern types of machine tools like single and multi-spindle automatics, single and special purpose machines and transfer lines for mass production, certain types of gear hobbing machines, precision hydraulic grinders, horizontal and vertical boring machines, production jig boring machines, centre lathes of much improved design with faster speeds and higher horsepower and generally all machine tools designed and powered for the use of carbide tools.

However, over the decades, the developing countries, mainly the newly industrialising countries, have been almost stagnant in their production technology mainly because they have neither a strong base nor the support of computer technology. The advanced world has undergone almost revolutionary changes in production technology using the immense capabilities of computer technology. Today the production engineers in these developed economies have at their disposal machine tools, cutting tools and unimaginable facilities of micro-electronics to develop software systems to evolve highly productive systems of manufacture like flexible machining systems, computer-aided manufacturing systems and computer-aided designs and graphics. With intelligent robots to perform many tasks like materials handling and loading, instruction and selection of parts as described in sections VI and VII of Part II of this study, the unmanned factory of the future in the developed countries is shaping up much faster on computer than previously estimated. The repercussions of this on the labour market in the developed countries is going to be more harmful to migrant workers from countries like Greece, Yugoslavia, India, Pakistan, the Philippines and countries in Africa, Asia and the Caribbean, since they will be the first to be out of jobs because of automation. Pakistan, for example, receives as much earnings in foreign exchange from its workers abroad as from its total exports. The same perhaps to a lesser degree could be true of other developing countries in Asia, Africa and the Caribbean, as well as Greece and Turkey. But when these migrant workers become insecure due to various reasons, one being the high degree of automation in the metalworking industries of the developed countries, even this source of employment and earnings for the developing countries could soon dry up.

The aggregate effect of the lack of development of the developing countries in areas like computer technology; advanced designs of machine tools like machining centres controlled by CNC or DNC; mini-computers; microprocessors, and highly advanced types of cutting tools that usually go with the sophisticated types of machine tools is the total absence of the latest computer-integrated manufacturing systems like computer-aided manufacture (CAM) and flexible machining systems. While it may be physically impossible for the developing countries to go all out to introduce robots in their manufacturing systems (and neither is this desirable in view of the availability of a large unemployed labour force), to some extent, robots could be employed in performing specified tasks which it is not usually possible or desirable for human beings to perform. But without the strong support of computer science, this cannot be achieved.

Consequently, the productivity of the metal-working industry in the developing countries is poor and levels of production in some of the key industries are low in comparison to the norms of the developed world. For example. the typical plant capacity for motor cycles is 20,000 per annum as compared to the typical plant capacity of producers in the developed countries of 1.2 million per annum. In the case of passenger cars, the capacity of India's largest plant is 25,000 cars per annum against the average standard of the developed world of 150,000 cars per annum; in the case of refrigerators, it is 100,000 against 1 million, in the case of General Lighting System electric lamps, 20 million against 600 million; and in the case of diesel engines, it is 10,000 against 120,000. Poor economy of scale has therefore been one of the constraints to improvements in the productivity of the developing countries. The main reason for this is the backward and almost outdated production technology employed in the developing countries. This in turn, is due to the extensive use of general purpose, older and obsolete types of machine tools which are fast disappearing from the production shops in the industrialized countries. In their place there is an extensive use of machining centres, single and special purpose machine tools and highly automated systems of manufacture like computer-aided manufacture, flexible machining systems and, in short, highly integrated manufacturing systems which are described in detail in Part II of this study.

Metalforming. In the field of metalforming presses, some of the developing countries are manufacturing conventional types of open-back-inclinable (OBI) and parallel frame presses with hydraulic and mechanical drives and shears and press brakes in large numbers. In fact in countries like Argentina and Mexico, these items amount to as much as 50 per cent of the total national production of machine tools.
However, the percentage of metalforming machines to the total production of machine tools in countries like India and the Republic of Korea, though increasing from year to year, is still below 25 per cent. There is also a trend in the developing countries as in the case of developed countries to increase the production of metalforming equipment from year to year.

Heavy duty hydraulic and mechanical types of conventional presses, mainly used in mass production industries like the automobile industry, are being made in some of the developing countries, but the hydraulic aggregates and other accessories are still being imported from the industrialised countries.

The technology gap between industrialised and the developing nations in the field of metalforming presses is widening each year. This is more discernible in the area of non-traditional forming methods such as helical rolling, ring rolling, spinning and flow-forming. In the developed nations, considerable R&D is being carried out in producing parts of high strength alloys of complicated shapes by forming with high-speed equipment e.g. powder metallurgy. Developing countries are behindhand in the production of cold forging presses and extrusion presses.

One of the main bottle-necks in metalforming is the manufacture of complicated dies and tooling. For this, it is necessary to use high strength alloy steels as raw materials to be machined on sophisticated machine tools like the copying machines of the type of Cincinnati Hydro-teil, and CNC controlled continuous path vertical or horizontal machining centres.

Another piece of sophisticated equipment of the hig speed metalforming industry is the transfer line press for automatic and progressive operations on transfer line, both in forging and forming. In this case, a transfer feed is provided to convey the part from station to station. Although some sheetmetal-forming transfer line presses are manufactured in the newly industrializing countries, heavy duty and progressive type forge presses are still being imported.

In the area of fine blanking and punching presses, developing countries have yet to reach the degree of sophistication of the developed countries.

Non-traditional machining. In the area of non-traditional machining systems, the progress made by the developing countries is negligible. For one thing, these metalworking processes have a relatively restricted field of application. Also the development. and in particular the application of many of these technologies, has yet to be perfected even in the highly industrialized countries. Therefore the developing countries cannot be expected to adopt readily such special machining processes when the development costs are high and the benefits doubtful.

From an overview of the developments taking place in this field in the developing countries, it can be observed that only the following processes are sometimes employed in the metalworking industries in some of the newly industrializing countries: Electrodischarge machining (EDM); Electrochemical Machining (ECM) and, Electron Beam Machining (EBM). Of these EDM and EBM welding have found greater usage than the others. In EDM, the wirecut process is becoming increasingly popular mainly in the production of high precision dies and press tooling. For instance, in the horological and instrument industries, the wirecut EDM procress is becoming quite advantageous. EBM welding technology also is receiving greater attention particularly in the more advanced industries like those of aircraft, atomic energy and space.

However, apart from very simple EDM and ECM machines, the rest of the machines and equipment are being imported in small numbers by the developing countries.

II. ECONOMIC IMPLICATIONS

Since developing countries are technologically less advanced in machine tool design and production technology, it is to be expected that their metalworking industries as a whole would seriously suffer from this wide technological gap. The products of the metalworking industry, particularly capital and producer goods, consumer durables etc. cannot be expected to easily attain the standard of excellence of the developed nations. Moreover, as highly productive, high precision, specialised and heavy and extra heavy duty machine tools required in some of the vital and strategic industries are not made indigenously, these will have to be imported to meet the requirements of the developing countries, thus resulting in a trade deficit and a shortage of foreign exchange.

It is not possible for any country, whether developed or developing, to become completely self-sufficient in its requirements of machine tools. This is not only unnecessary, it is also not economically desirable. The 10 largest machine-tool-producing developed nations of the world are themselves the biggest importers of machine tools. This type of interdependence: that a country imports its own requirements of machine tools and yet specializes in producing certain types of high precision and specialised machine tools, is a special feature of the global machine tool industry. Some of the East European countries who in the beginning aimed at becoming completely self-sufficient not only domestically but even in the CMEA bloc of countries had to give up the concept and today these countries import large quantities of specialised machine tools from the Western countries. This was necessary for them to improve the quality standards of the products of their metalworking industry and compete in the world markets.

What is important for the developing countries is to improve their technological standards in machine tool designs and mechanics and make the manufacturing activities highly productive. It should be possible through improved machine tool design and modern production technology to manufacture a variety of products of the metalworking industry to match international cost and quality standards so that these not only enhance the quality and productivity of the domestic manufacturing and engineering industry but also make the products of these industries exportable and competitive in the world market.

Economic progress and development depends very largely on improvements in overall productivity and the efficient use of resources such as labour, material and capital. In so far as it applies to machine tool technology, it is evident that economic prosperity depends on the productivity of the machine tools used in the manufacturing industry. Hence to improve the economic health of a developing nation, it is necessary to improve the productivity of the metalworking industry. Since machine tools and production technology are fundamental for the improvement in productivity of the manufacturing and engineering industries, machine tools and production technology have to be highly productive, modern and advanced. As the principal impetus for productivity is advanced technology, it is imperative for the developing countries to strive hard to narrow the technological gap between them and the advanced world in the field of machine tools and manufacturing technology.

Labour-intensive technology *per se* cannot be the universal remedy and its applicability to all types of productive activities is certainly not advisable. It is argued that production technology employing a comparatively large labour force could be as efficient as highly advanced and labour-saving technology. This is a fallacious statement and cannot be applicable under all circumstances.

Speaking of labour productivity in the developing countries, this is very poor compared to the labour productivity i.e., output (added value) per worker per annum in the advanced countries. As an example, the case of India may be quoted where it has been estimated that current labour productivity is increasing at a very slow rate. During 1977, it was Rs.11.000 per annum ($ 1375) at 1971 prices and rose to Rs.12,800 per annum ($ 1600) in 1978. The productivity of labour in the developed countries is at least eight times higher than these figures, mainly because of improved production facilities and advanced technology.

Furthermore, improvements in output (added value) per worker per annum, which is what the universally accepted measurement of productivity is. do not come entirely from the labour side because workers are working harder and better. It should be emphatically stated that the improvements in productivity come largely from non-labour factors: through the efficient use of material and capital resources. This in modern industry is possible mainly through better management of resources employing improved and advanced technology.

The lack of development in the machine tool and manufacturing industry of the developing countries is one of the reasons for poor industrial growth and the resultant poorer growth of the national economy. There is a real danger that in the year 2000 a large part of the developing world's population will still be living in poverty. It should be emphasised that human needs can only be met by the productive efforts of a society which strives to meet these needs. The only way to make this possible for developing countries is to enable them to build up and develop their own productive capability.

There is further a lack of understanding of the problem as to how to increase the productive capability of the developing countries, or rather, there are divergent views on the solution to this problem. In fact there is a situation where in the highly industrialised countries technological innovations and material changes are more advanced than most people realise, whereas in the developing countries, the consciousness and aspirations of many people seem to be ahead of material reality.

Over 90 per cent of the world's manufacturing industry is in the developed countries. The developing countries have only a small share in world manufacturing. This share remained stable at about 7 per cent in 1960s. However, in the period 1970 to 1976, the manufacturing output of the developing countries grew at 7.5 per cent per annum. This is indeed very hopeful for the developing world.

Unless there is a massive transfer of modern technology from industrially advanced countries to update the production processes of the developing countries, the developing countries with a growing population and rampant unemployment will be perennially weak economically. Simultaneously, developing countries should also develop their own technological capability to aim at producing a surplus of manufactured goods, machinery and engineering products which could stand world competition in the export markets.

It has been estimated that in India alone, 10 million jobs must be created every year from now to the year 2000 to cope with the population growth and the backlog of unemployment. With more than 650 million people, India has a GNP two-fifths the size of that of the United Kingdom, which has only 60 million people. The same is true for many of the developing countries of Africa and Asia. Part of the problem is that most of the developing countries depend heavily on agriculture and more than half of the products of these countries comes from this sector which employs two thirds or more of the labour force.

The main object of the policy

makers and the governments of the developing countries should be to relieve agriculture of this heavy concentration of labour by introducing mechanization and to a large extent divert the economically active labour to industries. This is only possible through rapid industrialisation using modern and productive technology. Certainly, development must mean improvement in living conditions for which economic growth and industrialisation are essential.

Most of the developing countries regard industrialisation as a central objective of their economic policy. They see it together with agricultural progress as an integral part of development and structural change. The drive towards industrialization reflects the deeply felt need for modernization and economic independence.

But industrialisation in the developing countries has been very uneven. Some of the middle-income countries, particularly in Latin America and South-east Asia, have made spectacular advances in industry. Several of them have around one quarter of their workers in the manufacturing sector, which is as much as some of the industrialized countries have at present.

Other countries show little change. In many of the poorest countries, less than 5 per cent of the work-force is engaged in the manufacturing sector. It would be highly misleading to present the developing countries as an unchanging picture of widespread poverty. Even among the low-income countries progress is taking place, the beginning of structural transformation. In a number of developing countries, moreover, there have been truly remarkable advances. In terms of sheer economic growth rates, the most striking cases have been the newly industrialising countries which have been thrusting ahead with manufacturing growth. Countries like Argentina, Brazil and Mexico have quite an old established industrial base which has increased rapidly in the post-war decade. A spectacular example is Brazil whose economy at the current growth rate will by 2000 rival in size that of the Federal Republic of Germany. It is also an important trading partner and thus a stimulus to growth for other countries in the South. The Republic of Korea is another outstanding example with tremendous scope for industrial and economic growth made possible through the use of the latest machinery and equipment and modern production technology. Several of what used to be called peripheral countries like India have become significant nerve centres of industrial production.

Other smaller industrialising countries illustrate how fast the economic map of the world is shifting. They have been able to take advantage of the international division of labour in highly competitive world markets. Many of them are in South-east Asia; the Republic of Korea, Hong Kong, Malaysia and Singapore. Their economies as a whole have been sustaining an average growth from 5 to 9 per cent over a decade and a half. There are other countries which have begun relatively recently to penetrate into export markets with their manufactures; Colombia, the Philippines and Thailand.

However, all these newly industrialising countries will suffer a serious setback with the development of microprocessors which could reduce some of their advantages. While they owe much of their expansion and technology to transnational corporations, they remain very vulnerable to the corporations' trading practices and technological advances.

In the area of technological advancement, the developing countries must realise that it is in their interest to advance technologically.

This does not mean that they should totally ignore the repercussions of sudden change from labour-intensive manufacturing technology to highly automated systems and robotics. In any case, such a thing cannot happen due to the sheer physical, financial and infrastructural deficiencies of the developing countries. Nevertheless, to be blind to the latest technological developments taking place in machine tool and production technology in the highly advanced economies could be dangerous. This could prevent completely the developing countries from making a judicious choice of the technology appropriate for them and one in tune with the interdisciplinary growth of other sectors of economic activities.

A recent study of the United Nations on the future of the world economy has shown that agriculture and mineral extraction activities in the developing countries will be expanding at a slower rate than the total gross product once overall growth is higher than 4 per cent per annum. At the same time, the total output of the manufacturing industries is expected to expand at higher rates than the gross product, namely 6-7 per cent in the non-oil-producing countries of Africa; 7.5-8 per cent in the non-oil-producing countries of Asia; 8.5-9 per cent in Latin America and 14 per cent in the oil-producing countries of Africa and Asia.

The study further postulates that one of the distinctive features of industrialisation in the developing regions is the generally lower growth rates of light industry when compared to those of heavy industry including machinery, mechanical equipment and industrial materials like steel, rubber and chemicals.

The tendency of heavy industry to grow more rapidly is well pronounced in all developing regions according to the study. Growth rates of this sector would reach 7-8.5 per cent in the non-oil-producing countries of Africa; 8-8.5 per cent in the non-oil-producing countries of Asia; 9-10 per cent in Latin America and 16-17 per cent in the oil-producing countries of Africa and Asia.
The accent on heavy industry is essential for industrialization and economic development on a broad regional,

though not necessarily on a small country basis. This opens vast horizons for co-operation and specialisation between developing countries, especially in the priority sectors of machinery, machine tools, manufacturing equipment and basic industrial materials like steel, rubber and chemicals.

Machine tools and manufacturing methods are fundamental means of producing products of the metalworking industry like capital goods and both electrical and mechanical machinery, transport vehicles - cars, buses and trucks - aircraft, power-generating equipment, plants for production of cement, sugar, paper and fertiliser and machinery required for steel mills. If the technology gap in the basic machine tools and manufacturing technology is quite large, it would mean that the production of capital goods and other engineering products - agricultural machinery, transport equipment, building materials, fertilisers, food and milk processing industries etc. - will all suffer the disadvantage of the lack of development of machine tools and production technology. Such a lack of development has a profound adverse influence on trade in the developing countries since in many cases, particularly in the vital processing industries like fertilisers, oil exploration, pharmaceutical and chemical industries, besides important metalworking industries like transport, communications, power-generating equipment, and agricultural machinery. the mechanical and electrical machinery needed will have to be largely met through imports. In the capital goods sector alone, it has been projected that by the year 2000, the need for these products by the developing world will be of the order of $ 1000 billion. Although the latest statistics of the volume of production of capital goods in developing countries are not available, judging by the figures for 1970 of a total production of a little over $ 18 billion, the deficit which has to be made up through imports is really staggering. A 7 per cent growth rate every year can be estimated in the volume of production of capital goods in the developing countries. This would place the current estimated production of capital goods in the developing countries at a yearly level of about $ 36 billion to $ 40 billion. Even so, the trade deficit (to make up $ 1000 billion) on this account alone is a figure which is indeed frightening.

One of the urgent and vitally important means of narrowing this huge deficit in trade is to narrow the gap in machine tool technology with all the resources at the disposal of the developing nations including available foreign aid, bilateral credit arrangements between the developing and the developed countries and the assistance of United Nations organizations like UNIDO.

Although it is not expected that in the time horizon of two decades an appreciable impact is conceivable, concerted efforts at national political and policy-making levels have to be made to develop, acquire and assimilate the modern technology of machine tools and manufacturing processes in consonance with the needs of each of the developing countries and the availability of industrial infrastructure. This could narrow the technology gap to some extent and avoid deleterious implications on the economic growth and social welfare of the developing countries.

In the proper place and circumstances, labour-intensive technology may be welcome but in machine tools and production technology, which are the main spring-boards for the rapid growth of productivity in the metalworking industry, including the capital goods industry, labour-intensive technology per se is not desirable.

The principal fuel for productivity is advanced technology. The quality of labour and the amount of capital are also factors, and important ones, but the foundation is the level of technology to which efforts of capital and labour can be applied. Some of the developing nations, particularly those newly industrialising countries like Argentina, Brazil, China, India, Mexico and the Republic of Korea are today at a crossroads in their choice of machine tool and manufacturing technology.

In the opinion of the author, any technology which is capable of producing goods and services at internationally comparable quality and costs is, in the long run, the only technology which should be employed.

III. RECOMMENDATIONS FOR THE DEVELOPMENT OF THE MACHINE TOOL INDUSTRY IN THE DEVELOPING COUNTRIES

Before attempting to recommend any strategy for the development of the machine tool industry in the developing countries, the fact will have to be recognized that even among the developing countries, there are those which have already developed their machine tools and capital goods industry to some extent such as the newly industrialising countries (NICs) and there are others, the least developed countries (LDCs), which have yet to make a significant beginning with any programme of industrialisation and plan for the production of capital goods including machine tools. Recommended steps to develop machine tool production in these two categories of developing countries will not, therefore, be the same. Hence, this issue will have to be dealt with separately.

Newly industrializing countries

As mentioned before, the machine tool and manufacturing industry in the newly industrializing countries (NICs) is well founded but technological progress, both in machine tool technology and production engineering has, it appears, remained practically stagnant for the past decade or so, though some countries like Brazil and the Republic of Korea, and to some extent India, have made a beginning with numerically-controlled (NC) machine tools and the related manufacturing technology.

1. The most outstanding feature of the development of the machine tool industry and manufacturing technology in the metalworking industry in the industrialised nations is micro-electronic and computer technology. There is a big gap in this area which has to be assiduously bridged to some extent by the developing countries. In some of these countries, the electronics industry has progressed fairly well, but mainly in the consumer/entertainment areas and the industrial application of electronics is just at the initial stage. The industry is still governed by the older concepts of transistor and hardwire circuitary of the first generation; and electronic machine tool controls, viz., NC, are based largely on the use of perforated cards and tapes or magnetic tapes.

In the advanced countries, NC has undergone phenomenal changes. The transistors have given way to integrated circuits and the advances in computer technology have helped to replace all logical hardware. Decision circuits are replaced by executive software in the form of minicomputers, thus giving birth to computer numerical controls (CNC). Furthermore, the development of micro- or minicomputers has been possible due to the spectacular evolution of large-scale integrated circuits (LSI). New machine tool control systems using very large-scale integrated circuits (VLSI) are just about to make their appearance in the highly industrialised countries, resulting in further miniaturisation of machine tool controls due to the reduction in the number of parts with far greater capabilities than LSIs. The computer and properly designed software have made increased sophistication of the CNC control possible. Furthermore, since the computer used in the CNC system has the ability to perform different tasks under different programmes, a proper programme can be written to make the computer work like a circuit tester instead of an NC controller, thereby providing a diagnostic programme.

Developing countries should pay special attention to computer technology and acquire knowledge and experience in the associated techniques of software like executive programming, part programming and diagnostics.

It may not be at this stage feasible for many developing countries to manufacture the microprocessor chips for CNC controls because of the enormous investment needed for the purpose, and the limited market possibilities. They are, however, well advised to obtain such of these components from abroad as are needed to build their own control systems. In fact, there are presently only two countries, viz., Japan and the United States, who are leading in the manufacture of silicon chips. Europe has been trying to enlarge its production of electronic chips with mixed success. Once computer technology is well understood and production engineers of developing countries are able to handle the computer, including the microcomputer in all its varied applications and become well trained in the preparation of software like the preparation of executive programming, part programming and diagnostic programming, they could then be in a position to interface electronic controls with machine tools and could attempt to produce the semi-flexible computer-aided manufacturing systems needed in their metalworking industry.

2. From this stage, it necessarily follows that some of the advanced designs of machine tools capable of being combined with numerical controls like MDI, CNC and even DNC could be produced in the developing countries. Simple machining centres with 3 to 5 axis/contouring possibilities in horizontal and vertical configurations could possibly be considered for regular production in these countries.

3. It has already been noted that in many of the newly industrializing countries, digital readouts (DROs) are commonly used. As a next logical step, manual data input (MDI) controls could be produced and used on many of the simpler types of machine tools like lathes and milling machines. Here, it is advisable to opt for the latest types of MDI controls based on microprocessors. In the advanced type of MDI system, the operator has the choice of either making a programme by machining the first part manually to automatically record the machine slide and tool movements

or using the keyboard for the input of work cycle commands from a programmed sheet on the basis of the part drawing. Since this type of control does not make use of punched tape, the tape reader which is normally a source of trouble is totally eliminated. If required, the part programmes located in the system memory could be transferred to magnetic cassettes for permanent storage. It is desirable for the developing countries to skip the older type of MDIs and go in for microprocessor-based MDI controls.

An appropriate example of such a control system on the lathe could be the "Universal Turning Machine", type NEF, manufactured by Gildemeister and Comp.,A.G., in Bielefeld in the Federal Republic of Germany. The only limitation in such MDI control at present is that it is made for machines of up to three axes. This is probably adequate for the developing countries at the present stage. However, what is most urgent and important for the developing countries is the training of programmers for these types of controls.

4. Continuous attempts will have to be made by the developing countries to modernise and upgrade their machine tool designs and mechanics

for high-speed and high quality machining. The types of machine tools currently produced in the developing countries will perhaps have to be redesigned for high speeds, faster feed mechanisms. larger torques and forces, significantly greater horsepower, much increased static and dynamic stiffness and suitability for NC controls.

5. As observed before, in machine tool manufacture many quite simple and less expensive methods are being employed in the industrialised countries which are ideally suited for the developing countries. For instance, the recent innovations in guideway technology have resulted in the development of glued-on guides and fixed-on guides. This new concept ensures the longevity of machine accuracy, reduces the frequency of maintenance and it is possible to replace guideway elements easily without resorting to costly and time-consuming scraping.

6. Distinct advantages are possible in the modular construction of machine tools. In order to meet the needs of the metalworking industry to machine a wide range of parts in small and large batches, with an ability to change over quickly

from one part family to another, various configurations of machining systems can be built from a range of standard module units. Metalworking industries in the developing countries could be best served, particularly with the aid of group technology, through the concept of modular units for building dedicated machine tools for high volume production. Machine tool builders in the developing countries could advantageously exploit this concept.

7. It is very necessary to update manufacturing methods employed in the metalworking industry of the developing countries. In many cases, the production technology that developing countries today employ in their metalworking industries is based on a large-scale use of general purpose machines like lathes, milling machines, radial drills, horizontal boring machines, capstan and turret lathes. For certain applications, single and multi-spindle automatics, single and special purpose machines and multi-unit head machines and transfer lines are in operation, particularly in the automotive and similar mass production metalworking industries.

These in many cases could make way for machining centres to be integrated into new machining concepts like semi-flexible manufacturing systems and computer-aided manufacture. For machine tool manufacturers in the newly industrialising countries (NICs), this may appear to be a somewhat difficult endeavour but it is strongly advocated that for smaller batch production, which is the main feature of metalworking industries in these countries, such concepts are ideally suitable for improving quality and reducing costs of the end-products.

8. Another important aspect to which the machine tool industry in the newly industrialising countries should address itself is the quality of the machine tools it produces. One of the important strategies of improving the productivity of the metalworking industry in these countries is to improve the quality of the machine tools. Japan has advanced by leaps and bounds in this regard. Machining centres manufactured by Japan may not be equipped with as many advanced design frills as perhaps those made in the Federal Republic of Germany or the United States. But they are sold all over the world in

large numbers mainly because of their high reliability and competitive prices. Also in Japan, the metalworking industry's stupendous growth and success has been primarily due to the superior quality of its products in the manufacture of which Japanese enterprises use extensively machining centres produced in Japan. Japan has made quality its main advantage over other competitors on the world market. The manufacturing industry of Japan has shown to the world that quality control involves the whole industrial process beginning with product design and continuing up to the delivery of the final product to the market.

9. Progress in measuring techniques has been so rapid that the resolution and accuracy of gauging have reached limits governed only by the inherent instability of machines/workpieces Besides, there has to be a greater emphasis on machine tool design to achieve greater accuracies for the parts machined. There must be in fact a greater drive towards even higher part accuracies, thus reducing rejects and ensuring longer product life. In-process gauging has to become a common feature of machining, particularly in the final

stages of component manufacture. The development of compact and reliable electronic probes has made possible in-process gauging on all automatic machining systems. In any case, if the developing countries are to go in for the production of machining centres, their quality standards will necessarily have to improve by at least two orders of magnitude of accuracy. Co-ordinate and dimensional accuracies and superior finish are only possible if the machine tools are designed and manufactured using modern technology.

10. The export of machine tools will bring the developing countries both tangible and intangible gains. Tangible gains are of course the earning of valuable foreign exchange, a better trade balance and an expanded market. An intangible gain is that because of the exposure of their products in the competitive world market, manufacturers of machine tools in the developing countries will become aware of the latest developments taking place in design, quality standards and manufacturing technology of machine tools produced in the industrially advanced countries. As a result, the machine tool industry of developing countries could endeavour to keep pace with the developments taking

place in machine tool design and production technology in the advanced world. Highly industrialised countries have some limitations in producing certain designs and types of machine tools with a comparatively higher labour content. In fact, they are fast giving up the production of many of these general purpose machine tools in preference to the advanced designs and types of machine tools. However, there is a sizeable demand also for general purpose machine tools in the industriallv advanced countries, mainly in the areas of maintenance, training and tool room and to some extent, by the small and medium-scale manufacturers. If the developing countries' machine tool industry is able to meet this need of the developed countries, then their exports of machine tools could be quite substantial as a percentage of their total production. This is possible provided the machine tools made in the developing countries are of modern design and reliable quality, and have competitive prices with guaranteed after-sales servicing and supply of spares.

The above are some of the recommendations considered important for the newly industrialising countries to update their machine tools and production technology. Certain recommendations may appear somewhat beyond the reach of the developing countries. But then, if efforts are not made to improve the designs of machine tools and introduce newer designs of machine tools and move on to more automatic productive systems in the metalworking industry, like flexible machining systems and partially integrated computer-aided manufacture, these countries might remain at a disadvantage in their production technology in the metalworking industry.

<u>Other developing countries</u>

For other developing countries, particularly smaller ones which have a very limited industrial base or none at all, and which depend upon imports of simple items of machinery and equipment to embark upon machine tool and machine building activities, there could be many hurdles and deficiencies in the essential infrastructure. However, for those which are keen to produce some of the capital machinery items, it may be advisable to give top priority to the production of basic machine tools since the main plank on which the machinery industry could be established is the machine tool industry. Without this, it is rather difficult to conceive of developing any engineering and capital/durable goods and consumer goods industries. The following are some recommendations for establishing this vital industry on a scale commensurate with the demands and resources of these developing countries.

1. The designs and types of machine tools depend upon the needs of the machine tool users. Normally in the less developed countries the demand could exist for simpler types of general purpose machines. Even in the simpler or less costly (but not cheap) classification of machine tools, designs could be modern incorporating features like higher speeds and feeds, built with high-grade castings (Meehanite type) having high tensile strength and greater wear resistance (higher Brinell hardness) and critical steel components like main spindles and screws machined from high-grade alloy steels, gears made from nickel or manganese steels, hardened and ground and with slides scraped to a high degree of precision and powered sufficiently to use carbide cutting tools. Designs in fact decide the degree of sophistication

and the cost of machine tools and other plant and machinery needed for the conversion of the designs into products. Depending upon the level of demand in the small developing countries, it is advisable to select appropriate designs and related production technology which are more suited for smaller batch production and relatively more labour-intensive than opting for automatic machines and automated assembly procedures etc.

In the beginning at any rate less developed countries will have to depend upon imported designs. In selecting suitable designs, care has to be taken because it is on this choice that many of the subsequent financial, technical and marketing considerations depend. First and foremost, market demand is what decides the types of designs and class of sophistication of machine tools that should be taken up for production. It can be safely assumed that in the less developed countries, there would be a need for simpler but modern designs of machine tools. Such designs and know-how in manufacture could be more advantageously obtained from newly industrializing countries. Although highly industrialised countries could licence such designs, developed as a result of their concentration on highly advanced designs and production technology. it may be that simpler designs have to be specially developed by them for the developing countries. Due to this and many other considerations like deputation of experts and training of personnel, the cost of acquiring design and know-how from the industrially advanced countries may become prohibitive for the less developed countries.

2. Notwithstanding the developing countries' dependence at the beginning on imported designs and know-how, one thing appears to be definitely essential and that is indigenous designs cannot be evolved progressively and production technology adapted and mastered without a scientific infrastructure and build-up of local R&D potential. In order to conserve rare resources, particularly the expert manpower resources to master designs and production know-how in machine tool building, it is recommended that there could be government-owned machine tool design and production technology institutes. These institutes could preferably be assisted or set up in collaboration with well-known, international machine tool design and research

institutes. A group of design experts in the institutes could design suitable machine tools needed by the country and build prototypes and thoroughly test them for soundness of design and production processes. Institutes could then offer the licence of these designs to interested entrepreneurs in the country. Designs could also be sponsored by entrepreneurs. With increasing experience, machine-tool-producing units could graduate to designing machine tools on their own. Government-financed machine tool design and research institutes on the other hand could switch over to developing more advanced designs to meet the growing demands of the metalworking industry. What perhaps still may be necessary is that manufacturers should be obliged to have their machine tools tested exhaustively and perhaps even graded by machine tool design, research and production technology institutes.

3. Cast iron foundries and pattern shops. In the less developed countries, it is advisable to give priority to setting up foundry facilities to produce high quality cast iron components like beds, columns, arms, base plates, gear boxes, headstocks and tail-stocks. In view of the ample work-

force available in these countries, it is suggested that the heavy castings could be hand moulded, perhaps using sandslingers. The sand conditioning plant, core blowing equipment, melting cupolas, core and mould drying ovens etc. need not be highly automated. However, it must be realised that the training of moulders, floor and machine moulders, coremakers, metallurgists and so on is essential for producing quality castings and keeping foundry product rejects to a minimum.

Pattern shops could be a captive operation of the centralised foundries. The making of pattern and core boxes is a skilled job and workers have to be specially trained in these trades.

4. Forge shop. The percentage of forged parts in the production of machine tools is much less and as such only a few central forge units can be set up in a country. Drop hammers and furnaces are the main items of plant and machinery needed in forge shops. As for the dies and tools, these may have to be procured from outside or from the central tool room service units.

5. Rolling mills. Mild steels, carbon steels, alloy steels and sheet steels are the essential raw

materials required in the production of machine tools. Compared to castings - ferrous and non-ferrous - the proportion of steels generally is less. Still, the latter constitute vital raw material for the manufacture of machine tools and for that matter, any machinery. Whether a developing country should develop its own iron and steel industry depends upon various factors. Undoubtedly, it is advantageous for a country to develop its own iron and steel industry if the necessary mineral raw material resources are available. However, many small developing countries which have not reached a high level of industrial development and which are not endowed with essential raw materials like iron ore, coal and gas, and infrastructure like adequate electric power, but which have a small-scale demand for steels of various types and sizes and so on would be well advised to import whatever small quantity of steels would be initially needed for the nascent machine tool and machine building industries. It is however recommended that it is advisable to set up rolling mills, whereby various operations from steel scrap melting to rolling several sizes of bars (including alloy steels), angles, channels etc. could be undertaken. Using modern technology, viz. the continuous casting (concast) machine and mills of adequate size and capacity, small rolling mills could turn out the required sizes and quantities of steel raw materials of different sizes and sections and even alloy steels and carbon steels to partly meet the needs of the machine shops engaged in the manufacture of machine tools and machinery.

6. Central tool room. Machine tool production units are not complete without a tool room facility. It is a common feature in all industrially advanced developed and developing countries to add tool room facilities to each manufacturing unit. This is necessary for maintaining a degree of flexibility and self-sufficiency and more specially to meet the specific needs of each manufacturing unit. But the difficulty that may be encountered in less developed countries concerns the availability of both highly skilled labour and experienced and resourceful tool designers. Besides, plant and machinery for tool rooms could be expensive. Due to these and many other reasons, including fuller utilisation of capacity, less developed countries are well advised to set up

central tool room facilities as an adjunct to the machine tool complex. The equipment of the central tocl room shouia include jig borers, universal tool room milling machines like the Deckel precision cylindrical and internal grinding machines, and thread grinding, high precision and gauge grinding and precision thread cutting facilities. The unit may have to be equipped with facilities for making high-speed cutting tools with furnaces and baths for heat treatment of high-speed steels. Precision equipment for grinding and resharpening of tools like carbide tools, hobs, reamers, taps is a common feature of most tool rooms. The tool room unit should be staffed with competent tool makers and designers who can design/make jigs, fixtures, special tooling for the machine shop and other production units including forge shops, rolling mills, sheet metal shops and even for the foundries and the pattern shops.

7. Ancillary shops. Ancillary shops like those for heat treatment, plating and sheet metal could be largely captive units of the machine tool production units. These could be large or medium size depending upon the load from the parent machine tool units. The main point is that these inde-

pendent activities could be run more efficiently with a degree of specialisation.

8. Production technology. The problem is to evolve modern production technology for the manufacture of machine tools in the less developed countries which is appropriate. In this regard, it should be borne in mind that any production technology which increases the cost of production and/or sacrifices quality is not appropriate. Hence, in assessing and selecting a suitable production technology, it must be ensured that the technology is capable of producing quality products at equitable costs.

The choice of production technology depends on the stage of industrial development of a developing country. Industries in developing countries have been established mostly in collaboration with the developed countries or industrially advanced developing countries. In many cases the pattern of establishing some of these industries under the technical guidance and collaboration of the collaborators has taken place on a large scale giving insufficient attention and importance to the development of small-scale and ancillary industries. Fundamentally, there has also been a high degree of self-sufficiency in the vertical planning of industrial units. Perhaps some of the heavy and capital-intensive processes may have to be established in a manner whereby most of the work is done under one roof and perhaps little scope exists for the decentralisation and distribution of work content among small and medium-scale enterprises. But this is not necessarily the case with many items of machinery including machine tool and other mechanical and electrical engineering products. These industries provide an ideal possibility for the decentralisation of manufacturing activities. The production technology employed could be such that it gives considerable scope for setting up a number of small-scale and ancillary units dispersed throughout the country to which simpler or less critical items and accessories and ancillary items could be farmed out. Such a pattern of decentralised production and labour-intensive technology will also serve the desired objective of providing employment opportunities and the maximum dispersal of industrial activities.

9. Production set-up for machine tool building.

The production activities of machine tool manufacture can be classified into two broad categories: (a) component manufacture and (b) assembly and testing operations. In fact, in respect of any machinery, whether it be electrical or mechanical, once the designs have been identified, subsequent processes are almost similar to machine tool production, viz., manufacture of components and assembly and testing operations.

(a) Component manufacture. In the case of components, there are normally two broad divisions: (i) The ready-made externally-purchased items like electric motors, switch gears, clutches, ball bearings, oil rings, circlips, limit switches, machine lamps, lubricating and other coolant pumps and (ii) those that are manufactured out of castings, forgings and steels to drawing specifications, which is the category on which this study focuses.

In dealing with manufactured components, it is advisable to produce these using general purpose machine tools with the extensive assistance of production aids like jigs and fixtures. Since the batch quantities are small, there is no necessity for highly rational, advanced special purpose machine tools. But one disadvantage of such a system of production is the scarcity of skilled personnel. It therefore becomes necessary to train skilled operators like turners, fitters, grinders, milling machine operators, jig boring operators intensively in central training centres and transfer them to production shops initially for on-the-job training before entrusting them with skilled tasks like boring of headstocks, grinding of spindles, thread cutting of screws and nuts, scraping of bedways, cutting and grinding of gears.

(b) Assembly of machine tools. The assembly of simpler designs of machine tools like lathes, knee-type milling machines, pillar drills could be somewhat labour-intensive. This calls for a highly skilled labour force which has to be trained specially for the trade. As a matter of fact, the basic trades in machine tool technology have been and continue to be, fitting and scraping. It takes a long period of experience to assemble modern types of general purpose precision machines. Assembly operators have to be even more skilful than machinists, since some of the machining inaccuracies of components have to be corrected in assembly by appropriate filing and scraping.

The assembly operation is normally split into two main divisions viz., (i) Sub-and unit assemblies and (ii) final assembly. Suitable assembly fixtures, test beds, control equipment etc. have to be provided so that assemblies - sub-and unit assemblies - are tested before sending them on to final assembly.

The testing of machine tools is a specialized task. There are international test charts and specifications like the Schlesinger charts according to which machine tools have to be tested by expert technicians who have to be specially trained to carry out these exacting tasks like alignment tests and performance tests.

Quality control is the heart of machine tool production. Suitable instruments and gauges like micrometers (internal and outside), thread gauges, snap gauges, go and no-go gauges, vernier calipers are used to check components passing through various stages of machining. Sub-and unit assemblies also have to be rigidly tested on specialised test beds meant for testing particular unit assemblies so that when they are sent to final assembly, they should not only fit properly and be able to be easily assembled without much alignment or fitting work, but also at the final inspection stage, the machine tools should conform to the specified alignment and performance tests.

10. Structure. It is advisable that separate factories/units are established with 100-200 employees to produce different types of machine tools, for instance, one unit specialising in the family of lathes, another for milling machines, yet another for production of drilling machines and so on. This is advantageous from many considerations, but the major ones are greater degree of rationalisation, bigger size of batches, and above all, technical specialisation. The number of employees could be even less if the major operations like foundry, heat treatment, tool room facilities and training centres are each a separate operation and serve as common facilities for the production of different types of machine tools in different units. There also should be a possibility of further decentralisation of production by farming out certain items and accessories to ancillary industry.

The above scheme may appear rather elementary and unsophisticated. On the contrary, for small, developing countries, which have to start almost from scratch, to embark on establishing a precision machine tool industry, it is necessary, as a part of training, that they should pass through all the basic stages in order to be capable eventually of producing more advanced designs of machine tools using advanced production technology.

Bibliography

Anderson, Ashburn. American machinist (New York) March 1976 to November 1980.

Arndt, G. A survey and some basic considerations of the layout of flexible manufacturing systems. Paper prepared for the International Conference on Manufacturing Engineering, Melbourne, 25-27 August 1980.

Atkey, Martin. Edge on inserts give milling a new face. Metalworking production (London) 118:10:91, 1974.

Bell, D. Coming of post-industrial society: a venture in social forecasting. New York, Basic Books, 1973.

Bells are ringing up success for the young water jet. Engineer (London) 236:6098:32-33, 25 January 1973.

Bollinger, John G. Computer control of machine tools. C.I.R.P. annals (Berne) 21:2:215-218, 1972.

Bryan, J.B. and E. G. Loewen. The limit of accuracy of machine tools. Proceedings of International Conference on Production Engineering, Tokyo, 1974. Part II; pp. 24-32.

Bylinsky, Gene. The second computer revolution. Fortune (New York) November 1975.

——————— Those smart young robots on the production line. Fortune (New York) 17 December 1979.

Cutting tools. Manufacturing engineering and management (Dearborn) January 1974.

Dyke, R. M. Qualified tool holders for numerical control machining. Carbide journal (Bridgeville) March/April 1974.

Far eastern economic review (Hong Kong) 29 August 1980.

Fuentecilla, J. Coming soon: smart machine tools. Industrial world (New York) 204:8:15-21, August 1979.

Guide to machine tool control: Part 1 - Programmable controllers. Part 2 - Numerical control system. American machinist (New York) Special Report No. 659:119-142, September 1973.

Heaton, James W. Insight into an insert. Carbide journal (Bridgeville) July/August 1975.

Impact of technological progress of society as a guide for the orientation of research in C.I.R.P. C.I.R.P. annals (Berne) 21:2:239-245, 1972.

King, Alan G. and W. M. Wheildon, Jr. Ceramics in machining processes. New York, Academy Press (1966).

Koenigsberger, F. Trends in the design of metalcutting machine tools. C.I.R.P. annals (Berne) 24, Part 2, 1974.

__________ Use of group technology in the industries of various countries. C.I.R.P. annals (Berne) 21:2:209-214, 1972.

Larsen, Raymond J. Where machines leave off, people take over. Iron age (Radnor, Philadelphia) 19 May 1980.

Lindsay, R. P. and N. P. Navapro. Principles of grinding with cubic boron nitride wheels. Machinery and production engineering (Brighton) 124:3191:74-81, 23 January 1974.

Machine Tool Task Force report on machine tool technology. American Machinist (New York) October 1980.

Machine tools: 1980 industrial outlook. Industrial world (New York) 205:2, February 1980.

Makers plan: developing unmanned machine building plant in seven years. Japan economic journal (Tokyo) 19 June 1973.

Merchant, M.E. Forecast of the future of production engineering. C.I.R.P. annals (Berne) 20:213-225, 1974.

__________ Technological forecasting and production engineering research. C.I.R.P. annals (Berne) 18:5-11, 1970.

__________ The computer aided factory. Seminar proceedings. University of Salford, United Kingdom of Great Britain and Northern Ireland, 1975.

__________ The future of batch manufacture. Philosophical Transactions, 1973.

__________ World trends of machine tools and production technology - glance from the foot-prints of George Schlesinger. Lecture delivered at Technische Universität, Berlin (West), 6 October 1980.

Metal cutting: the shape of things to come. Iron age (Radnor, Philadelphia) 17 December 1979.

Metal working research today. American machinist (New York) Special Report No. 658:69-76, 9 July 1973.

New competitors in machine tool market. Industrial world (New York) 205:1:18-23, 1980.

North-South: a programme for survival. The report of the Independent Commission on International Development Issues under the chairmanship of Willy Brandt. London, Pan Books, 1980. 304 p.

Only know-how sells engineering. Machine tool review (Coventry, United Kingdom) January/February 1975.

Peters, J. What we do by "true value in measurements". C.I.R.P. annals (Berne) 21:2:205-208, 1972.

Polycrystalline diamond tooling. American machinist (New York) 118:24:61, 1974.

Powder HSS production moves into top gear. Metalworking production (London) 118:11:85-90, 1974.

Production engineer (London) October and December 1979, April and June 1980. Journal of the Institution of Production Engineers, United Kingdom.

Recent research and development in grinding. By B. Coding and others. C.I.R.P. annals (Berne) 21:2:157-166. 1972.

Robot revolution. Time (New York) 8 December 1980.

Robots join the labour force. Business week (New York) 9 June 1980.

Society of Manufacturing Engineers. Technical report: MRR-79-01-1979. Dearborn, Michigan, United States of America.

Technical Policy Board. Current and future trends of manufacturing management and technology in the UK, "The way ahead". London, The Institution of Production Engineers, 1980.

The future of the world economy: a United Nations study. By Wassily Leontieff and others. New York, Oxford University Press, 1977.

TIC coating concept. Carbide journal (Bridgeville) September/October 1973.

Uttal, Bro. Europe's wild swing at the silicon giants. Fortune (New York) 28 July 1980.

Annex I

Extract from Report by the TECHNICAL POLICY BOARD

on

CURRENT AND FUTURE TRENDS OF MANUFACTURING MANAGEMENT AND TECHNOLOGY IN THE UNITED KINGDOM

"The Way Ahead"

August 1980

published by the Institution of Production Engineers, United Kingdom

"4 Chronological Summary of Delphi[1/]

4.2 Professor Eugene Merchant of Michigan University, who is a pioneer of the use of 'Delphi' surveys for technical prediction. conducted a 'Delphi' survey in 1970-1 within the members of CIRP. Some results from this paper entitled "The Future of Production Engineering" have been included, for comparative purposes, in the analysis of the detail of the Institution of Production Engineers 'Delphi' survey ...

CHRONOLOGICAL SUMMARY - UNITED KINGDOM SURVEYS

1980 - 1981

1. In this period there is an expectation by many employees for work to contain more responsibility and challenge. ...

2. There will be a considerable increase in both general and technical training of a formal nature. ...

3. Machining accuracy is expected to be greatly improved by more scientific design of machine

1/ "Project Delphi" was the name of a US Air Force-sponsored Rand Corporatio study, begun in the early 1950s, with the aim of obtaining expert opinion mainly through the use of questionnaires.

tools - possibly made from composite materials (concrete, plastics, carbon fibre, etc.).

4. Very high pressure (413MPa) liquid jets will cut fabric, leather or glass or carbon fibre, etc.

5. Thermal control of the environment will be adopted.

<u>1982 - 1983</u>

1. More training and more involvement by management will be widespread in Quality Assurance and getting products 'right first time'.

2. Production designers will be able to use a programme to determine the economic benefit of using Group Technology - but see 1986/87 as there is some doubt in Japan and U S A and many U K experts think 1983 is too early.

3. Paper tape will begin to disappear in the U S A by 1982/83 when 40% will cease to have it on new machine tools. ...

4. 20% of U S A systems will be fitted with diagnostic sensors and indicate changes or failures.

5. 10 to 15 % of NC tools will have pallet transfers (shuttles).

6. There will be increased demands to improve productivity and reduce the dependence on manual arc welding skill. As a result there will be more use of mechanised welding in which computer selection of welding conditions will become common.

7. Sensors for tracking and control of welding variables will be developed and applied. An increasing use will be made of arc welding robots and of specialised automatic equipment. With semi-automatic arc welding special power sources will improve the performance of the welder.

8. Although arc welding processes will not be replaced in the forseeable future they will lose out to other processes such as electron beam welding.

9. The laser will find application for precision welding of small components (in which it will compete with low power electron beam); and for surface treatment.

10. The tendency towards increasingly severe service conditions will make the use of heat and corrosion resistant coatings more common, also inserts and dissimilar metal joints.

11. Greater use will be made of 'in process' quality and control, and of instrumentation.

<u>1984 - 1985</u>

1. Computer aided manufacture will use a network of graphics terminals to inform management on the

shop floor of the situation of any product and some will convey 'set up' and operations instructions.

2. Increasing pressure will arise on material conservation and a certain amount of reclamation will occur, some of it enforced by statutes.

3. NC machine tools will not normally by now, use paper tape, 'floppy disks' will have taken over.

4. The cost of part programming will be reduced by one third by computer aids on interactive pre- and post-processing and by expanded data bases. Computer Graphics will be in use for CAD - CAM by about 5% of companies. ...

5. Computer aided material handling systems integrated with manufacture will be used by a small (2%) number of companies but this will grow - see 1990. ...

6. Smaller companies will have only 1% of their work designed by computer interactive graphics which in turn is used by CAM. ...

7. By this time 10% of all manufacturing industry will have a considerable amount of automatic inspection ('on line') with diminishing 'post manufacture' inspection. This process will extend well beyond engineering products into such areas as textiles, paper and box or can manufacture. This will be a continuous area for development - see 1995. ...

8. In these years the proportion of companies using integrated CAD - CAM for both product and tool design will be

U K	-	5%	10%
Japan	-	10%	20%
U S A	-	10% by 1990 these figures	= 25%

9. Managers expect working hours to reduce to 38 per week.

10. Consultation will be universal with workers in at least 30% of all companies engaged in manufacture. ...

11. Office staff will be working under some forms of productivity schemes, though this is considered to be difficult to install.

12. Computers will be utilised by the majority of manufacturing units, certainly those with at least 250 employees and most processing plans will be done by computer, this will reduce management (manual) paperwork.

13. 50% of manufacturers will have costing and machine scheduling on computers and this information will be available to managers on request on their desks by VDU display.

14. Mini and micro computers will be used to assist both physical movement and information in Materials Handling situations.

15. In precision turning and grinding 'in-process' sensing of finish and dimensions will reduce scrap

by 25% : and eliminate much 'post' manufacture inspection.

16. It should be possible to predict and specify the surface finish needed to give required 'wear life' in rotating shafts or sliding surfaces.

17. Adaptive control strategies for metal removal by turning, rolling or grinding will be available and these will be adopted by 10 % of industry - see also 1990 and 1996.

18. Both paint spraying and automatic welding by Robots will be widespread where it is applicable (i.e. up to 40 % of industry using these processes).

19. Lasers will be used for 'in process' control (non-contact) of accuracy. ...

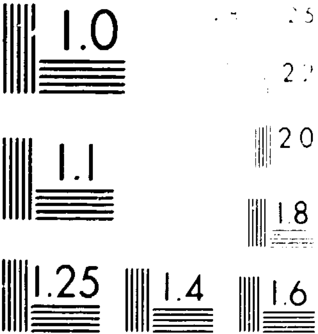
20. The structure of most new machine tools will be composite to avoid vibration and to give stiffness and thermal stability and reduce noise.

21. In the U.S.A. many industries will use Group Technology, 10 % by 1987.

22. Lasers will be used for cutting and welding both here and in the U S A.

23. Software systems will be developed to predict costs based on part definition only.

24. 75 % of U S A assembly systems will have automatic inspection.


1.0
2.0
1.1
1.8
1.25
1.4
1.6

25. By 1985 direct labour in car final assembly will be replaced by programmable automation; 30 % is thought likely.

26. Part storage and retrieval in the U S A will be automatic.

1986 - 1987

1. In the U S A by 1987 they consider that 10 % of all machining will be done by Group Technology. ...

2. Working hours will be reduced to 36 per week.

3. The knowledge will be available to use the computer to indicate whether it is economical to employ Group Technology for any particular part. ...

4. By this time in larger firms 50 % of all the process paperwork for manufacturing will be computer generated. As a result there will be a 25% or 30 % reduction in machine tool part-programmers but where there is more CAM there will be more CAD and there may be some transfer to the designer. ...

5. 20 % of all printed circuit board and electronic manufacturers will use part classification and coding systems. ...

6. 50 % of electrical wire harnesses and automotive harnesses insofar as they exist in their present form will be designed by CAD. ...

7. Automatic assembly will have penetrated into 20% of mass-production companies.

8. The Japanese predict coding of sheet metal parts for classification, by 20 % of companies; ...

9. A harmonised scheme of working for most of the work force, i.e. not many hourly paid workers, but flexible hours of work for office staff will not extend to production workers in general.

10. There will be a considerable extension of all types of standards arising from EEC regulations, Health and Safety and Consumer protection and also for manufacturing reasons.

11. Most NC machines will have dedicated micro-computers at this time.

12. Spark Erosion (SF) will have developed and become the dominant method for tool making where applicable.

13. 20% of mass production companies will be using dedicated automatic assembly by which time modular robots will exist which will make equipment prices competitive with specially designed single purpose automatic assembly equipment. These will be in small quantity until 1990.

14. In the U S A 50% of new machine tools manufactured will be NC.

1988 - 1989

1. In the field of electronics manufacture it is expected that this industry will be a leader in the application of computer aided ideas. CAD and CAM will be applied to 50 % by these years. ...

2. Computer programmes for die making control and optimum design will exist.

3. By 1989 some 75 % of all CAM systems will be relying on distributed computing system concepts. It is considered that only 10 or 20 % of the systems will rely on control or main frame computers. ...

   The proportion between differing systems is thought to be (see figures)

	NC	CNC	DNC
U K	10%	80%	10%
U S A	20%	50%	25%
Japan	30%	40%	30%

4. There is considerable doubt as to whether any large proportion of NC machines will employ conversational interrogation based on set 'menus' from the 'shop floor' since it is likely that control would be lost in large units. Some specialised small units may use this for jobbing work.

5. By 1988 the U S A think that 20 % of manufacturers will have a computer model of their operations. ...

6. 20 % of mass production industry will by this time be using dedicated automatic assembly robots. ...

7. Central computers will control 80% of 'in process' and finished parts inventory.

1990 - 1991

1. Many people expect it to be necessary to ration energy and certain raw materials particularly some metals. •••

2. 10 % of all special tool and fixtures will be designed by interactive computer graphics. •••

3. 25 % of all machined parts will be designed on interactive computer graphics in the larger companies and 10 % of these results will be introduced through CAM. •••

4. About 10 % of all machining operations and some types of fabrication will be made on group technology or 'cell' operations in the larger companies. This procedure has not always been economic for foundry or fabrication.

5. 50 % of process plans will be computer generated in the larger companies. •••

6. Developments of optical scanning of drawings and digitising will put CAM data into data bases for either retention or subsequent processing - some engineers question the economics of this development.

7. Classification of laser (optical) scanning of labels for inventory control will be used by 10%

in materials handling. ...

8. 25 % of set up and operations instructions will be conveyed on video screens from computer graphics to the shop-floor supervisors. ...

9. By this year 75 % of all conventional NC equipment will have been replaced by CNC or more likely DNC equipment. ...

10. 20 % of all small batch companies will use programmable robots for some forms of automatic assemblies but usually not unless the batch size is 50.

11. Paper tape will be largely superceded by 'floppy discs' or 'diskettes' VDU type CNC which will be capable of supplying job operations, graphics, 'set up' data instructions to the operators. ...

12. U S A expects the work week to be down to 32 hours.

13. 50 % of the working force in Manufacturing will be skilled largely in computer maintenance....

14. The U S A and the U K consider that by this year 20 % of industry will have combined materials and process planning in computer aided control. ...

15. The U S A, Japan and the U K all agree that by 1990 methods development will be performed by computer for 33 % of this work instead of by manual staff. This also applies to the development of standards and for process control.

16. In the U S A it is considered that 75 % of simple programme controlled equipment will be replaced by multi-stored programmes and multiprocessor control. ...

17. 20 % of industry will use adaptive control strategies for metal removal - turning, grinding and milling.

18. There will be a marked reduction of noise from machine tools - possibly 85dB will be mandatory.

19. Robots should by now be able to assemble "families" of parts (as opposed to single items) because optical identification will be possible.

20. 30 % of assembly will be made by structural adhesives.

21. The Americans predict a 32 hour week by which time some 50 % of the work force will be skilled.

<u>1992 - 1993</u>

1. 10 % of <u>smaller</u> companies (less than 1000 staff) will employ Group Technology or "cell" manufacture by 1993 although size is not a major criterion. ...

2. 20 % of UK industry will by this time have a computer model of manufacturing operations. ...

3. 25% of all manufacturing units will have installed computerised;

a) Control of stock.

b) Automatic identification of items.

c) Using pallets to convey through the whole process - this may be a year or so later than (a) and (b).

4. There will be general availability of facilities for automatic sensing and replacement of broken or worn tools.

1994 - 1995

1. Robots will also be installed in 50 % of industry where CAM is used.

2. 25 % of machined parts will be designed by computer-interactive-graphics even in the firms with less than 1000 employees.

3. Working hours will reduce to 32 but it is unlikely that a four day week will ever be adopted. Small companies will use Group Technology at this time for 10 % of all machining operations.

4. By this time some 20 % of all machine tools installed will have the following characteristics:

a) Automatic loading and unloading and transfer.

b) Sensing and changing tools for wear or breakage.

c) Complete monitoring and recording by computer.

...

5. Smaller firms will generate 50 % of their process planning on computers as well as manufacturing paperwork for parts and assemblies; and 30 % will use NC even in companies with 50 workers only.

6. Feedback sub-systems ('on line') will sense and correct deviations (back to the part standards) in 25 % of manufacturing organisations. ...

7. Operations of the manufacturing process will be modelled by 25 % of companies in 1995 but even by 1992 there will be perhaps 20 %. ...

8. 20 % of machine tools supplied at this time will incorporate necessary co-ordinate measuring (probably of a non-contact nature) and feedback control to adjust deviations. ...

9. The percentage of special tool and fixture design by computer graphics will by now be 25 %. ...

... —— ...

11. It will take until these years for as many as 25 % of all smaller companies (1000 or less) to fully implement CAM. This will also be the case where the batch sizes are normally as low as 50 off. ...

12. Industrial robots will be integrated into CAM systems in 50 % of companies where there is assembly - moving - etc.

For very small units perhaps rather later. ...

13. Most of manufacturing work forces will have to become highly skilled in diagnosis and maintenance of automatic machirery and computers.

14. All firms will hold information and motivating sessions to maintain staff morale.

1996

1. 25 % of machine tools will form part of a versatile machining system with automatic part handling between machines with central process control.

It is considered that any results beyond this year would be unreliable."

ANNEX II

QUESTIONNAIRE

TECHNOLOGICAL PERSPECTIVES IN THE MACHINE TOOL INDUSTRY IN THE NEXT DECADE AND THEIR IMPLICATIONS FOR DEVELOPING COUNTRIES

By

Dr. S.M. PATIL

QUESTIONNAIRE

1. What technological changes, in your opinion could take place in the next two decades in the field of machine tools produced in the industrialised countries, particularly relating to the following areas:

   1.1 Metal cutting and metal forming processes;

   1.2 Control system: DRO and NC-CAD, CAM and adaptive controls;

   1.3 Will there be more of plasma cutting, laser beam technology, explosive forming, rotary forming etc.

2. Will there be a greater emphasis on N.C. controls and if so, of what type? Will computer aided manufacturing technology replace largely the traditional production methods?

3. What are the principal changes in machine tool design which could take place in view of some of the above changes taking place in metal cutting and metal forming technology in the next two decades?

4. What are the new developments in cutting tools and press dies particularly viewed against the background of some of the innovative changes taking place in machining processes and machine tool designs?

   4.1 Ceramic tools - could they become more adaptive to practical applications?

   4.2 Machine tools with high and super high speeds will cut metal at higher speeds and feeds, with a high degree of precision and finish. Will the present types of sintered tungsten carbide tools undergo further changes in metallurgy and tool geometry?

   4.3 Could you conceive of any new types of cutting tools?

5. In sophisticated industies like aircraft, space and nuclear, more and more hard metals are going to be used.

   5.1 Will this reflect on designs of machine tools, cutting and metal forming processes?

   5.2 Cutting tools will have to be simultaneously developed to meet this challenge. How and in what specific areas are these developments going to take place?

6. Will there be any scope for computer integrated automatic factories? If this happens on a large scale, what are the implications for machine tool design and production technology?

7. In view of rapid and revolutionary changes that have taken place over the past three decades in machine tool designs and cutting tool applications, do you think that the scope for general purpose machine tools (GPM) will diminish specially in the industrialised countries?

8. If the answer is yes, do you think that for many applications particularly in small batch inexpensive production, one could use economically sophisticated replacements of GPM?

9. If the answer is no, could you assess what important changes will still be inevitable in design and applications of GPMs?

10. What is your advice for developing countries (DCs) intending to update and/or start their machine tool industry? Do they have to take up more sophisticated designs, which are/and will be produced in the industrialised countries? If yes, what is the essential infrastructure they have to build up? If no, do you think that DCs should go in more for manufacture of GPMs? If GPMs are to be made by DCs what standards of designs should they take up? Do you advocate them to go in for certain types, say for example, the cone pulley lathes or modern designs of all-geared headstock lathes?

11. If you consider that DCs should stay on manufacturing GPMs of modern designs, don't you feel that technologically they would continue to be at a disadvantage and have to import their requirements of advanced designs of machine tools permanently from the developed countries?

12. How will they find resources to import their requirements of more advanced designs of machine tools? Do you advocate export by them of the modern types of GPMs to the developed countries?

13. How best can the advanced countries help the DCs to acquire new and modern designs of machine tools and production technology? Have you the right environment to develop some of these designs which perhaps are nowadays not being produced or rapidly being given up by the developed countries in preference to highly automated and special types of machine tools?

14. Is there scope for sharing the machine tool market of the world between the developed and developing countries - with developed countries exporting advanced designs of machine tools and DCs exporting modern general purpose machine tools to the world markets including the industrialised world?

15. If so, what suggestions do you have for the DCs to enable them to build up their capacity and technological strength?

16. In what specific areas of machine tools could the industrialised countries do more to advantageously transfer technology and licence designs and know-how?

17. Do you feel some of the more advanced machine-tool-producing developing countries could licence designs and transfer the technology better than the highly advanced developed countries? If yes, what are the special areas where they could fit in better and where DCs would still need to co-operate with advanced countries?

18. What is your opinion about the possible implications of rapid developments in machine tool designs and production technology in the developed countries on DCs?

19. If the implications are such that the DCs are going to be left behind in their industrial development and the technological gap between them and the industrialised world could thereby vastly widen, what are the possible repercussions of such a state on the industrialised countries themselves? Will they not be losing a part of the potential market for their industrial products and services? Is it not better to enhance the purchasing power of the

developing countries so as to convert them into becoming good prospective markets for the developed world?

20. Will not mutual trade and equitable distribution of wealth and affluence between North & South result in a more harmonious atmosphere in the world and reduce social strains, stresses and upheavals? If so, what do you suggest DCs should do in developing and strengthening their industrial base and technological capacity in general and in particular to enhance their machine building activities by updating production technology and designs of machine tools produced by some of them and others who have no machine tool industry as yet, to initiate steps to manufacture modern machine tools?

Bangalore
17.4.1980

ANNEX III

NAMES OF THE COMPANIES AND INSTITUTES VISITED

Date	Place	Persons met
SWITZERLAND		
19.5.1980	Zürich	Dr.Stephen Renz President
		Dr.B.E.Meyer Vice President Marketing and Engineering
20.5.1980	Zürich	Prof. E.Brem and his colleagues
UNITED STATES		
27.5.1980	New York	Mr.Thomas R. Rudel Chairman of the Board
29.5.1980	Detroit	.r.Kurt Tech Vice President
		Mr.Robert W.Kynast Director Corporate Engineering

AND PERSONS INTERVIEWED

Institute/factory	Remarks
Oerlikon-Bührle Machine Division Machine Tool Works Oerlikon-Bührle AG CH-8050 ZÜRICH 11 Birchstrasse 155 Switzerland	Discussions followed by a visit to the factory
Eidgenössische Technische Hochschule ZURICH Bergstrasse 18 Switzerland	Discussions
The V&O Press Co., Inc. 100 East 42nd Street (19th Floor) NEW YORK CITY U.S.A.	Discussions followed by a visit
Cross & Trecker Corp. FRASER (Detroit) U.S.A.	Discussions followed by a visit to the factory
The Cross Company 17801 Fourteen Mile Rd. FRASER Michigan 48026 U.S.A.	

Date	Place	Persons met
2.6.1980	Chicago	Mr.Melvin D.Verson Chairman
3.6.1980	Greenlake Wisconsin	Mr.Ralph J. Kraut Chairman of the Board
3.6.1980	Fond-du-Lac Wisconsin	Mr.Orville E.Erhardt Vice President, Manufacturing
		Mr.James B.Simon Vice President, Engineering
4.6.1980	Fond-du-Lac Wisconsin	Mr. S.M.Marathe Supervisor Industrial Engineering
4.6.1980	Milwaukee	Mr.John R.Joerger Vice President International Sales

Institute/Factory	Remarks
Verson Allsteel Press Company 1355 East 93rd Street CHICAGO Illinois 60619 U.S.A.	Discussions followed by a visit to the factory
Giddings & Lewis Inc. 545 Illinois Av. GREENLAKE Wisconsin 54941 U.S.A.	Discussions
Giddings & Lewis Machine Tool Co. 142 Doty Street FOND DU LAC Wisconsin 54935 U.S.A.	Discussions followed by a visit to factory
Giddings & Lewis Electronics Co. 666 South Military Road FOND DU LAC Wisconsin 54935, U.S.A.	Discussions followed by a visit to the factory
Kearney & Trecker Corporation 11000 Theodore Trecker Way MILWAUKEE Wisconsin 53214 U.S.A.	Discussions followed by visit to the factory

Date	Place	Persons met	Institute/factory	Remarks
6.6.1980	Cincinnati	Dr.E.Merchant Director of Research Planning	Cincinnati Milacron Inc. 4701 Marburg Avenue CINCINNATI Ohio 45209, U.S.A.	Discussions followed by a visit to the factory
6.6.1980	Cincinnati	Mr.William H. Ackerman General Manager Mr.V.A.S.Setty Director	HMT (International) Ltd. 7968 Kentucky Drive FLORENCE Kentucky 41042 U.S.A.	Discussions
9.6.1980	New York	Mr.Anderson Ashburn Editor	American Machinist 1221 Avenue of the Americas New York, N.Y. 10002 U.S.A.	Discussions
12.6.1980	Los Angeles	Mr.Frank S.Wyle Chairman of the Board	Wyle Laboratories 128 Maryland Street EL SEGUNDO California 90245, U.S.A.	Discussions
UNITED KINGDOM				
17.6.1980 and 18.6.1980	Brighton	Mr.David Sinclair Director and General Manager N.C. Division Mr.Graham Felstead Director, Designs and Development Mr.James Dawson Manager, Marketing	Kearney & Trecker Marwin Ltd. Crowhurst Road Hollingbury BRIGHTON BN1 8AU U.K.	Discussions followed by a visit to the factory

Date	Place	Persons met	Institute/factory	Remarks
JAPAN				
11.8.1980	Tokyo	Mr.Michio Oiwake Director and General Manager	Nippon Bankan Kogyo Co. Ltd. Omori Kitaguchi Building 5-13 2 Chome Sanno Ota-ku TOKYO 143, Japan	Discussions followed by a visit to the factory
12.8.1980	Tokyo	Mr.Toyo Yasui Manager, Design Department Mr.Isao Deura Export Represen- tative	Mitsui Seiki Kogyo Co. Ltd. 2-13-1 Shimomaruko Ota-Ku TOKYO 146 Japan	Discussions followed by a visit to the factory
12.8.1980	Tokyo	Mr.Hiroyasu Kagawa Managing Director Mr.Takenori Tsuchiya Manager	Japan Metal Forming Machine Builders Association Kikai Shinko Building 5-8, 3-Chome Shibakoen Minato-ku TOKYO, Japan	Discussions
13.8.1980	Tokyo	Mr.Ichiro Kuwata Managing Director Mr.Masaya Kitai President Kitai Sangyo Co.,Ltd 114 12-22 Horfune 3-Chome, Kita-ku Tokyo Mr.Hiroshi Matsuda President Matsuda Seiki Co., Ltd. 2-55 Kobanshita Higashi-Tada, Kawanishi City Hyogo Pref, Japan 666-01	Japan Small Machine-Tool Builders Association 506 Kikaishinko Kaikan Building 3-5-8 Shibakoen Minato-ku TOKYO, Japan	

Date	Place	Persons met	Institute/factory	Remarks
13.8.1980	Tokyo	Mr.Shinshichi Abe Executive Director Mr.Yutaka Takahashi Manager of Technical	Japan Machine Tool Builders Association 3-5-8 Shibakoen Minata-ku TOKYO Japan	Discussions
14.8.1980	Osaka	Mr.Y.Matsumoto President	Toyo Kikai Boeki Kabushiki Kaisha Towa Building (Room No.702) 26, Shiomachi-Dori 4-Chome, Minami-ku OSAKA 542, Japan	Discussions
18.8.1980	Chiba-Ken	Mr.Masahiko Fujimoto General Manager Production Planning Dept. Mr.Goro Tejima Director, Manager of Production Division Mr.Toshio Shiina Manager, Sales Eng.Dept. Mr.K.Iwakoshi, Manager Production Planning Section	Hitachi Seiki Co., Ltd. 1, Abiko Abiko-Shi CHIBA-KEN 270-11 Japan	Discussions followed by a visit to the factory
1 .1980	Shizuoka	Mr.Goro Yasui Manager, Sales Eng.Dept. Machine Tool Division Mr.Akira Akune Manager, General Admin. Dept.	Toshiba Machine Co., Ltd. 2068-3 Ooka Numazu-Shi SHIZUOKA-KEN Japan	Discussions followed by a visit to the factory

Date	Place	Persons met	Institute/factory	Remarks
20.8.1980	Tokyo	Mr.M.Hayami Senior Managing Director	Citizen Watch Co., Ltd. Shinjuku Mitsui Building 1-1, 2 Chome, Nishi Shinjuku Shinjuku-ku TOKYO, Japan	Discussions followed by a visit to the watch factory at Tanashi-shi
		Mr.Y.Okamoto Executive Director, Marketing	Citizen Trading Co., Ltd. Shinjuku Mitsui Building 1-1, 2 Chome, Nishi Shinjuku Shinjuku-ku TOKYO, Japan	
20.8.1980	Tokyo	Mr.Kenji Nissato Director and Manager of Machine Tool Division Mr.H.Samura Director	Citizen Watch Co., Ltd. 6-1-12, Honcho Tanashi-shi TOKYO 188, Japan	Discussions followed by a visit to the machine tool factory
	Saitama	Mr.Ken Sekiguchi, Manager, Machine Tool Division	Citizen Watch Co., Ltd. 840 Takeno Shimotomi TOKOROZAWA-SHI SAITAMA, Japan	
		Mr.M.Umehara Deputy Manager Administrative Dept. Machine Tools and Measuring Instrument Division		
20.8.1980	Saitama	Mr.Tomotsune Abo Director, Technical Laboratory	Citizen Watch Co., Ltd. Laboratory 840 Takeno Shimotomi Tokorozawa-shi, SAITAMA Japan	Discussions followed by a visit to the Laboratory

Date	Place	Persons met	Institute/factory	Remarks
20.8.1980	Tokyo	Prof.Dr.Kiyoshi Nishimoto Department of Mechanical Engineering	Tokyo Institute of Technology 2-12-1 Ohokayama Meguro-ku TOKYO Japan	Discussions

---

AUSTRALIA

28.8.1980 and 29.8.1980 – Melbourne

1.9.1980 to 4.9.1980 – Sydney

NOTE: The author attended the 30th General Assembly of International Institution for Production Engineering Research (CIRP) held in Melbourne and Sydney, Australia from 28.8.1980 to 4.9.1980. Some of the participants with whom the author had discussions are named below.

Prof. G.Lorenz
Senior Principal Research Scientist
Commonwealth Scientific and
Industrial Research Organization (CSIRO)
Division of Manufacturing Technology
88 Kerr Street,
FITZROY, Victoria, Australia 3065

Prof. J.Peters
Institut voor Werktuigkunde
300 B Celestijnenlaan
3030 HEVERLEE
Belgium

Prof.R.Weill
Technical Secretary of CIRP
Faculty of Mechanical Engineering
Technion - Israel Institute of Technology
Technion City, Haifa 32000
Israel

Dr.E.Merchant
Director of Research Planning
Cincinnati Milacron, Inc.
4701 Marburg Avenue
CINCINNATI
Ohio 45209, U.S.A.

Dr.Ehud Lenz
Professor of Mechanical Engineering
Vice President for Research
Technion - Israel Institute of Technology
Technion City, Haifa 32000, Israel

Mr.M.Veron
Centre Universitaire de Commande Numerique
(CUCN), Laboratoire d'Electricité et d'Automation
Université de Nancy
C.O. 140
54037 NANCY-Cedex
France

Prof. Dr. Ing. Elso Kuljanic
Technicki fakultet Rijeka, University of Rijeka
N.ustanka 58, 51000 RIJEKA, Yugoslavia

Mr.Tetsutaro Hoshi
Doctor of Engineering, Professor, School of Production Systems
Toyohashi University of Technology
1-1, Hibariga-oka, Tanpaku, TOYOHASHI,440, Japan

Dr.Ing.Hans-Jurgen Warnecke
O.Professor, Institutsdirektor
Institut für Industrielle Fertigung und
Fabrikbetrieb, Universität Stuttgart
Holzgartenstrasse 17, D-7000 STUTTGART 1, Federal Republic of Germany

NOTE. On 3 September 1980, at a Group Meeting of the participants of the 30th General Assembly of CIRP, the author initiated a discussion on the subject of this study and discussed the questionnaire (see Annex II) with them. Valuable suggestions were made by the members, some of which have been incorporated in this study.

Date	Place	Persons met	Institute/factory	Remarks
SWITZERLAND				
6.10.1980	Zürich	Dr.B.E.Meyer Vice President, Marketing and Engineering Machine Tool Division Mr. Hans Gut	Oerlikon-Bührle AG Machine Tool Works Birchstrasse 155 CH-8050 ZURICH 11 Switzerland	Discussions (2nd round)
SOVIET UNION				
13.10.1980	Moscow	Mr.Vasilyev Sergey Vladimirovich Candidate of Technical Science Laboratory Chief Mr.Shuvalov Vladimir Yulyevich Candidate of Technical Science	Experimental Scientific Research Institute of Metalcutting Machine Tools (ENIMS) 5-y Donsky proyezd, 21-b MOSCOW V-419 USSR.	Discussions followed a visit to ENIMS Institute
13.10.1980	Moscow	Mr.Igor K.Koukin Deputy Director	Department of International Organizations USSR State Committee for Science and Technology 11 Gorky Street K-9 MOSCOW, USSR	Discussions
14.10.1980	Moscow	Mr.Yurh A.Savinov Doctor of Economics Head of Research Dept. Mr.Alexei S.Kosymnin Senior Economist	Market Research Institute USSR Ministry of Foreign Trade Pudovkina St. 4 MOSCOW 119285, USSR.	Discussions

Date	Place	Persons met	Institute/factory	Remarks
CZECHOSLOVAKIA				
16.10.1980	Prague	Mr.Milan Dlouhý First Deputy Director Head of Machining Technology Research Dept. Mr.Ing. V.Dvořáček	Research Institute of Machine Tools and Machining (VUOSO) Na Zertvach 24, PRAGUE 8 Czechoslovakia	Discussions followed by a visit to the VUOSO Institute
16.10.1980	Prague	Mr.Josef Bubeníček Ms. Jarmila Drnovská	Ministry of General Engineering of the Czechoslovak Socialist Republic PRAGUE 1 Náměstí Maxima Gorkeho 32 Czechoslovakia	Discussions
16.10.1980	Prague (Hostivař)	Ing. František Horčička Chief Technologist	TOS Hostivař U tovaren 31 102 12 HOSTIVAR Czechoslovakia	Visit to the factory
17.10.1980	Sezimovo Ústí	Ing.Dvořáček	KOVOSVIT IVU 320 SEZIMOVO ÚSTÍ Czechoslovakia	Visit to the factory
BELGIUM				
18.10.1980	Brussels	Mr.Emile Deletaille President	Mondiale Ltd., 13 Rue de Sablons BRUSSELS, Belgium	Discussions

Date	Place	Persons met	Institute/factory	Remarks
FRANCE				
18.10.1980	Maubeuge	Mr. Albert Pascal President Directeur Général Conseiller du Commerce Exterieur de la France	Muller + Pesant (S.A.) 46 rue du Faubourg-St.-Lazare 59605 MAUBEUGE France	
LUXEMBOURG				
19.10.1980	Luxembourg	Mr.R.Yogeshwar Executive Director	HMT (International) Ltd., Schrondweiler LUXEMBOURG	Discussions
BELGIUM				
20.10.1980	Andenne	Mr.C.Kirchen President Mr.R.Vanolande Director, Commercial Mr.H. Beisemann Director General Mr.M.Chevalier Design & Research Manager	Pegard S.A. Avenue Reine Elisabeth 59 B-5220 ANDENNE Belgium	Discussions followed by a visit to the factory

For the discussions, Pegard invited:

Mr.Philippe Gaudissart
Ingénieur-Chef de Service
C.R.I.F.
Centre de Recherches Scientifiques et Techniques de l'Industrie des Fabrications Metalliques
Campus Arenberg
Celestijnenlaan 3003
B-3030 HEVERLEE
Belgium

Date	Place	Persons met	Institute/factory	Remarks
FEDERAL REPUBLIC OF GERMANY				
22.10.1980	Aachen	Prof.Dr.Ing.Manfred Weck Prof.Dr.Ing.Wilfred Konig	Laboratorium fur Werkzeugmachinen und Betriebslehre, Sommerfeldstrasse 2 Sammebau fur Maschinenwesen D-5100 AACHEN, Federal Republic of Germany	Discussions followed by a visit to the laboratories
24.10.1980	Düsseldorf	Mr.Franc Pecar Chairman of the Board Mr.Hans Gunther Fleck Managing Director	Wotan-Werke GmbH Am Trippelsberg 92 D-4000 DÜSSELDORF Holthausen, Federal Republic of Germany	Discussions followed by a visit to the factory
BERLIN (WEST)				
28.10.1980	Berlin(West)	Mr.Klaus Fleck Director	Deutsche Industrieanlagen (DIAG) Fritz-Werner Strasse 1000 BERLIN 48 (West)	Discussions followed by a visit to the factory
28.10.1980	Berlin(West)	Mr. H.Fenner Manager Director (Retd)	DIAG 1000 BERLIN 33 (West) Douglastrasse 22A	
29.10.1980	Berlin(West)	Prof.Dr.-Ing.G.Spur Director	Institut für Werkzeugmaschinen und Fertigungstechnik, Technische Universität Berlin 1 BERLIN 12 (West) Fasanenstr. 90	Discussions followed by a visit to the Institute of Tool Design and Production Technology
		Mr.S.Ganiusufoglu Research Assistant	Institut für Produktionsanlagen und Konstruktionstechnik Kleistr. 23-36 1 BERLIN 30 (West)	

Date	Place	Persons met	Institute/factory	Remarks
FEDERAL REPUBLIC OF GERMANY				
30.10.1980	Hannover	Mr.Hans Rudiger Chairman Dr.Ing.Reihard Dornhoefer General Manager (Industrial Engineering) Mr.H.Diekmann General Manager (Projects)	H.Wohlenberg GmbH & Co. Wohlenbergstrasse 6-8 3000 HANNOVER 1 Federal Republic of Germany	Discussions followed by a visit to the factory
31.10.1980 to 3.11.1980	Bielefeld	Mr.Karl Grautoff Chairman (Retired) Mr.Dirk Grautoff Director Prof.Dipl.-Ing. D. Weidemann Mr.H.J.Kreutner Manager Dr.Ing.D.Sankaran Manager	Gildemeister Geschaftsbereich N.E.F. Gildemeister & Comp., A.G. Morsestrasse 1 D-4800 BIELEFELD 11 Federal Republic of Germany	Discussions followed by a visit to the factory
4.11.1980	Stuttgart	Dr.Ing.Konrad Eckert President Mr.H.Zimmerer Technical Director	Robert Bosch GmbH Wernerstrasse 51 STUTTGART-FEUERBACH Federal Republic of Germany	Discussions followed by a visit to the factory

Date	Place	Persons met	Institute/factory	Remarks
UNITED KINGDOM				
5.11.1980	Manchester	Mr.A.J.McLaren Group Vice President	Cross International KNOWSLEY Prescot Merseyside L34 9EZ United Kingdom	Discussions followed by a visit to the factory
6.11.1980	Manchester	Prof.B.John Davies Department of Mechanical Engineering	The University of Manchester Institute of Science and Technology P.O. Box No.88 MANCHESTER M60 1QD United Kingdom	Discussions
6.11.1980	Manchester	Dr.A.J.P.Sabberwal Managing Director	TAC Construction Materials Ltd. P.O. Box 22 Traffort Park MANCHESTER M17 IRU United Kingdom	Discussions
10.11.1980	Coventry	Mr. N.T.Heaton Director, Marketing and Product Plans and Services	John Brown Machine Tool Division Banner Lane COVENTRY CV4 9GE United Kingdom	Discussions