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ECONOMIC AND TECHNOLOGICAL ASPECTS OF COMPUTER APPLICATIONS IN ENGINEERING INDUSTRIES IN INDIA 1/

by

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C O N T E N T S

INTRODUCTION

Computers have been revolutionising the human activities in various fields. Use of computers in the field of design is rather recent, but judging from what has already been achieved, its impact is going to be far reaching. As in other fields, design with computer aided techniques drastically reduces the time to arrive at the optimum design - some times as high as 90%. Because of this, those who use these techniques advance industrially at a speed which increases the gap with those who do not use it. In other words, absence of these techniques in the developing countries will widen the gap between them and the developed countries further and further. As a matter of fact, design and manufacture which are the basis for any industrial activity, are getting revolutionised by the computer techniques. Any country which fails to take note of this, will literally miss a second Industrial Revolution.

India has been conscious of the importance of design capability and has taken collaborations liberally in various industrial activities after her independence. This has helped to build more or less a firm foundation for further advance.

Of late, in the field of computer also, India has generated expertise. The first computer was introduced in the country in 1956 which was mainly for processing large amount of data required for Life Insurance policies. Since then, the number of computers has

grown to 300. Hardly 3 - 5% of these are used for computer aided engineering applications. Even this small percentage of computer usage in engineering field has emerged only recently, since 3-4 years.

This situation lasts for such a long time because of

i) lack of awareness of the use of computers for engineering applications.

ii) lack of availability of computers at a price that engineering industries could afford.

iii) lack of qualified personnel in the field of computer sciences.

However, the country has acquired sufficient expertise during this period in computer sciences and designing of machinery particularly machine tools. Computer techniques have been applied in the field of designs to a limited extent during the last 3 - 4 years.

This paper deals with the existing status of computer aided techniques in India in various fields and their technological and economic aspects.

Also, experience gained in Computer Aided Programming for NC machines and the problems in the introduction of computer aided manufacturing are touched upon.

Computer Aided Design (CAD) activities in the country in the electronic field, especially for the design of Printed Circuit boards and Integrated Circuit Masks are briefly explained.

Attempt is also made to explain the application of satellite micro-computers around mini computer in DNC operating mode.

1. COMPUTER AIDED DESIGN (CAD)

CAD, as is known to day, is a term to describe the interactive

use of computers by designers as routine aid to their work. The interactive nature of relationship between the computer and designer is an essential part of CAD. In India, though no work of this nature has been done, except in electronic field, calculations by computers have become of routine nature in design work. Of late, some work in the field of structure analysis has also been done.

1.1 Design by Computers

1.1.1 Routine design Calculations:

Calculations for shafts, gears, bearings, clutches etc. are done by established computer programmes. After taking up manufacture of NC machines in HMT* programmes for positional accuracy scatter and SCR drives have been prepared. Hydrodynamic bearing with tilting pad and plain journal bearing calculations for a grinding machine have been done by computer. These calculations by computer have considerably reduced the design time and released the designer from routine work for more creative work.

1.1.2 Structural analysis:

Two classic examples of structural analysis have been done by HMT and CMTI@

Case 1:- This is for a lathe bed of main drive 20 HP with horizontal bed configuration.

Two conceptual designs were given for computer analysis to assess the relative merits of the design, and to optimise the better design by parametric study. After the analysis a new design for the bed was proposed.

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It was predicted that this will behave better in all cutting conditions and will weigh 41 Kg. less than the original designs.

The analysis of the bed consisted of the following aspects of structures.

i) Structural properties and location of elastic and neutral axis using finits element technique under bending, shear and torsion.

ii) Static stiffness of the machine between tool and work-piece in X axis and perpendicular to chip thickness.

iii) Natural frequencies and mode shapes at each frequency.

iv) Real response characteristics between tool and work-piece in the direction perpendicular to chip under harmonic excitation represnting the actual loading configuration.

The last three were done using lumped mass techniques and representing the structure by beam model.

This machine is being produced at the rate of 600 per annum. Considering the material saving alone, ₹ 10,000/- is saved every year. All the three beds were tried and the computer predictions have been proved while testing.

Case 2:- This is for a bed of an NC lathe having main

drive of 40 hP with slant bed configuration. The machine has two pairs of guideways - one for saddle and the other for tailstock. Guideways are so disposed that saddle can pass over the tailstock

Three conceptual designs were prepared for the purpose of analysis. Initial analysis showed that one of the three has greater potential to optimise the metal distribution so as to be far superior to the other two designs. On this basis a new design was obtained and analysed in the following aspects.

i) Structural properties and location of elastic and neutral axis using finite element technique under bending, shear and torsion.

ii) The deformed patterns of the structure element under critical loading conditions to identify the contribution by local deformations relative to structural deformation.

iii) The relative static stiffness at tool tip in X axis direction representing the elements as beam elements for proper force transmission.

Prototype of this machine is being built. The finalised bed will have 15% less metal content than the initial designs for comparable performance. These analysis has taken hardly three months. The same analysis can not be done manually. To arrive at the same optimisation in design without computer analysis will require

3 prototypes, the cost of which would be very high, not to speak of time that will be lost. Developing countries can not afford such loss of money and time.

In the above two analysis, the approach followed is mainly of comparative assessment due to a number of limitations. For absolute evaluation and optimisation, problems like non-linear behaviour of joints, damping in the machine need to be solved. Further, there is great scope to derive benefits by widening the scope of computer application to areas like thermal strain, stress optimisation in forming machines, optimisation of subsystems like drives, servos etc. It is felt that UNIDO can be of great help in this.

1.2 <u>CAD activities in Electronic field:</u>

Printed circuit board layouts are being made using computer and interactive graphics. The hardware equipment involved are a mini-computer, interactive graphic terminal with a data tablet, light pen, photo flood plotter, drum and flat bed plotter and key board terminals. All the above are imported from USA. Software for particular applications are written by the users. The level of sophistication reached is that describing a circuit diagram and the component sizes in a prescribed format the complete arrangement

of the components and their inter connections with double sided printed circuit board are resolved by user software. The actual film master exposure is done on line with the computer using a photo flood plotter in a dark room thereby avoiding any further drafting or photographing. The whole process takes 2-3 days compared to 5-6 weeks in the conventional method of drafting. The cost with the computer techniques works out to ₹.70/- for a double sided printed circuit board as compared to conventional ₹.150/- per board for making the master film. This comparison is considering direct costs. Compared to this there are so many other indirect cost savings e.g. when once a printed circuit board layout is designed the design can be stored as a file in a data base library on a magnetic tape or disc. This file may be recalled and modified interactively and saved as another file for a new printed circuit board layout. As the library grows bigger the cost for a new design progressively reduces whereas the cost for the conventional design remains same. Similarly, interactive graphic techniques are employed for the design of Integrated Circuit masks. This is an essential area of development as the I C technology is far behind the developed countries where L S I technology has already come in the electronic industry.

2. COMPUTER AIDED MANUFACTURING (CAM)

Computers are being used for nearly a decade now in large machine tool, Aircraft, Heavy engineering and Heavy electrical industries in in the Public Sector and few large private industrial houses for steel,

cement and chemical industries. Computers are put to use in such establishments for a higher order of data processing like scheduling, Inventory Control etc. Since the introduction of NC machines, computer has emerged as a vital and necessary element in the manufacturing process. The activities which are currently being done using computers are briefly explained here.

2.1 Computer aided scheduling:

This has been adopted in HMT about 12 years ago with an ICL 1903, 3rd generation computer. This is used to list out the components to be manufactured for assembly of machines for which order has been received.

Each machine has a particular No. called variant No. Under this number computer stores the list of assemblies required to build the machine. Each assembly consists of the components list required with quantity and material. The computer gives a print out of the following.

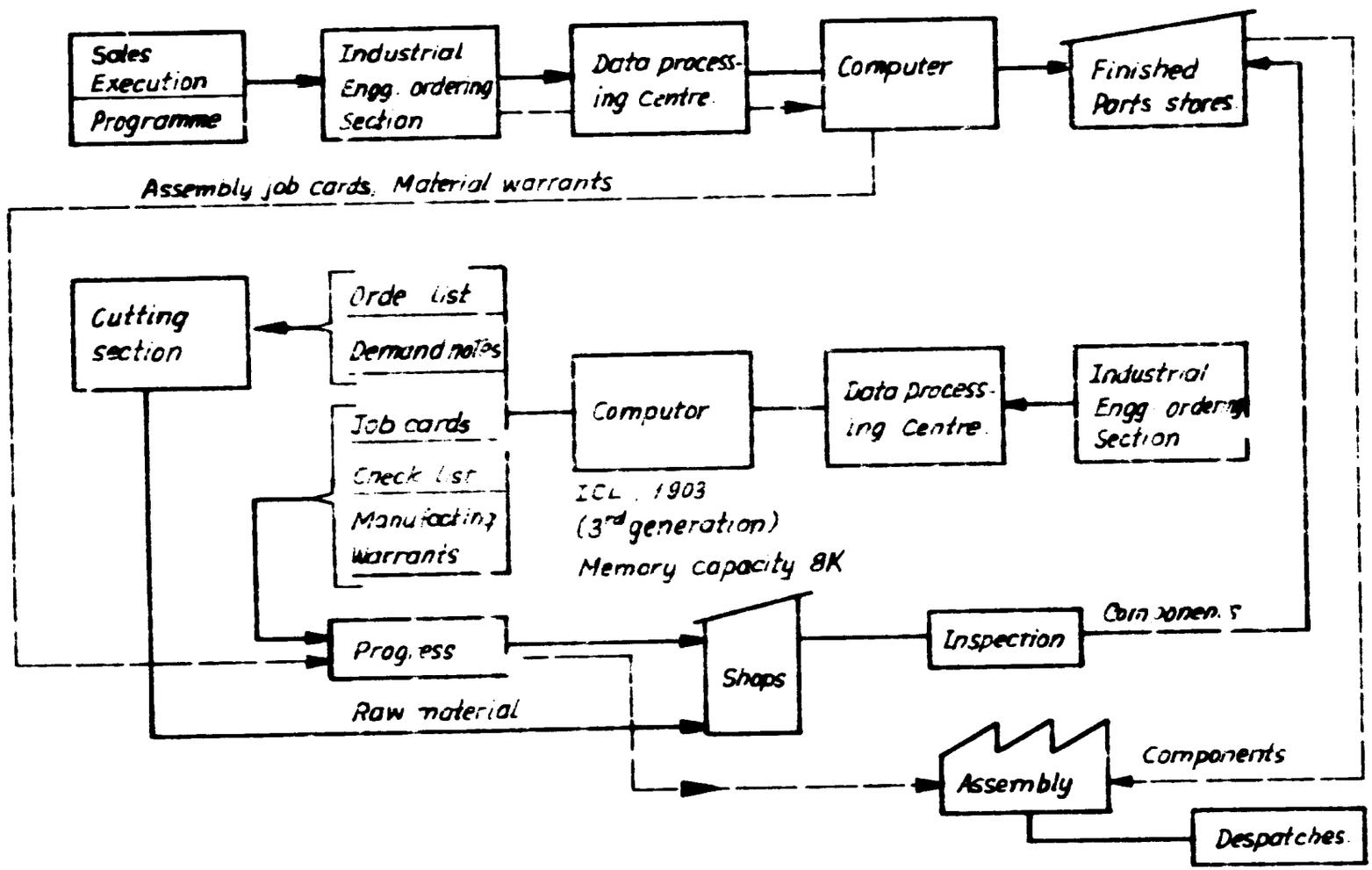
1) Order list
2) Demand Notes
3) Job Cards
4) Check list and
5) Manufacturing Warrant.

Flow chart of the whole scheme is shown in Fig. 1. With this system the lead time required for getting started with the actual manufacture from the date of receipt of order has been considerably reduced to a week from a month.

2.2 NC technology in manufacturing:

NC machines appeared in the Indian Industry as early as 1956.

PRODUCTION CONTROL CHART



There are about 70 NC machine tools in the country to-day. With HMT's entry into the field of NC machine production, this is expected to go up rapidly. The main difficulties experienced in the introduction of NC machines are

i) lack of adequate maintenance support.

ii) lack of knowledge in programming.

iii) high capital cost involved.

iv) general lack of awareness of NC potential.

To over come the above difficulties and also to help prospective industries select suitable NC machines, a NC Centre is being established in CMTI with UNDP assistance. Details of this centre are given later in this paper.

2.2.1 Computer aided NC programming:

First application of using computers in India for programming of NC machines was started in CMTI. A study in 1974 for the introduction of computer aided programming for NC machines showed that the most powerful APT language has been implemented on large computers and this involved large investment. An attempt was made to make use of existing computers of IBM 360 - 370 size in the country for NC programming. However, this could not be done for the following reasons. The computers were situated in cities where NC machine tools were not concentrated. The computers did not have provision to augment their capacity to take up APT language. High speed tape punch both in

hardware and supporting soft ware drives was not available. Personnel handling these computers were trained for scientific and commercial data processing work rather than on NC programming and preparation of Post Processors. He ce it was decided to go for an in-house mini computer.

Accordingly a 16 bit mini computer was installed at CMTI with an APT type Programming system at a cost of ₹ 200,000 in 1974. Six engineers were trained in the use, maintenance and operation of the computer and in the NC programming language and in writing Post Processors. Fig. 2 shows hardware and software available at the computer centre. The engineers trained have so far imparted to about 45 engineers the technical know-how on computer programming for NC tools. 5 Post Processors have been written and established - 3 for indigenous and 2 for imported NC machines. The computer and programming system has been used on 7 NC machine tools on regular production in Bangalore itself. The computer aided programming has substantially reduced the tape preparation time and cost.

The Computer Centre is being used to demonstrate physically the possibilities of computer aided programming so that major manufacturing industries desirous of going for NC machines can understand and derive the benefits of the centre.

CMTI COMPUTER INSTALLATION

1 **HARDWARE:**

a) 16 bit Mini computer with 56 K Memory

b) 2 Nos. 1.2 Million Words Moving Head disc drives.

c) 1 No. 9 Track 800 BPI Magnetic Tape Unit.

d) 1 No. 30" width CALCOMP Plotter.

e) 2 Nos. Line Printers (60 LPM & 300 LPM).

f) 2 Nos. Teletype (ASR 33).

g) 1 No. Alphanumeric display with keyboard.

h) 1 No. High speed Paper Tape Reader (300 cps) and Punch (50 cps).

i) 1 No. Laboratory Peripheral System with 8 channel A/D Converter.

j) 1 No. Flexowriter.

k) 1 No. IBM Card Puncher.

2 **SOFTWARE:**

a) RSX - 11D Multi Programming Operating System.

b) Fortran, COBOL Compliers, Assemblers, Editors, Utilities.

c) NC Programming System.

d) 10 Nos. Post Processors.

e) Basic DNC Communication Software.

Fig. 2.

Some of the typical applications in which the computer aided NC programming have been done are briefly explained below.

2.2.1.1. Machining of Cams:

In one of the research establishments involved in the design of gas turbine blades the time required to make a master cam was 7 to 8 weeks. Using the computer aided programming with the APT it was possible to generate the control tape for an NC milling machine in 6 hours. Actual machining was performed in less than 2 hours. The total cost of preparation of tape including computerised inspection was ₹ 150 whereas the cost for making the master cam involving an average of 3 to 4 rejects is ₹ 350. The cost of cutting a new cam by NC is just ₹ 20 as against ₹ 350 by conventional methods.

2.2.1.2 Machining of Aerofoils and Aircraft Models:

The full utilisation of computer aided programming has been felt in the manufacture of 3 D Profiles in aerofoil sections and aircraft models for wind tunnel testing.

The facility provided by the Ruled Surface Module in the APT system for linear fairing of different geometries into one blended shape has been fully utilised for the complex air craft models. The conventional method of copy milling used to take 5-6 months per air craft model. This is now made possible using the computer generation of the tape in 1 to 2 weeks. Now it is possible to modify the designs in quick succession. The economies realised are with the computer aided technique the cost of making the model is about ₹ 400/- as against an average of ₹.1,600/- per model using the conventional method. Any slight modification in the model design costs only the changes to be made in the Programme already written and the cost of computer time which hardly works out to ₹. 40/- as against ₹.1,600/- which remains the same for conventional method. But the saving in time using the computer for producing newer designs far out weighs any other economic considerations.

2.2.1.3 Development of Post Processors:

There is only one computer aided programming system in the country. Many of the difficulties being experienced in developed countries

are not felt here in terms of proliferation of NC languages, cutter location data formats, Post Processor vocabulary uniformity and standardisation. Since APT type system has all the capabilities of APT and since it is applied on a low cost minicomputer, it appears to be the most advisable in house NC Programming system for Indian conditions and in general for developing countries. Nearly 4 man years of soft ware effort has been spent at CMTI for developing the basic Post Processor system structure. The Post Processor vocabulary has been standardised as per ANSI standards. Many of the present buyers of NC machines in India are advised to go for Post Processor written by CMTI as many difficulties are experienced if bought from abroad. These are essentially communication difficulties in the mutual understanding of the Post Processor specifications. It is our experience, at least in a developing country, it takes one year to debug a Post Processor after its supply to bring it to a fairly complete working level. Even in USA, this process takes 3-5 months in spite of the most efficient communication system.

Hence it is necessary to standardise on a programming system in a developing country and provide a centralised programming and Post Processor support as the number of NC machines increase. The cost of writing indigenously a Post Processor works out to ₹. 2,500/- to ₹. 4,000/- depending on the complexity of the NC machine and systems, whereas the cost of an imported Post Processor including duty works out to ₹.7,000/- to ₹. 10,000/- with all its problems mentioned before.

2.2.1.4 Computer Numerical Control

NC lathe 'Mogul' designed and built by HMT is available with an imported CNC system. Attempts are also being made to design a CNC system indigenously based on micro processors. The computer in CMTI will be used for the preparation of necessary software for the CNC.

CNC appears to be the right choice for NC in developing countries, as the maintenance of CNC system is simplified through the built-in diagnostic programme in the executive software. In addition there are very

few hardware electronic circuits to be maintained.

2.2.1.5 Computerised offline tape preparation System:

Those who have one or two NC machines cannot afford to go in for an in-house mini-computer based programming system. They resort to flexo-writers by which tapes are prepared manually. Since flexowriter does not have editing and correcting facility, the possibility of mistakes is more. This increases the tape preparation time and also the idle time of NC machines. Of late micro computer based tape preparation systems have come out at a price comparable to that of flexo writer. These are 15 - 20 times faster and have the flexibility to edit and convert codes from EIA to ISO. Attempts are being made in CMTI to develop this tape preparation system as peripherals like key board data terminals, high speed paper tape reader and punch are available in the country. The cost of tape preparation using the computerised tape preparation works out to 2 to 3 cents per foot of tape as compared to 10 cents per foot of tape with the conventional method.

2.2.1.6 Direct Numerical Control - DNC:

Micro computers have become available at phenominally cheaper prices compared to mini computers. For certain logical decisions making, their capability approaches that of mini computers. This is taken advantage of for DNC and work has already started in CMTI. The scheme is as per Fig. 3.

The prosperity of micro computers to operate in a distributed processing mode is utilised in this scheme. The 16 bit mini - computer is the central NC data processing computer and is situated about 30 meters away from machines in the shop floor. Each machine can communicate with a slave micro-processor through an alpha-numeric display situated near the machine. Slave micro processors in turn communicate with a master micro processor and a common memory. The master micro processor communicates with mini computer through a high speed serial communication link at 2400 bands. The Master micro processor collects the NC tape data from the mini-computer disc storage and stores it in

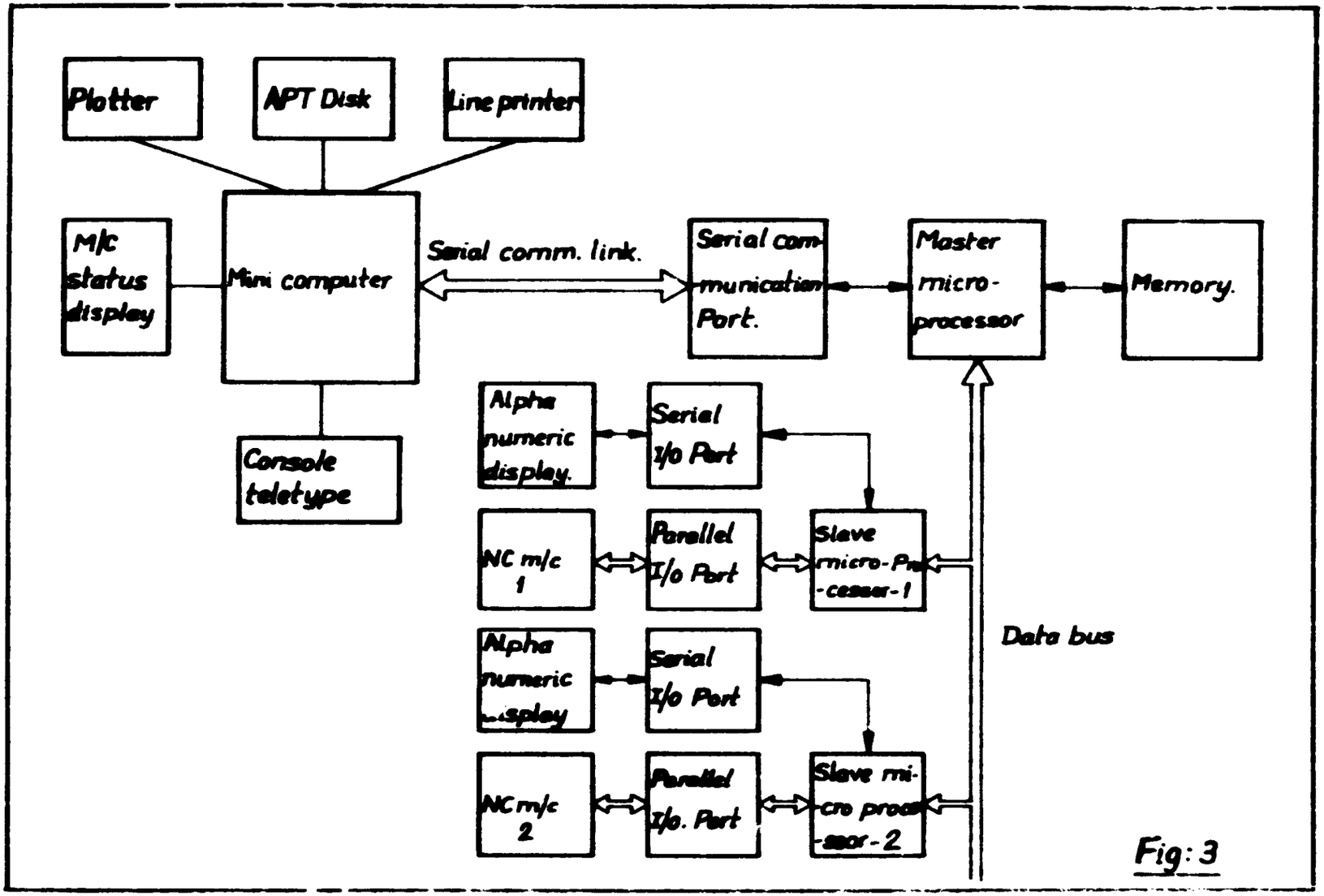

Plotter
APT Disk
Line printer
M/c status display
Mini computer
Serial comm. link.
Serial communication Port.
Master micro-processor
Memory.
Console teletype
Alpha numeric display.
Serial I/o Port
NC m/c 1
Parallel I/o Port
Slave micro-Processor-1
Alpha numeric display
Serial I/o Port
NC m/c 2
Parallel I/o. Port
Slave micro processor-2
Data bus

Fig: 3

segments of memory allotted for each NC machine tool and passes on control of memory to appropriate slave micro processors as per a pre-determined priority arbitration scheme. The slave micro processors directly transmits tape data from memory to the NC system to which it is linked. Similar onward transmission from the terminal placed near the NC machine to the Central mini computer takes place first through the slave micro processor and then through the master micro processor. This communication can be used to display the tape programmes stored in the disc of the mini computer or to ask a particular tape data displayed on the alpha numeric display near the machine for editing purposes. Management informations like number of parts machined, down time etc also can be displayed.

2.2.1.7 Real time computer aided design and Analysis:

To test, analyse and evaluate machine tools, a real time analogue data acquisition system has been developed in CMTI. This consists of an analogue digital converter for 8 channels and 12 bit

resolution working as a peripheral to the 16 bit mini computer. Analogue voltage inputs derived from vibration, noise transducers etc mounted on machine tools are simultaneously brought in through electrically conditioned cables to the central computer from the shop floor at 40-50 Meters away. These signals are converted to digital values and either recorded on magnetic tape for later processing or processed immediately through FORTRAN programmes and complete analysis given in a plotter immediately. By adopting this process what used to take several weeks for analysis and redesign is being done in 2-3 days. A qualitative economic figure only could be given as regards this method as 20 to 25 times faster and 10 to 12 times cheaper as compared to conventional manual method.

2.2.1.8 Computer aided inspection:

A coordinate Measuring Machine with tele tape terminal for logging the coordinates measured is used for inspecting components with complicated shapes. The machine simultaneously punches a tape while logging the coordinates. This tape is brought to the

computer centre and read through a paper tape reader. The profile is plotted on a zero shrink paper in the drum plotter for physical comparison with a master profile on a profile projector. Simultaneously the theoretical profile data base is compared at suitably selected intervals and errors are calculated and plotted. Components with complicated shapes can be inspected within an hour whereas previously it was taking weeks. A qualitative figure of 10 to 12 times can be quoted as the economic advantage over the conventional method. More than this advantage the correctness and precision of the inspected results is a great advantage.

Soft ware packages for determining the centre coordinates of bores, the inclination of surfaces, radius of curvature etc. are being developed.

3. STATUS OF INDIGENOUS MANUFACTURE OF COMPUTERS

One of the large Public Sector Companies in India is manufacturing third generation 16 bit mini computer completely with indigenous efforts. Software developments have also taken place simultaneously. FORTRAN, COBOL compliers are all available on this computer.

Disc and magnetic tape operating system have also been developed. However, one difficulty is that computer peripherals are not being made in the country. Import of these peripherals sometimes make the cost of the computer higher than that of the imported components. Another large Public Sector undertaking in the field of electronics is developing almost all peripherals for computers and is expected to meet the demands in the country by the next 5-6 years. There are 2 or 3 small private companies which are developing mini computers.

4. NC CENTRE AT CMTI

An NC Centre is being set up at CMTI with main objectives of helping industries in maximum utilisation of NC machines and give advice on maintenance, programming, manpower, tools, spares and techno-economic aspects of NC machines. Establishment of this centre by the Government shows the importance we attach to NC technology which has practically revolutionised metal cutting industries. Other government agencies and professional bodies have made the establishment of the centre possible by their deep appreciation of the technology involved. While these are the developments at National level, it is heartening to note that UNI attaches great significance to this technology in developing countries.

The centre will conduct courses and seminars for International participants details of which are given in Annexure 1.

It is felt that the NC centre with the nucleus of expertise and equipment will further the export potential of NC machines from India whose conventional machine tools are being well received in developed countries. HMT has already made a beginning in this with

their MOGUL lathe and Machining Centre .

MC Centre will keep pace with the new developments in the field of computer aided techniques so that designs can be updated with new technologies. India is already using general purpose computers for industrial production. Probably, during the course of next 5 - 10 years computers could be more in use in directly linking up to NC machines, coordinate measuring machines, production schedules etc. The MC centre will have a predominant role to play in these developments.

5. FUTURE DEVELOPMENT

5.1 Computer aided design:

In para 2.1.2, the work done on structural analysis has been described. It is felt UNIDO can be of great help by providing experts and software packages in the following fields.

5.1.1 To develop techniques for assessment of behaviour of joints and damping in the machine for accurate prediction of overall stiffness and dynamic response.

5.1.2 Development of dynamic analysis packages using finite element techniques.

5.1.3 Use of automatic mesh generation and interactive techniques to reduce high incidence of manual errors in input data preparation and to effect faster solution.

5.1.4 Analysis of torsional drives and servo systems.

5.1.5 Development of computer aided design of machine tools using interactive graphics. For this purpose computer and graphics hard ware are also required.

5.1.6 To make the NC Centre at CMTI ultimately a full fledged CAM Centre at the national and international level.

In addition to the above, UNIDO can help by sending experts in above fields and also training our engineers by way of fellowships in various institutes.

ANNEXURE -1

NC Centre Courses & Seminars at CMTI, Bangalore, India.

A) COURSES

1. Maintenance of Numerically Controlled Machine Tools - 2 weeks (3 Programmes).
2. Computer Aided Part Programming for NC Machines - 2 weeks. (2 Programmes).
3. Seminar/Course for Production Supervisors of NC Machines - 1 week (1 programme).
4. Design of Numerically Controlled Machine Tools - 4 weeks. (2 Programmes).
5. NC Tooling and Production Technology - 1 week. (2 programmes).
6. Machine Tool Inspection and Testing - 2 weeks. (1 Programme).
7. Machining Technology Course - 2 weeks. (1 Programme).
8. Machine Tool Design Course - 8 weeks. (1 Programme).
9. Hydraulic System for Machine Tools - 1 week (1 Programme).

B) SEMINARS

1. NC: CNC: DNC: - Seminars for Executives - 1 week.
2. Seminar on Economic Justification of NC Machines - 1 week. (1 Programme).

Details of the above may be obtained from:

Training Section,
Industrial Operations Division,
United Nations Industrial Development Organization,
P.O.BOX 707, A - 1011,
VIENNA, AUSTRIA.

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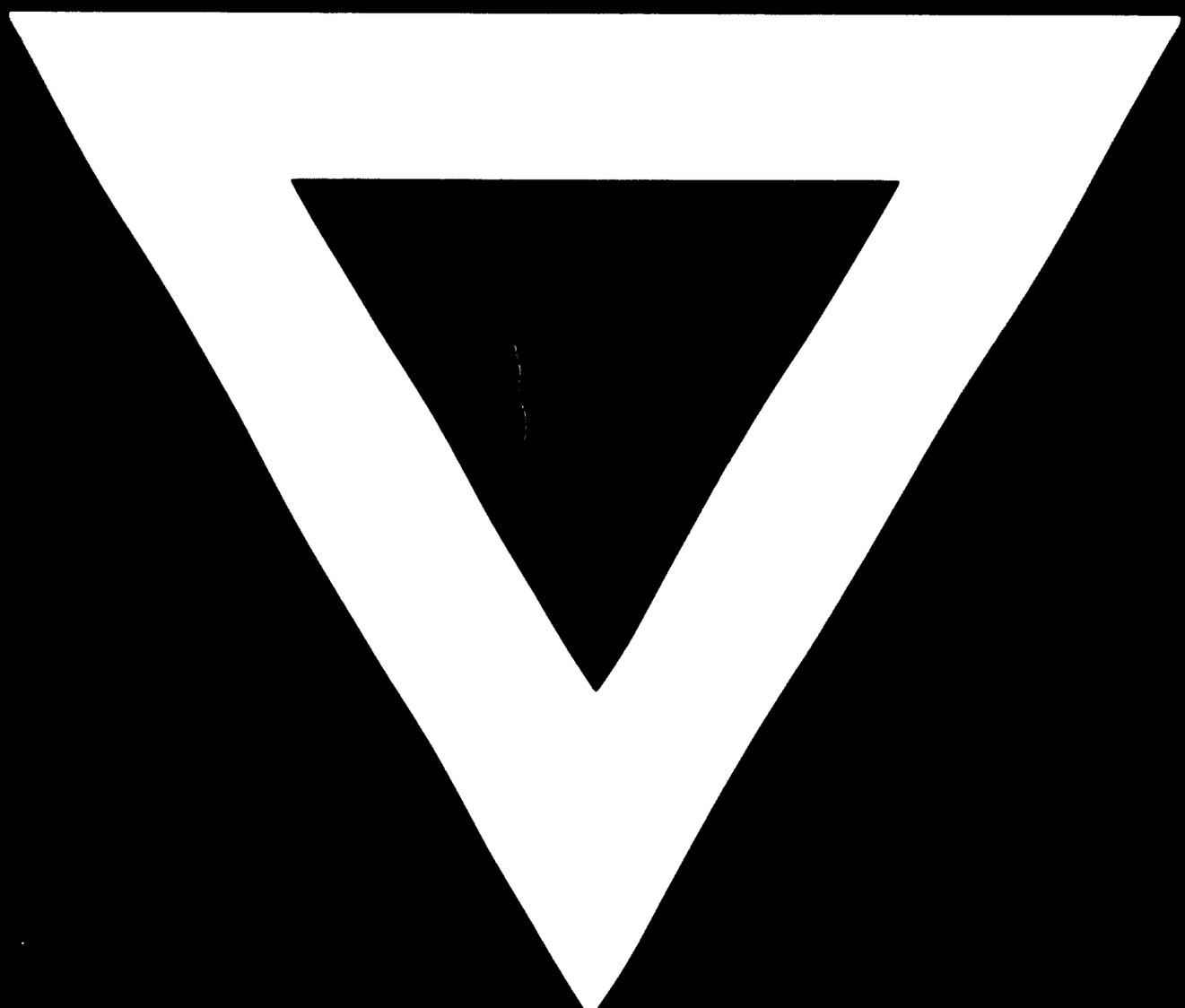

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