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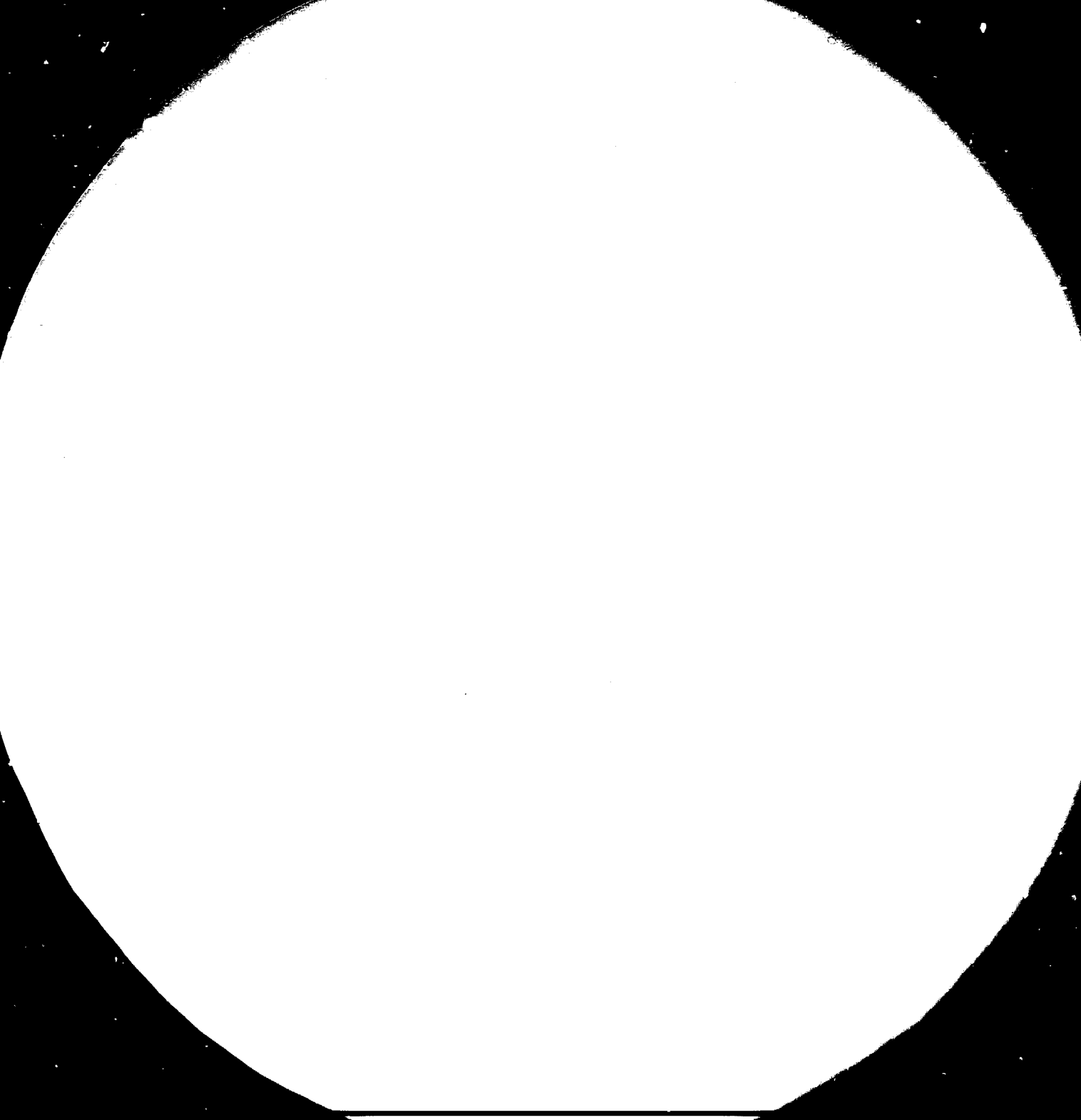
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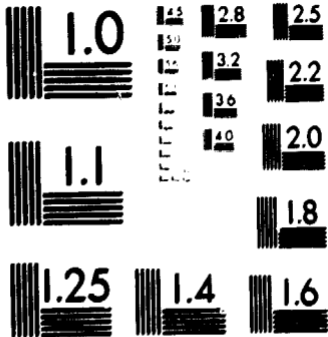
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**KIST-INDUSTRY CO-OPERATIVE PRODUCTIVITY PROGRAMME
(MECHANICAL ENGINEERING AND RELATED INDUSTRIES)**

DP/ROK/74/006

REPUBLIC OF KOREA

Technical Report: Cutting Tool Technology*

**Prepared for the Government of the Republic of Korea
by the United Nations Industrial Development Organization
acting as executing agency for the United Nations Development Programme**

**Based on the work of G. Barrow,
Expert in Cutting Tool Technology**

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**United Nations Industrial Development Organization
Vienna**

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1. INTRODUCTION

This report contains the results and recommendations from a study of the knowledge and application of modern cutting tool technology in the Republic of Korea. The study took place between July 20 and August 13 1983, a detailed itinerary is given in Appendix I.

Due to the short duration of the mission no briefing was held in Vienna prior to the visit. The objectives of the mission were established at an interview in London and from correspondence with Dr K W Jenkner, UNDP Seoul. The objectives can be summarized as follows:-

- i) To assess the level of equipment etc at KAIST.
- ii) Evaluate to what extent modern cutting tool technology is applied in industry.
- iii) Identify problem areas in industry which could form the basis for industry/KAIST cooperation.
- iv) To give relevant lectures/seminars.
- v) To advise on future research and teaching programmes.

During the mission the author was based at the Korea Advanced Institute of Science and Technology KAIST in Seoul and the Korea Institute of Machinery and Metals KIMM in Changwon.

Whilst at KAIST the author was situated in the CAD/CAM section of the Research Division (formerly KIST), several discussions were however held with staff and graduate students from the Academic Division (formerly KAIS). Discussions on course syllabi as well as research took place. A series of four lectures, each of two hours duration, were given. Engineers from industry as well as graduate students and staff from KAIST attended these. A brief description of the lecture content is given in Appendix II. During the visit to KIMM the author was situated in the NC Centre, one of the five operating divisions (see section 3). Discussions were held with staff from the NC Centre and limited discussions were held with other relevant staff. Visits were made to two industrial companies. Two seminars of 4 hours duration were held, these covered the same material as those given at KAIST.

At both KAIST and KIMM several discussions took place on relevant research topics for future study. The areas of work undertaken by overseas, particularly UK, academic and research institutes were discussed with a view to obtaining relevant data, software etc and to assess their capability for staff training.

2. KOREA ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY KAIST

2.1 Structure of KAIST

The formation of KAIST from the two separate Institutes KIST and KAIS has resulted in it having two physically separate sections. These are the the Research and Development Division and the combined Faculties of Science and Engineering. The policy of integrating both sections is still continuing. The Faculties of Science and Engineering comprise 14 separate departments which undertake both teaching and research, all the teaching being at postgraduate level. There are 6 Divisions in the Research and Development Division, these tend to concentrate, but not exclusively, on the more applied areas of research. Some staff from the R and D Division are also part time professors in the two Faculties. The work within the author's field of expertise is carried out in the Department of Production Engineering and the mechanical section of the Division of Electrical and Mechanical Engineering.

2.2 Overview of Research and Teaching in the Manufacturing/Machine Tool Area

The overall impression was that activities within this area had been developed very recently, although in some areas eg forming there had been research activities for some time. Most of the more senior staff had obtained PhD degrees quite recently from France, Japan, United Kingdom, United States and West Germany, the United States being the most popular. In view of this their knowledge of modern equipment and techniques is first hand and quite extensive. The wide range of topics studied by overseas trained personnel and the significantly different training systems in the various countries, has given KAIST an excellent base for developing a variety of research areas.

Research

Current and past research covers a wide range of manufacturing subjects such as extrusion, ring rolling, control of spot welding, grinding, machine tool vibrations and tool wear sensing etc. In addition facilities in numerical control engineering, robotics and CAD/CAM have recently been developed. However, many of the projects are quite small, mainly as a result of the MS and PhD programme format, the implications of this will be discussed later. In the Production Engineering Department the current projects falling within the author's field of interest are:

Modal Analysis of Machine Tool Structures by Time Series Approach
 Tool Life Monitoring by Time Series Approach
 Machining Dynamics Identification
 Machinability Data Base

In the Mechanical Engineering Division, projects in Numerical Control and certain aspects of CAD/CAM and Robotics were relevant.

Teaching

Courses leading to the degrees of MS and PhD are offered. Both degree courses are planned on American lines having credits for both taught courses and research.

The MS degree requires at least 24 credits of coursework, 3 credits of factory training and 12 credits for a thesis.

The PhD programme typically consists of at least 42 credits of coursework beyond the BS degree and 30 credits of research and thesis into which the thesis credit of MS may be counted.

The MS degree usually takes 1½ to 2 years and the PhD degree 3 to 5 years after the MS degree. Currently there are 45 students registered for the MS degree and 10 for the PhD degree.

2.3 EQUIPMENT

The equipment relevant to machining and machine tool technology is mainly concentrated in three laboratories/workshops. Namely the central workshop in the R and D Division and the forming and numerical control laboratories in the Faculty of Engineering.

Central Workshop

This is an extensive facility covering the whole range of metalworking, including such aspects as shearing, welding, heat treatment and fairly extensive metrology equipment. The grinding and precision machining facilities are particularly good. The overall impression was a well ordered workshop, but somewhat underutilized.

Most of the conventional equipment is not really suitable for modern machining research, largely because the power and speed ranges are insufficient for modern tooling. However, for certain types of project eg machine tool chatter, some of the machines could be usefully employed. Machines in this category are the HITACHI SEIKI horizontal and vertical milling machines, the LE BLOND and MONARCH lathes and several of the grinding machines.

Situated in the central workshop at present are the main NC/Robotics facilities, these comprise:-

- A 2½ axis FANUC TAPE CENTER E with a FANUC 5M controller.
- A 2½ axis WADO drilling/milling machine with a FANUC 3000C controller.
- Two FANUC type 170 single spindle drilling machines.
- A FANUC SYSTEM P programming unit.
- A PUMA 10 robot.

In addition to these a RENO robot and a FERRANTI co-ordinate measuring machine are on order.

The single spindle drilling machines are not in use and it is doubtful whether they are of any use for research or teaching, except for very simple demonstration purposes. The 2½ axis machines are basically turret drilling machines with light milling capability. The metal removal capabilities of these machines are low and as such they could not be used effectively for any project aimed at demonstrating increases in productivity etc. They could however be useful for certain research projects eg development of flexible manufacturing systems (FMS). The PUMA robot is a good piece of equipment and suitable for many applications.

Forming and NC Laboratories

In addition to small items of equipment and facilities not particularly relevant to machining and machine tools, the main equipment comprises

A MAZAK M4 CNC lathe
A LODGE and SHIPLEY 54" x 17½" lathe
A DAEWOO 400 x 750 lathe
A retrofitted BRIDGEFORD milling machine.
Two small BOXFORD lathes
A JET universal milling machine
A JONES and SHIPMAN surface grinding machine.

The MAZAK lathe is an old design and is not working at present. It is understood that problems have always existed with this machine. It would appear that some considerable effort is required before this machine can be effectively used. The LODGE and SHIPLEY lathe has an infinitely variable speed drive and as such is well suited for research purposes. Other useful machines are the DAEWOO lathe and the BRIDGEFORD milling machine which has been retrofitted with stepping motors. The only specialised piece of metal cutting research/teaching equipment evident was a two dimensional strain gauge dynamometer. Adequate but not extensive recording instruments eg oscilloscopes etc were observed. For the analysis of machine tools a frequency analyser and a two channel FFT analyser is available.

CAD/CAM Laboratory

This newly developed laboratory contains several graphics terminals and a PRIME 750 computer.

3. KORKA INSTITUTE OF MACHINERY AND METALS KIMM

3.1 Structure of KIMM

The Korea Institute of Machinery and Metals comprises three stations at Changwon, Daeduck and Seoul. The Seoul station started around 1966 under a UN development programme. Its main function is to offer a testing and inspection service for electrical and other machinery. It is also involved with calibration and standards. The Technology Transfer Centre which was formerly at KAIST is now situated in the Seoul station of KIMM.

The Daeduck station which is located in a science park together with other research institutes, concentrates on shipbuilding.

The Changwon station's main concern is research and development for the machinery and metals industries. Changwon station is split into 5 Divisions as follows:-

Mechanical Engineering Division - this deals with such topics as thermal machinery, energy utilization, tribology, fatigue and fracture etc.

Transportation Division - this deals with IC engines, emission control, testing and inspection of autoparts etc. A small section deals with aeronautical machinery, this will expand as aerospace industry develops from engine assembly to engine and airframe manufacture.

Metallurgical Division - this deals with mechanical properties of materials, composites, powder metallurgy and surface treatment etc.

Technical Supervision Division - this is not a R and D division, but supervises standard of plant construction, specifications and safety etc.

Numerical Control Centre - this was formed only seven months ago, before that it was part of the Mechanical Engineering Division. It concentrates on two areas, manufacturing techniques and automation and control engineering.

3.2 Overview of Research in the Numerical Control Centre

The NC Centre was developed by UN and Korean funds. Although only seven months old, research work (present or planned) is quite extensive and covers a diverse range of activities.

It is anticipated that the present staff of 30 will grow considerably as research increases. At present approximately 10 of the staff are gaining experience in academic or industrial establishments abroad. It is a firm policy to send as many people as possible to a range of industrialised nations.

In the author's field of general interest, research topics currently in progress or planned are:-

- Development of computer programs to simulate the grinding process.
- Development of a computer base for machining data.
- Design and development of a pneumatic loading/unloading robot KIMBOT-1.
- Post processor development for local industry.
- Use of CAD/CAM graphics for die and mould manufacture.
- Dynamic and Kinematic simulation packages for development of industrial

robots.

Production of experimental cutting and grinding data for precision parts manufacture.

Analysis of machine tools in order to assist machine tool manufacturers develop structural and control parts.

Dynamic testing of existing Korean machine tools.

3.3 EQUIPMENT

Machine Tools

At present the only metal cutting machine tools are situated in the central laboratory/workshop. As in the Central Workshop at KAIST this is primarily a manufacturing facility and for such purposes is well equipped. The main metal cutting machine tools are:-

A WEISSER HEILBROUN Junior centre lathe
 A WHA CHEON 420 centre lathe
 A WEILER Bridgeport type milling machine
 Two KANSAI universal milling machines
 Two small DECKEL universal milling machines.
 One ELB SCHELFF surface grinder
 One KARSTENS cylindrical grinder

With the possible exception of the WEISSER HEILBROUN lathe and the two grinding machines non of the machine tools are really suitable for metal cutting/machine tool research.

Funds are available to purchase NC equipment, a grinding machine, a machining centre and a lathe are envisaged. In addition two industrial robots will be purchased.

Other Equipment

The main analysis and measurement facilities are a two channel FFT analyser and very comprehensive B and F. noise and vibration equipment. Extensive stress measurement equipment is available, this includes strain gauges and associated power supplies etc and brittle lacquer facilities.

There is available hot isostatic powder metallurgy equipment and a 30 lb capacity vacuum induction furnace. This equipment is particularly suitable for supporting research on cutting tool development.

CAD/CAM Facilities

The main computer is a VAX 11/780 with ANVIL software. For FEM analysis ADINA software is available.

4. INDUSTRIAL VISITS

Unfortunately visits to only two industrial companies were made. This was mainly due to the fact that the mission coincided with the main vacation period in Korea and some visits were cancelled at short notice. Thus the author's first hand knowledge of industrial conditions and practice is very limited. However, additional knowledge was obtained secondhand from staff at KAIST and KDM and it is considered that a reasonable, if somewhat limited, picture of the state of cutting tool technology in Korea was gained. Both

companies visited were situated in the Changwon Industrial Complex.

4.1 TONG MYUNG HEAVY INDUSTRIES CO LTD (TMHI)

TMHI is a relatively small company employing some 250 people. Most of the products are made under licence from Japan or USA. The company has four divisions, a Defence Division which was not visited due to security reasons and divisions dealing with hydraulic machinery, industrial machinery, and transport service machinery. Thus a wide range of products are made from small motor and pump components to large presses and steel constructions. The machining facilities were quite good, most machines, although of conventional construction, being quite modern. NC facilities were limited to a turret lathe, turret drilling/milling machine and a precision machining centre.

Cutting tools from leading international manufacturers such as Sandvik and Valenite were used as well as tools from Japan and Korea.

Nearly all the shop floor workers were on vacation, so working practices could not be determined.

Very comprehensive and modern quality control equipment was evident.

Specific Problems

The following were discussed in some detail and, where possible, suggestions for their solution were made.

1) Machinability Data Base

TMHI suggested that they had no experience on which to select machining conditions. Some relevant data handbooks and sources of material were suggested. The need for generating 'in house' data was emphasised.

1i) Hole Production

Several problems associated with producing holes having large length to diameter ratios were discussed. In particular one problem was producing a hole approximately 10 mm diameter x 650 mm long. With the facilities available it was suggested that the part be sub-contracted for gun drilling.

1ii) Boring of Hydraulic Cylinders

Some difficulty was experienced in the boring of large hydraulic cylinders. In particular it was felt that metal removal rates were too low and that chatter was often experienced. Some indications of cutting conditions to be used and a brief explanation on the influence of cutting conditions on chatter were given. The use of a tuned and damped boring bar was suggested and a brief explanation of how one is constructed was given.

4.2 GOLD STAR CO LTD

This is a large company which makes a wide range of products and is regarded as one of the most advanced in Korea. The particular section visited was the Machinery Plant which specialises in die and mould

manufacture and the associated presses. The plant was formed in 1958 in Pusan and moved to Changwon in 1981. The standard of engineering is generally high and the training programme for operators is excellent. Gold Star is particularly proud that many of their apprentices (trainees) have won gold medals in international competition.

The standard of equipment is quite high, although at present little NC equipment is used. However, they intend to invest heavily in NC in the near future.

General knowledge of available cutting tools appeared to be quite high. Quality control equipment was of a very high standard.

About 50% of the total output of dies and moulds go to the various Gold Star companies, the remainder being for outside customers, including export.

Two areas of mutual interest were discussed in some detail.

i) Machinability Data Base

Some discussion took place on the availability of suitable machining data bases. Again it was emphasised that at some stage 'in house' data must be generated. The ways of doing this using existing data manuals as a starting point were discussed.

ii) Purchase of NC Equipment and Tooling

The author's views on certain design features of modern NC machining centres were sought. In addition the suitability, particularly with respect to high metal removals, of certain tooling systems were discussed.

5. OBSERVATIONS AND RECOMMENDATIONS

5.1 Current State of Development in Cutting Tool Technology and Related Areas

The general impression is that whilst Korea is now producing a significant number of engineers, the majority of these are in the more theoretical areas. This I understand is particularly true at the BS level.

If we now consider manufacturing engineering, in particular cutting tool technology and machine tools, even at KAIST teaching in these areas only started in 1977 by the introduction of the production engineering programme. However, metal cutting processes was taught in 1983 for the first time in 7 years and subjects like machine tool design are still not offered. At present there are still no faculty members at KAIST in the cutting tool technology/machine tool design area. Although I am led to believe that there is some research activity in this area at certain Korean universities. It would appear that many of the recently qualified staff have specialised in such areas as system design, CAD/CAM and robotics, etc. Whilst expertise in these areas of modern development is desirable, due attention must also be paid to the basic technologies. This 'leap frogging' of the basic technologies can, in the author's opinion, often lead to a slower application of the modern technologies.

This lack of knowledge in certain basic technological areas can, and often does, lead to misconceptions regarding such processes as machining. This often manifests itself in the belief that once a system has been designed, it is only a matter of inserting readily available data. Nothing can be further from the truth. This sort of attitude was observed on several occasions. The only real solution is an improvement in the courses offered in the basic technological areas and 'in service' training of engineers from industry. However, before this training can be effective, more qualified and experienced staff in such institutes as KAIST and KIMM are required.

It is, therefore, recommended that some priority be given to recruiting and/or training staff in the cutting tool technology/machine tool area. Although in the author's opinion extensive industrial experience for faculty members is by no means essential, some exposure to industry is. Staff should, therefore, be encouraged to spend some time in industry, say 2/3 years and/or run more joint research projects with industry. In addition, the integration of appropriate areas of the Mechanical Engineering Division with the Department of Production Engineering should continue. It is essential, that students on advanced courses are exposed to as much modern research work as possible.

From the foregoing it is apparent that in the author's opinion there is a shortage of well trained engineers in the cutting tool technology/machine tool area. This was confirmed by the limited industrial visits and discussions. There is no doubt that the extensive use of foreign licences reduces the need for certain skills etc. However, as more Korean designed products are introduced, particularly such products as machine tools, there will be an urgent need for highly qualified cutting tool/machine tool technologists. These will only be produced by a judicious integration of research and teaching programmes.

It is anticipated that KAIST/KIMM will play a leading role in providing

the expertise required.

it will not be enough to train people to apply standard techniques such as commercially available CAD/CAM packages. for example, it is relatively easy using modern instrumentation to undertake a modal analysis of a machine tool, it is quite a different thing to know what you should do with the results.

5.2 Relative Roles of KAIST and KIMM

As already mentioned the main vehicle for improving expertise in manufacturing will be the work of KAIST and KIMM. It is anticipated that this will take the following forms.

1. The education of engineers through the MS and PhD programmes.
2. The development of long term fundamental research areas.
3. Medium and short term research projects of industrial relevance.
4. Organisation of specialist seminars and courses for re-training of engineers from industry.
5. To undertake consultancy work for industry and to provide specialist test facilities and expertise.
6. Development of prototype products.

It is not possible to precisely define the function of each institute and there will, inevitably, be some overlap in their activities. However, provided expensive facilities etc are not duplicated unnecessarily then some overlap is considered desirable. It is essential that the taught courses at MS and PhD level include realistic examples of industrial application. This is most effectively brought about by faculty being involved in day to day industrial problems. Conversely if KIMM is to assist industry in developing certain new machines and products, some research experience is essential.

Obviously KAIST will concentrate on education and fundamental research, whilst KIMM will concentrate on the more practical aspects.

The relative roles of KAIST and KIMM as envisaged by the author is shown in Fig. 1.

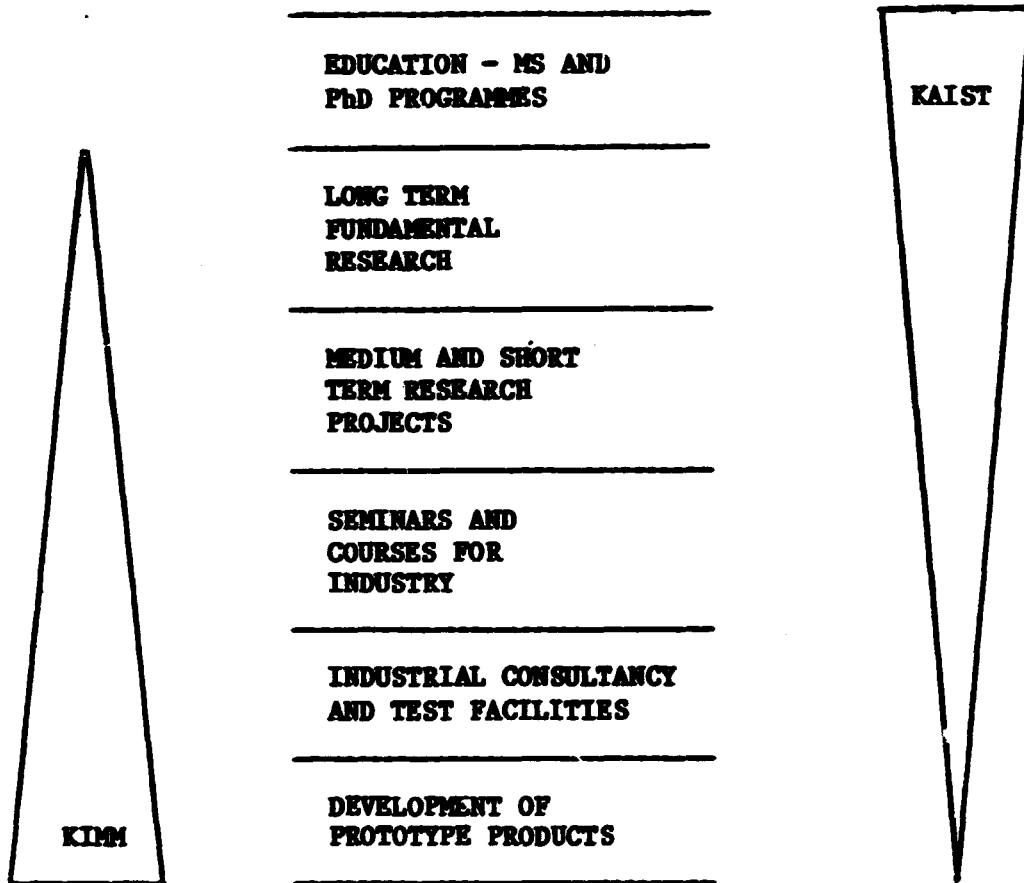


Fig. 1

Some discussion on how the various functions may be carried out is given in section 5.4.

5.3 The Need for Increased Activity in Cutting Tool Technology/Machine Tools

From the various discussions and visits four main areas within the cutting tool technology/machine tools field can be identified where an increase in expertise will lead to more effective working.

1. Development of Cutting Tool Industry

There is no doubt that Korea should continue to develop its cutting tool industry. The general impression gained was that at present Korean cutting tools are somewhat unsophisticated and that considerable development work is required.

It is not suggested that at some stage in the future, Korea should become self-sufficient in cutting tools. There will always be special areas where importation is desirable and in many cases special tools are more readily available when the supplier is a well established importer or manufacturer. In addition as Korea builds up its exportation of machine tools, the use of internationally accepted tooling systems will often be desirable.

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trained manufacturing engineers and

joint research programmes between KAIST/KIMM

test facilities and pilot manufacturing

Tool Industry

that the majority of machine tools built in Korea are of the more conventional type, and are produced. There is a strong desire to improve machine tools. In order to do this, KIMM will be an advantage. As discussed, KIMM will have to develop their own expertise to offer the help required.

of CAD/CAM

There are not enough well qualified engineers in Korea to support the CAD/CAM developments in the machine tools field. Whilst this is more true of Korea, expertise in machine tool design is necessary to fully transfer the results of CAD packages to manufacturing. There are considerable problems associated with respect to manufacture by machining. It is the applications of CAM worldwide are very diverse. NC machining and certain other NC machining are significant applications. Even in this respect such as selection of machining methods, and successful applications are usually made by engineers and/or operators.

Technological areas of CAM cannot be overemphasized. They take the form of more trained engineers and available technological data bases.

ing Data

Machining data for use in connection with machine tools. Machine data for conventional and stand alone NC machining there is a need to provide economic application of machining conditions. As unit labour costs increase and there is an increase in machine tools.

likely to take the form of relevant short term technical problems.

Recommendations of the Various Roles of

KAIST/KIMM could assist industry were outlined and discussed in more detail here and in some detail will be made. In addition some further

5.4.1 Education - MS and PhD Programmes

With respect to the educational programme the MS degree programme could be seen to have a different function than the PhD programme. The MS degree is seen as the main vehicle for training engineers for industry. On the other hand one would expect the majority of PhDs to enter academic establishments, research institutes and R and D sections in industry. In the author's opinion, the relevance of these programmes to improving manufacturing engineering in Korea must be questioned.

MS Programme

As mentioned earlier the format follows that which is common in the United States.

It is now generally accepted that the level of basic manufacturing engineering in the USA lags behind that in Europe and Japan. There are of course many reasons for this, but it is the view of many US academics and industrialists that a significant factor is the lack of good training programmes for manufacturing engineers in the US universities. The broadly based, often scientifically oriented courses in the US may be relevant to certain branches of engineering, but often leave much to be desired as a training for the manufacturing industries. Students from these courses normally receive their industrially orientated training in industry itself. This can be inadequate if the industry is itself underdeveloped or in certain areas of rapidly advancing technology.

It is not suggested that KAIST abandons its present MS programme format, but rather that it looks at it in relation to alternative methods and then formulate a revised programme geared to Korean industry.

It is perhaps, pertinent to consider briefly the training in Europe in order to highlight the differences from the US system. There are fundamental differences between the systems in Europe as a whole and that operated in the United Kingdom. The different systems are described in Appendix IV.

A consideration of the various European systems, indicates that whilst they differ considerably in detail, there are similarities in that they tend to be more practically orientated than the US system. It is the lack of relevance and practical orientation in many of the US manufacturing engineering programmes that is considered to contribute to the relative low levels of manufacturing expertise in many US industries. In general the European system is more laboratory based and thus requires higher levels of funding.

It is appreciated that a rapid change in programme structure is neither feasible or desirable, since present funding and staff expertise would not allow this. If one considers the course content (24 credits) for the MS degree, it allows for 8 courses to be taken. However, consideration of the courses listed in

(or sections of courses) will not be studied. The main problem is that too many diverse courses are offered.

It is suggested that sections of certain courses could be combined to form a new list of more relevant courses. Unfortunately many of the courses offered are standard courses in the main faculty based MS programme and as such agreement for considerable change would have to be sought or some duplication of lectures would be necessary. The author is well aware of the problems associated with such action and in the short term at least alternative solutions should be sought.

A possible compromise would be to offer a 'core' of say 4/5 courses specially designed for people entering manufacturing industries which could be supported by 3/4 'elective' courses.

Typical core courses would be

1. REMOVAL PROCESSES - Machining, Grinding, EDM, ECM etc.
2. DEFORMATION PROCESSES - Forging, Extrusion, Sheetmetal Forming etc.
3. FABRICATION PROCESSES - Casting, Welding, Brazing, Bonding etc.
4. MACHINE TOOLS - Basic Design, Testing, Accuracy, Chatter etc.
5. NUMERICAL CONTROL AND AUTOMATION - Types of Machines, Programming, Tooling, Automatic Machines etc.

In addition attempts should be made to have some of the thesis topics industry based.

PhD Programme

Since the PhD Programme is not considered to be a significant method of training manufacturing engineers, some of the courses regarding the MS programme are not entirely relevant.

As well as training students in research methods, the Ph. programme should contribute to the development of long term research expertise.

In the European system where no courses are usually taken, the PhD students often make significant contributions to knowledge as a result of their lengthy concentrated research projects. This is much more difficult with the US system due to the shorter time available and sometimes lack of concentrated effort. In the latter case therefore, much of the advanced research is often done by faculty staff.

With the present staffing levels, faculty staff are heavily involved in teaching course development and routine research supervision, thus leaving little time for personal research.

It is recommended therefore, that consideration be given to an increase in staffing levels and/or some change in the PhD programme format.

5.4.2 Long Term Fundamental Research

As indicated in sections 2.2 and 2.3 long term fundamental research in the area of cutting tool technology/machine tools has only just started in Korea. The need for this type of research cannot be over-emphasised. The majority of the major developments over the last quarter of a century in the general area of machine tool technology, have stemmed from fundamental research in university and research institute laboratories. If Korea is going to develop its own technology, a solid fundamental research base must be established. This will not only produce the basic research which is necessary but also provide well trained researchers who can further develop the basic ideas in industry. Turning to the types of research project necessary, it is always difficult to predict which areas will prove the most important. However, there are areas where it is evident that further research is necessary. In many of these areas several research groups on a world wide basis are already making significant advances.

With respect to the machining process itself, it is well known that the various theories advanced are not sufficiently accurate to predict what happens in practice. In view of this there has been extensive use of empirical formulae and thus the selection of sub-optimum conditions. The new approach to this problem is to develop sensors for the important cutting parameters and to link these to suitable optimization routines.

The trend with machine tools appears to be attempts to increase their output by better structural design and by the development of machine tools with higher material removal capabilities.

Research areas which should be considered are

- 1) Sensors for tool failure, tool wear, chip control and surface finish etc.
- 2) Development of suitable algorithms for the optimization of machining processes.
- 3) Development of routines for selecting machining methods for process planning applications.
- 4) Investigation of tool breakage in interrupted cutting operations.
- 5) Structural analysis of machine tools in order to increase performance by better distribution of mass etc.
- 6) Investigation of visco-elastic materials for improving damping in machine tool structures.
- 7) Development of high speed and high load bearing systems.
- 8) Development of fast response - high accuracy feed drive mechanisms

5.4.3 Medium and Short Term Research

One would expect the majority of topics in this area to be formulated by industry. However, there are certain topics which are general in nature, but which cannot be classed as long term or fundamental. In this category are such topics as the creation of a machining data base. It has been mentioned earlier in the report (section 4) that companies should be encouraged to generate their own 'in house' data. However, there is a need to form a general base and develop procedures on which companies can build.

As a first step existing data from data handbooks and tool manufacturers etc should be collected with a view to assessing their relevance to Korean materials and the available tooling. There is also a need to undertake research in order to form a base on which to build the long term fundamental projects. In many cases this will mean repeating, at least in part research which has been done elsewhere. However, this is a necessary step towards building up the required expertise and if omitted entirely can lead to serious consequences. Let us take for example the development of a sensor for detecting tool wear and tool failure. It is difficult to interpret the results unless the researcher has had experience of the different modes of tool failure and the different forms of tool wear that occur. Within KAIST it is envisaged that much of this expertise will be generated by the MS thesis projects.

5.4.4 Seminars and Courses

The retraining and updating of engineers by various seminars and short courses is seen as an important mechanism for improving the efficiency of the manufacturing industries.

Courses should be designed for and offered at various levels. The duration of the courses will vary according to the subject etc, but due attention should be paid as to how long industry is prepared to release a particular grade of staff for.

Typical courses could be economics of machining processes, tooling systems, tool materials, programming of NC machines etc. Where possible courses should be supported by laboratory type exercises. This is not always feasible, but video recordings are a good and sometimes a better substitute.

5.4.5 Consultancy and Test Facilities

In many areas, particularly in the smaller companies, expertise and facilities are limited. It is essential therefore, that important expertise and facilities are available from KAIST/KIMM.

The basic expertise for consulting will of course be generated by the research programmes and staff training schemes, but will have to be backed up by the appropriate equipment. The test facilities will take two basic forms, static equipment based permanently in KAIST/KIMM and portable equipment for undertaking tests in industry. The author does not consider it to be within his terms of reference to determine which expertise and facilities should be developed in which institute. However, as mentioned previously some overlap will occur and is considered desirable.

Within the author's field of interest facilities are required to assist in the development and use of both cutting tools and machine tools.

For the development of cutting tools adequately powered machine tools are required in order to offer a tool testing facility. In addition it is essential to have means of measuring forces and

metallurgical and scanning electron microscopes are required. Expertise for advising on the selection of cutting conditions and the development of machining data bases is required.

The facilities required for the development and application of machine tools are possibly more comprehensive.

CAD packages for many aspects of machine tool design have been in use for a number of years. These include routines for structural analysis and the design of spindles and bearings etc. It is recommended that some of these are obtained and/or developed.

The design of existing machine tools can be considerably improved by an analysis of the structure. Both mechanical vibration and acoustic noise measurement facilities are required.

For the efficient use of machine tools and in order to achieve good component quality, high accuracy is required. In order to check machine tools laser interferometry equipment should be available. This type of instrument is also important for calibrating co-ordinate measuring machines.

5.4.6 Development of Prototype Products

This is not expected to be a major activity, particularly if one includes final manufacture. However, some activity in relevant areas, eg assembly robots etc is foreseen.

5.4.7 Equipment and Staff

In the instrumentation and measurement area, much of the basic equipment to support the proposed research etc is available in either or both institutes. As activity increases this will require augmenting and some of the less specialised equipment will have to be duplicated. The major piece of equipment not available in either institute is a laser interferometer for calibrating machine tools etc. In view of its importance, purchase of this equipment should be given some priority.

It has already been mentioned that the workshops in both institutes are more than adequate for their manufacturing role, but contain few machines that are really suitable for research in the cutting tool technology/machine tool area. In particular there is no lathe or milling machine with the power and speed range to adequately test modern cutting tools. If cutting tool development is to be supported, this situation must be rectified and more sophisticated force measurement equipment developed or purchased.

It has already been mentioned that KDM intend to purchase three NC machines. It is important that these have good material removal capability. In addition, some consideration should be given to manufacturers who are prepared to supply enough information about the hardware and software to facilitate research and development.

High respect to staff, the lack of staff in the area of

discussed. It should however, be remembered that approximately 10 staff from KIMM are currently being trained overseas. It would appear that until strong faculty groups in the relevant areas are established, much of the training of KAIST/KIMM staff will have to be done overseas. It is recommended that where appropriate this training is carried out in industry.

APPENDIX I ITINERARY

JULY	19	Arrive Seoul 20.45
	20	am KAIST pm UNIDO/UNDP
	21	KAIST
	22	"
	23	am KAIST
	25	KAIST
	26	am KAIST pm Lecture
	27	"
	28	"
	29	"
	30	am KAIST
	31	To Changwon
	AUGUST	1
2		"
3		am Tong Myung Heavy Industries Co Ltd (TMHI) pm Gold Star Co Ltd
4		am KIMM pm Seminar
5		"
6		To Seoul
8		KAIST
9		"
10		KAIST
11		"
12		am UNIDO/UNDP
13		am KAIST Leave Seoul 17.10

APPENDIX II LECTURE/SEMINAR CONTENT

The lectures concentrated on the more practical aspects of the cutting processes and modern developments. More fundamental aspects were however, included in the text which was given to all participants.

1. Basic Mechanics and Tool Materials

Brief introduction to chip formation and review of simple cutting analyses. Magnitude and distribution of normal and shear stresses. Heat generation and temperature distribution. Type, properties and classification of tool materials with particular reference to high speed steel and carbide tools.

2. Tool Wear and Tool Life

General form of tool wear. Tool wear mechanisms. Brittle and plastic tool failure. Tool design to avoid failure. Tool life criteria and influence of machining conditions. Development of tool life equations for turning and milling. Influence of thermal cycling on milling cutter life. Problems associated with milling mode and entry and exit conditions.

3. Machining Economics and Selection of Cutting Conditions

Basic cost equations for turning and milling. Appropriate economic criteria. Calculation of optimum tool life for minimum cost etc. Influence of cutting fluids and cutting fluid management systems. Brief outline to the selection of tools for turning and milling. Influence of machine cost and tool cost on selection of cutting conditions.

4. Optimization and Current Developments in Machines and Tools

Computer methods for selecting turning conditions with particular emphasis on process constraints and file structure. Possible extension to milling processes. Development of higher speed machines. Modern developments in quick change tools and tool setting. Current state of development of cubic boron nitride, diamond and ceramic tools. The text supplied comprised 159 pages of typescript, including diagrams. Some 5 or 6 engineers from industry attended the course at KAIST and approximately 50 at KIM.

**APPENDIX III POSTGRADUATE COURSES IN THE DEPARTMENT OF PRODUCTION
ENGINEERING AT KAIST**

- a) **Common Courses** - Manufacturing Processes, Metrology, Solid Mechanics, Instrumentation, CAM, Factory-training.
- b) **Manufacturing Processing Courses** - Bulk Deformation Processes, Sheet Metal Processes, Polymer Processing, Welding Processes, Welding Metallurgy, Nondestructive Testing, Mechanical Behaviour of Solids, Metal Fatigue, Fracture Mechanics, Experimental Stress Analysis.
- c) **Production Automation Courses** - Automatic Control, Automated Production, Advanced Control Systems, Analysis and Design, Fluid Power Control Machine Control Lab., Optimal Control, Engineering Measurement, Pneumatic Control, Discrete-Time Control, Application of Microprocessors, Robots.
- d) **Machine Tool Courses** - Vibration in Linear Systems, Metal Cutting Processes, Machine Tool Dynamics, Machine Tool design, Noise Control, Random Data, Analysis and Control, Time Series and System Analysis, System Identification, Tribology, Hydrodynamic Lubrication.
- e) **Production Management and Process Design Courses** - Production Management, Manufacturing Process Design, Product Design, Facilities Planning and Design, Quality Control, Advanced Manufacturing Process Design, Advanced Production Management, Manufacturing Economy and Cost Analysis.

NOTE

- i) Many of the courses are given by staff from other departments.
- ii) At present none of the courses in the area of Production Management and Process Design are offered.
- iii) Most of the courses are worth 3 credits towards the MS or PhD degree.
- iv) Each course is 3 hours per week for one semester (15 weeks).
- v) Appropriate courses are supported by suitable laboratory exercises.

APPENDIX IV BRIEF DESCRIPTION OF ENGINEERING TRAINING IN EUROPE

General European System

The normal professional engineering training in most Western European countries eg W Germany, Netherlands etc is a course of some 5 years or more leading to the Dipl. Ing. degree or equivalent. The final level of this degree is comparable to the MSc degree in the UK or MS degree in the US. The latter part of the programme includes a substantial, usually individual, research project. In Europe, particularly in West Germany, Industrial Research Institutes are often attached to the major technological universities. The research projects are usually associated in one way or another with these research institutes and therefore, are of industrial significance. It is usual in the latter stages of the programme to specialise in a particular area of engineering eg manufacturing technology etc.

UK System

The basic format of the UK system is similar to the US system in that the majority of engineers enter industry with a BSc degree (US BS degree), although an increasing number do have a MSc degree. The main difference between the BSc degree and BS degree is that the former is more structured in that less optional subjects are allowed. There are, or can be, significant differences between the MSc and MS degrees. There are basically two different ways of obtaining the MSc degree.

- i) By thesis only
- ii) By course and thesis.

The latter method is now more prevalent, but specialist schemes for method i) exist. In method ii) the course and thesis carry the same approximate weighting. In manufacturing engineering, few options are usually allowed, the courses being designed to give a broad training relevant to a specific area eg machine tool design. The research project is often of direct industrial relevance and may be carried out in industry. For certain industrial situations eg manufacturing engineering it is considered that training of more industrial relevance is desirable and two schemes, the teaching company scheme and total technology scheme are operated by the government.

Teaching Company Scheme (TCS) - This is a two year industry/university integrated scheme which usually leads to a MSc degree, although the main aim is to provide training. Basically the student undertakes a project or projects in industry under the joint supervision of an academic from the university and an engineer from industry. The training in industry is supported by attendance at courses/seminars which are tailored to the student needs. The scheme is currently in the second of three phases. In the first phase the scheme was 100% government funded, whilst in the second phase funding is on a 50:50 government/industry basis. In the third phase it is intended to be 100% industry funded. The students receive a salary roughly equivalent to what they would receive in permanent industrial employment.

Total Technology Scheme (TTS) - This is a smaller scheme than the TCS and trains people to PhD level over a period of 3 or more years. Basically a research topic of industrial importance is followed. In general, however, the student is expected to relate his work to a broader base eg he should not only consider technological matters, but also consider the relevance of his findings with respect to such factors as marketing etc. The selection of the

PhD Programme

The PhD programmes are fairly comparable throughout Europe. Unlike the US system they do not normally include coursework and as such the thesis is usually larger and of a higher standard. Some are highly theoretical whilst others are very practical.