LECTURE NOTES

ON

Computer Aided Design and Manufacturing

Subject Code - MME-1213

By

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Computer Aided Design and Manufacturing
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Course Objectives:

Developments of software computer interface in design of various elements

Use of software for manufacturing

Automation of manufacturing methods

Course Contents:

Module - I

Fundamentals of CAD: The design process, applications of computer for design, creating the Manufacturing, Database, The design workstation, Graphical Terminal, Operator input Devices, Plotters and other devices, the CPU secondary storage [8]

Module - II

Computer graphics Software and Database: Configuration, Graphics Packages, Constructing the Geometry, transformations, Database structure and content, wire frame versus solid modeling [8]

Module - III

CAM – Introduction, Numerical Control and NC Part Programming: NC Coordinate system, NC motion control system, Economics of NC, Manual and Computer Aid Programming, the APT language, NC programming with interactive graphics [12]

Module - IV

Problems with conventional NC, NC technology: CNC, DNC combined DNC/CNC system, Adopter control manufacturing systems, Computer Integrated manufacturing system, Machine Tools and related Equipment, Materials Handling and Storage system, computer system [12]

Text Book(s):

1. Computer Aided design and Manufacture, Grover M.P.Simmers, E.W. Prentice Hall
2. CAD/CAM/CIM P.Radhakrishnan & Subramanyam, Willey Eastern Limited.
3. Automation, Production System and CIM, Goover, Prentice hall

Course Outcomes:

Define the principles of optimum design

Apply surface modelling techniques

Analyze production systems at operation level

MODULE 1

COMPUTER AIDED DESIGN AND MANUFACTURING

CAD/CAM :- The use of computers to aid the design and manufacturing process.

- It is concerned with the application of computers to the manufacture of engg. components, from the drawing phase to the ~~pro~~ production phase (to the m/c and assembly shops), to the quality control dept & to the warehouses.
- The technology of CAD/CAM represents an efficient, accurate and consistent method to design and manufacture high quality products.

The Role of Computers in manufacturing :-

It is classified into two groups :-

1) Computer monitoring & control of the manufacturing process.
2) Manufacturing support applications, which deals with the preparations for actual manufacturing & post manufacturing process.

- In the 1st category, computer is directly interfaced with the manufacturing process for monitoring & control functions.

  Ex:- In a chemical processing industry, a number of process parameters may be monitored.

- In the 2nd category, all support functions are included for the successful completion of manufacturing operations.

  Ex:- CAD :- Use of computer method to develop the geometric model of the product in 3D form.

  CAE (Engg) :- . . . . to support basic error checking, analysis, optimization, manufacturability.

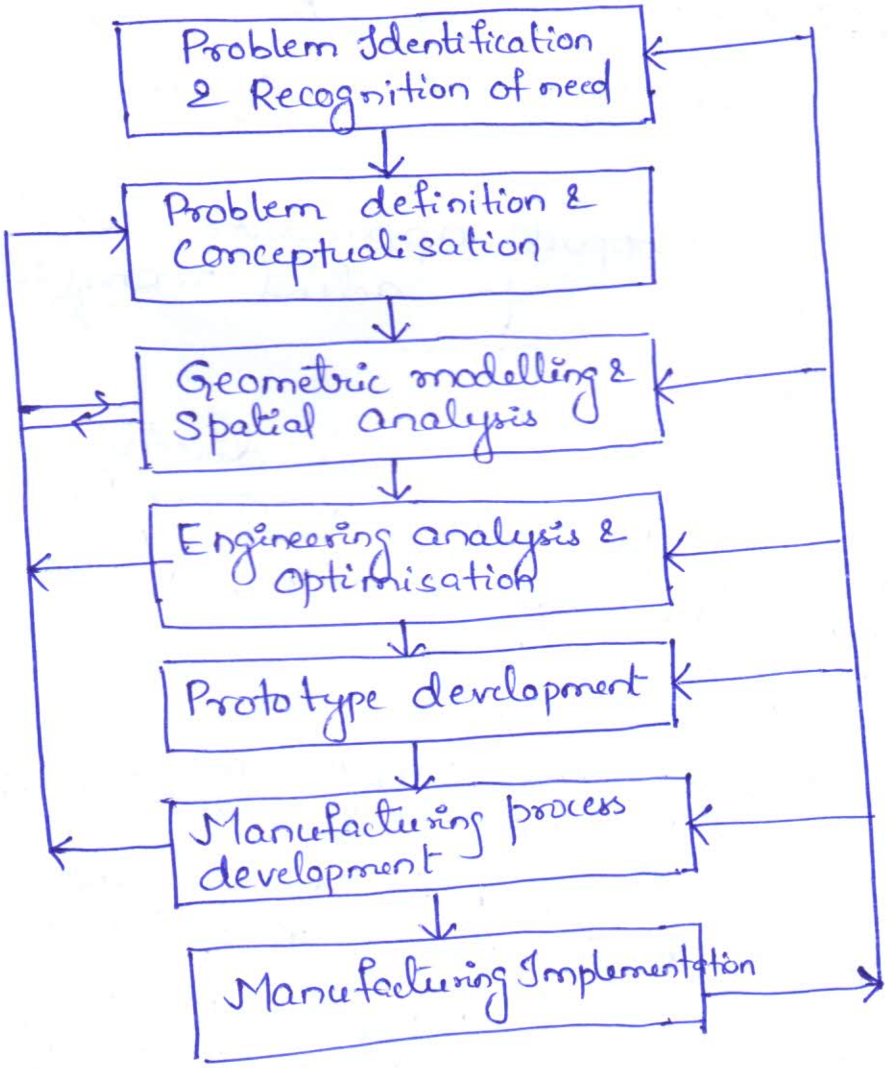
- CAM:- Use of computers to generate software to develop the Computer Numerical Control post programs for machining & other processing applications.

- CATD (Tool Design):- Computer assistance to be used for developing the tools for manufacture of Jigs, fixtures, dies, moulds.

- CAQ (Quality Assurance):- The use of computers and computer controlled equipment for accessing the inspection methods.

DESIGN PROCESS

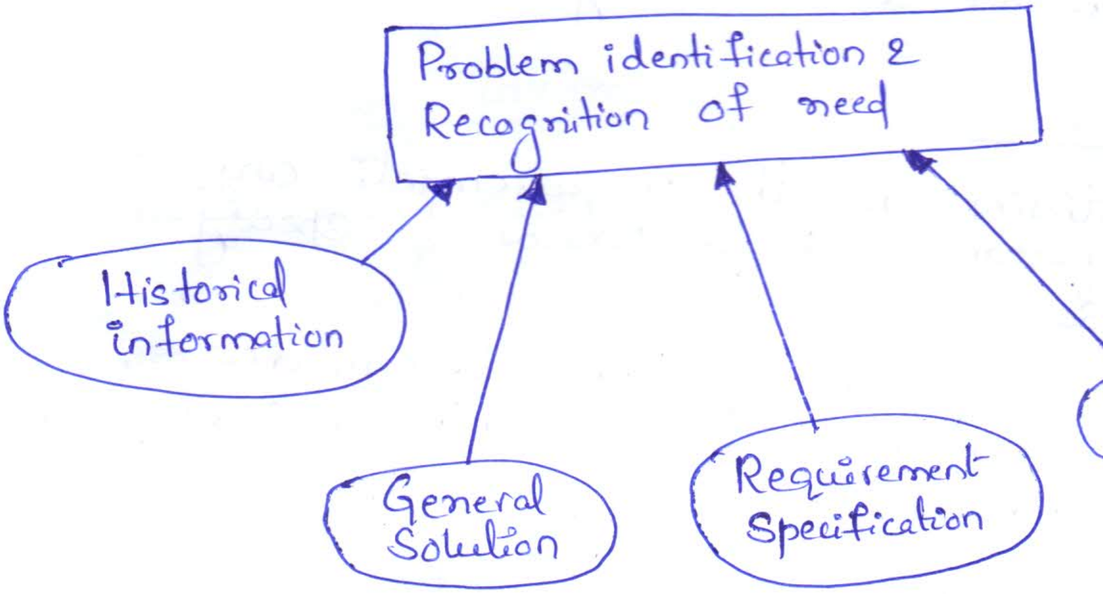
Stages in Design process



STAGES IN DESIGN PROCESS

- Ideally, the designer should consider all these factors while finalising the design.
- It is impossible for a single individual to carry out all these functions. So, it is carried out by a team of specialists, who have specified knowledge and experience in the individual areas.

PROBLEM IDENTIFICATION



Processes involved in the problem-identification stage

- The starting point of the design process is the identification of the needs of an unsatisfied demand for a particular product or conceptually a new idea to start a fresh demand.

(1) Historical Information :-
- This is related to the already existing information collected through the literature, market surveys, etc.

(2) Requirement Specification :-
- A clear definition of the requirements is specified at this stage. This helps in understanding the

product from the current business practices and manufacturing resources of the plant. This also helps in understanding short-term or long-term potential of the new product introduction.

(3) Market forces

Before going with product design, it is essential to consider the various market forces that will affect the product in one way or the other.

(4) General Solutions

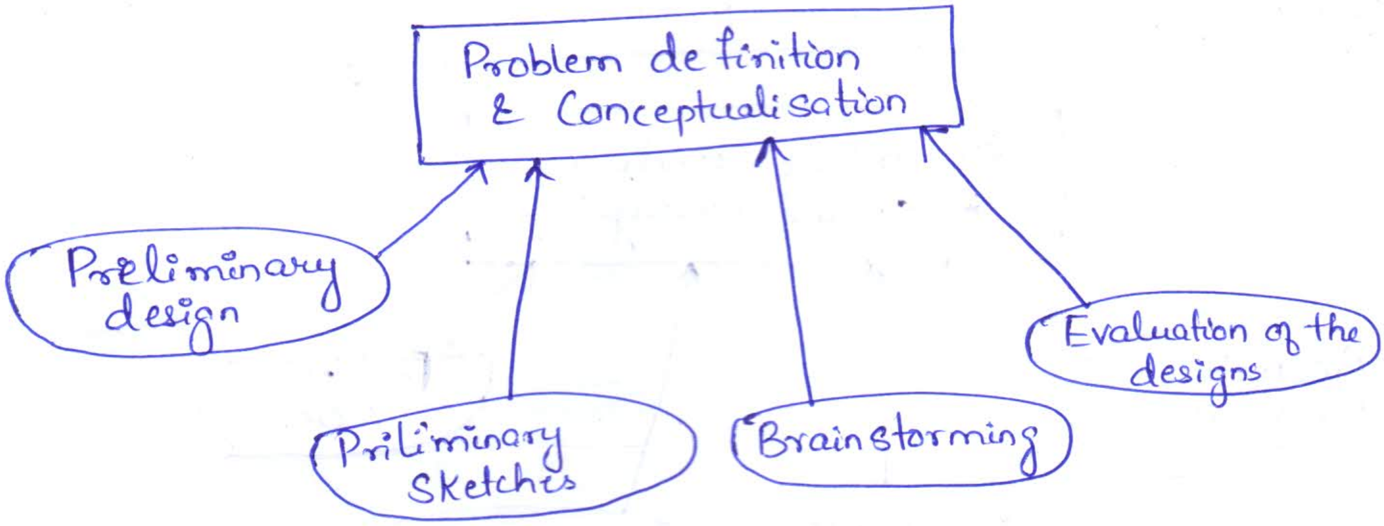
- Having identified all the requirements and controlling factors, it is possible to specify a general solution.
- This can be done by resorting to past designs, engineering standards, technical reports, catalogues, hand books, patents, etc.

II Stage :- Problem Definition

- The next stage in the design process is the → clear definition of the problem and coming up with all possible ideas for solutions.
- This stage is carried out as follows:-

(1) Preliminary Design :-

- The necessary elements which are important for the design process are identified at this stage.
- This basically identifies the likely difficulties to be faced in the design process as well as identify some imp. design elements, that help in design process.



Processes involved in the problem-definition stage

(2) Preliminary Sketches :-

- The basic solutions that have been identified in the earlier stage are to be detailed with the necessary sketches to examine their suitability for finalisation.

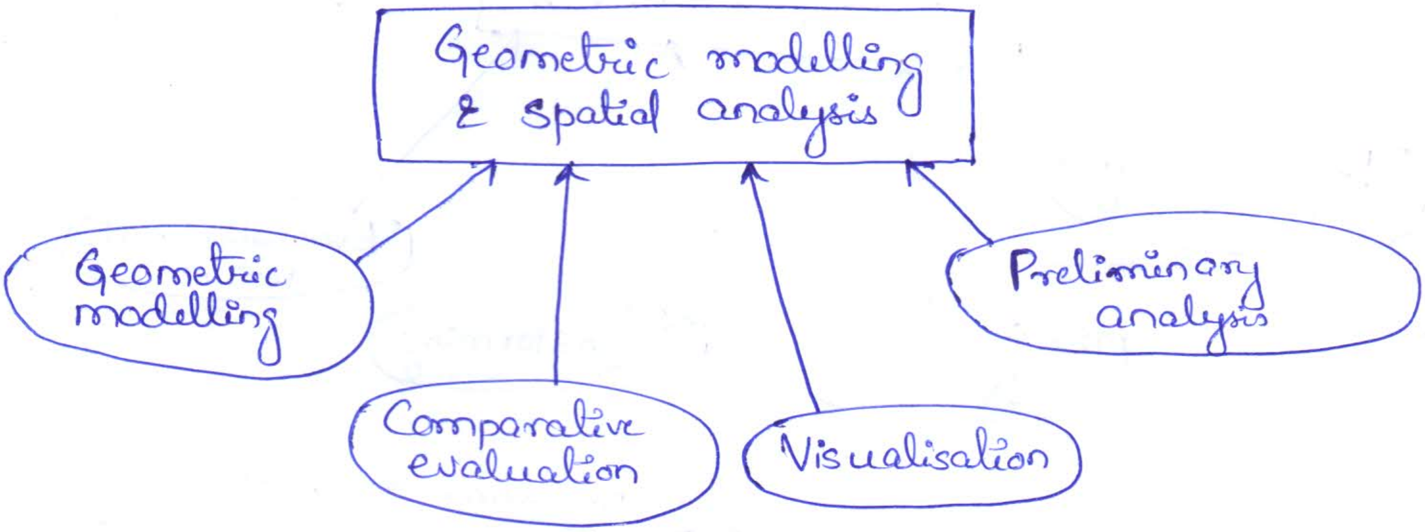
(3) Brain storming :-

- This is basically a group solving technique, where each one of the design team members spontaneously comes up with ideas.
- It is necessary to collect all the ideas during these sessions that are then be further processed to identify a final solution.

(4) Evaluation of the designs :-

- A no. of concepts have been identified in the previous stage.
- It is necessary to evaluate each of the choices in terms of feasibility, cost, ergonomics and human factors, environment, maintainability, etc.
- At this stage, it is possible to identify the final design based on all the factors such as market requirements, technical feasibility, economics, manufacturing expertise & resources available.

STAGE- III :- GEOMETRIC MODELLING



Geometric-modelling stage in the design process

(1) Geometric Modelling :-

- provides a means of representing part geometry in graphical form.
- It is important that the geometric model generated should be very clear and comprehensive.

(2) Visualisation :-

- One of the important requirements of modelling is the ability to visualise the part in actual service condition.
- This is done by giving various colours & surface textures to the part.
- This would allow the part to be visible in actual condition, without really making the prototype.

(3) Preliminary Analysis :-

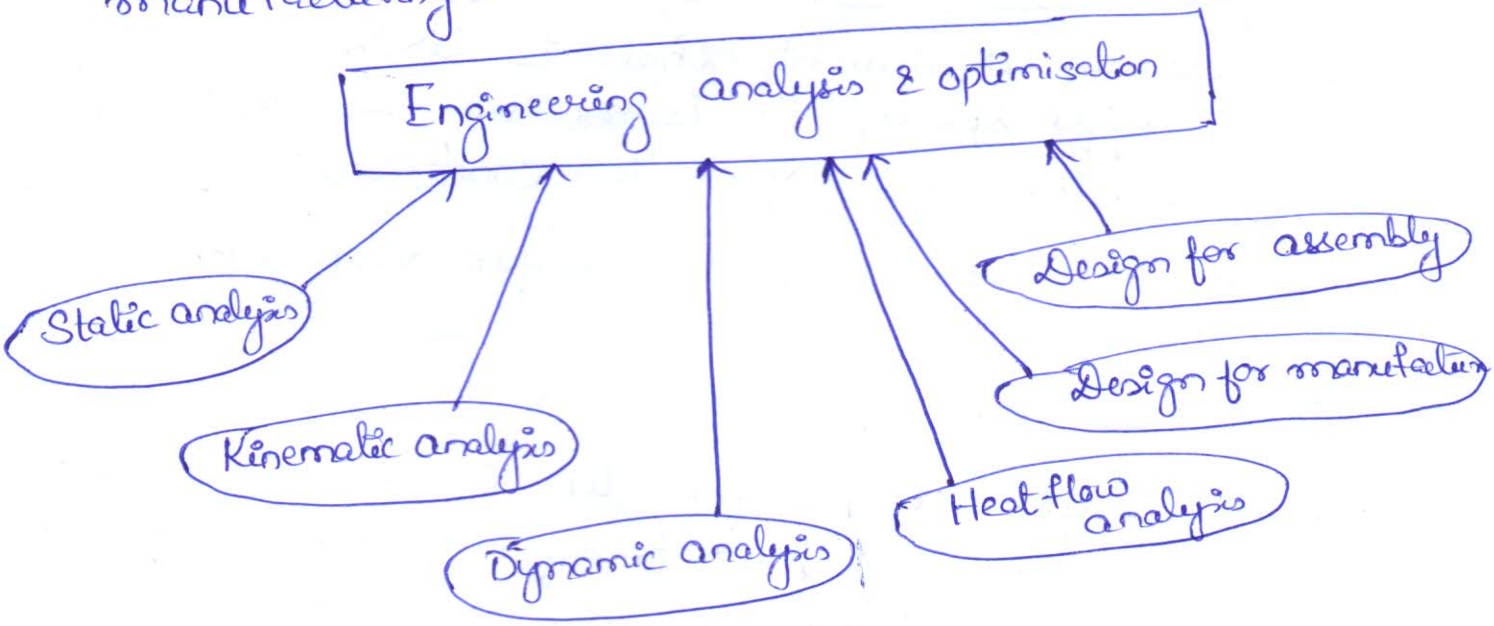
- This allows for simple analysis techniques such as volumes & masses, inertia, spatial analysis, etc.
- Also, ergonomics & human factors requirements can be analysed at this stage.

(4) Comparative evaluation :-

- Based on the data collected so far in terms of modelling, basic analysis and other factors, it would be possible to rate the various options in terms of technical feasibility, market acceptability and overall economics.
- This would allow for finalising the design.

STEP IV ENGINEERING ANALYSIS

- In this stage of design process, a thorough analysis of the product is carried out to get as much information as possible before committing to final manufacturing.



Analysis stage in the design process

(1) Static analysis :-

- It is necessary to obtain the stresses & strains in the component, when it is in service.
- Analytical methods are feasible for simple shapes & configurations.

- For complex shapes, it is necessary to use finite element analysis (FEA) methods.
- FEA breaks a model into small uniform elements and applies loading & boundary conditions for each of the elements.

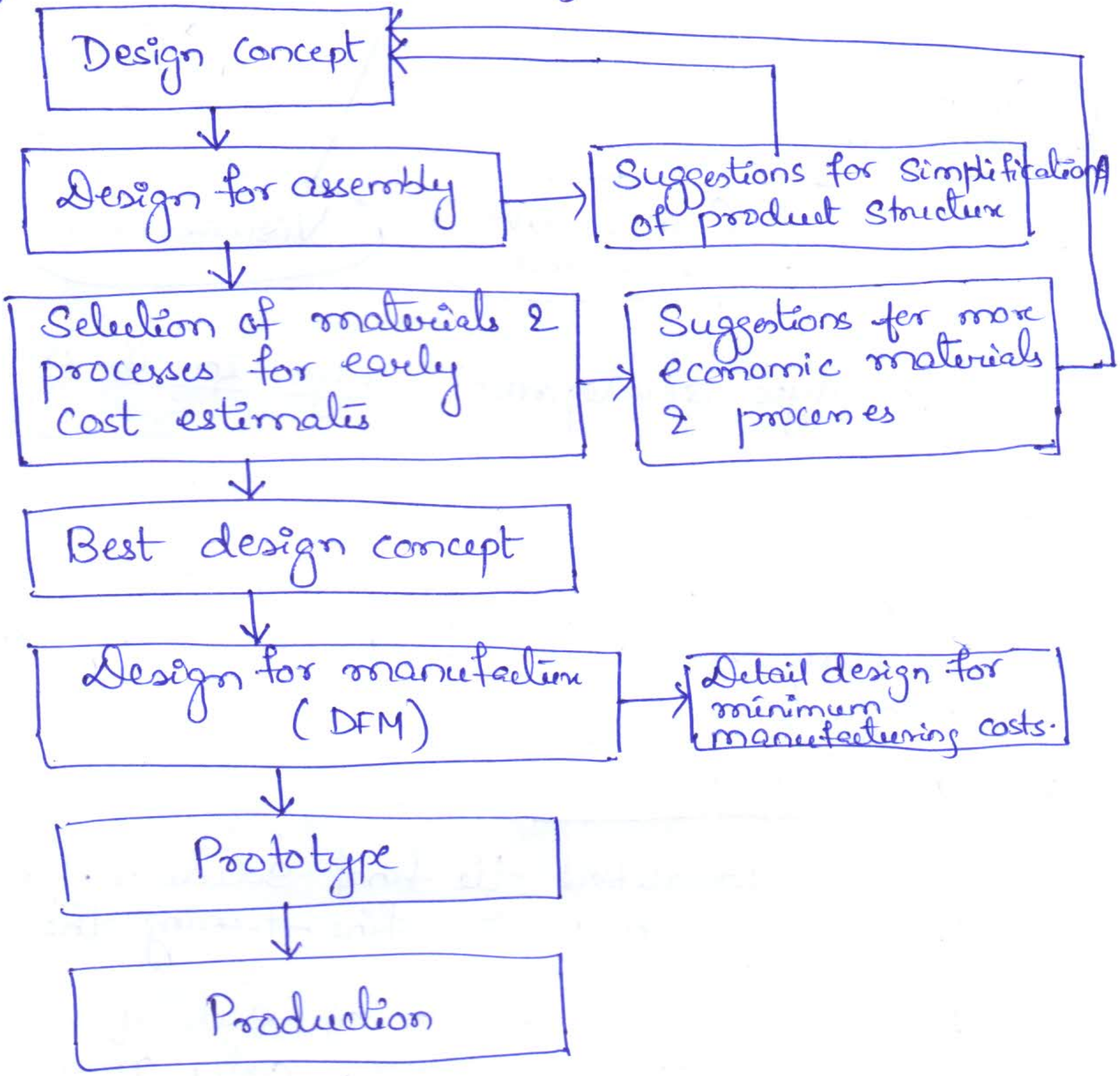
(2) Kinematic analysis:-
- Many components have relative motion requirements under service.
- Kinematic analysis systems allow the user to optimise the product performance, by providing a fundamental understanding of how a design will perform in its real-world environment.

(3) Dynamic Analysis:-
- For certain equipment, that is likely to be operating under high speeds, it is necessary to extend the above system for dynamic conditions.
- Using this analysis, designs for vibration, can be evaluated.

(4) Heat flow analysis:-
- This would allow for the evaluation of the part in terms of the heat-transfer analysis by evaluating the temp, thermal stresses.
- It is also possible to evaluate the flow characteristi by employing the FEA analysis.

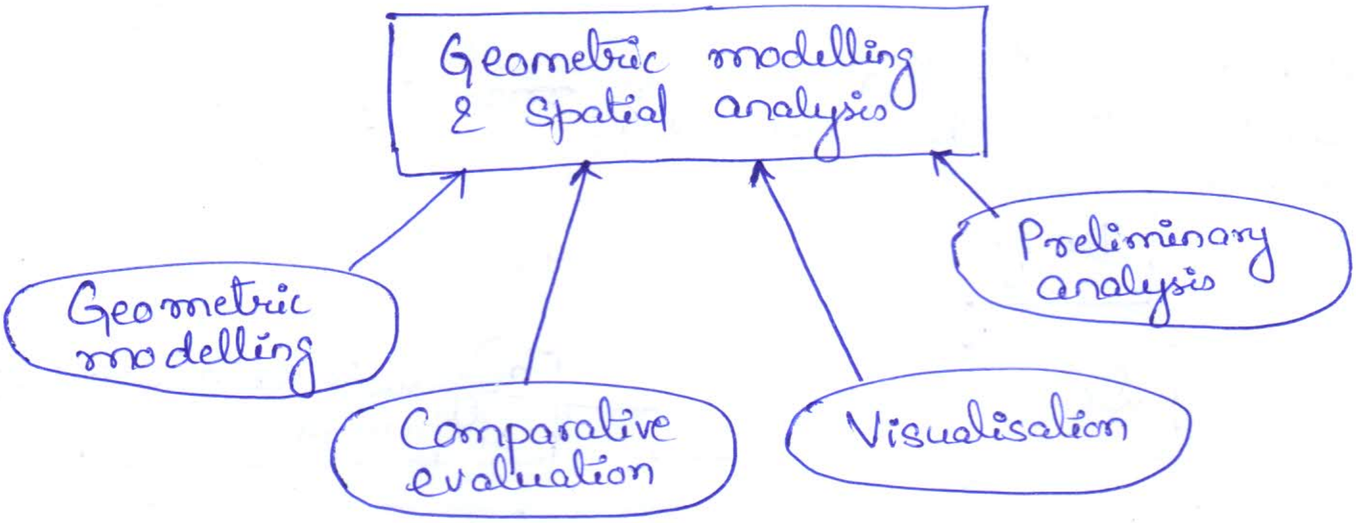
(5) Design for Manufacture & Assembly:-
- This analysis allows for a reduction of the assembly costs, along with a reduction of the overall costs, while improving the reliability of the product.

- Methodology ~~for~~ of design for manufacture & assembly is shown in Fig.



STAGE. V PROTOTYPE DEVELOPMENT

- Before committing the design to manufacture, it is essential to carry out some physical tests on the part.
- This will be in addition to the computerised analysis carried out using various facilities.
- The possible components in this stage are shown in Figure.
- Using conventional methods for developing the physical models is often time consuming & expensive. So RP techniques are used to develope them.



Prototype-development stage in the design process

Then, a) Test & Evaluation

- The actual prototype developed earlier is utilized to carry out actual testing to verify the computer simulations.

b) Design Refinement

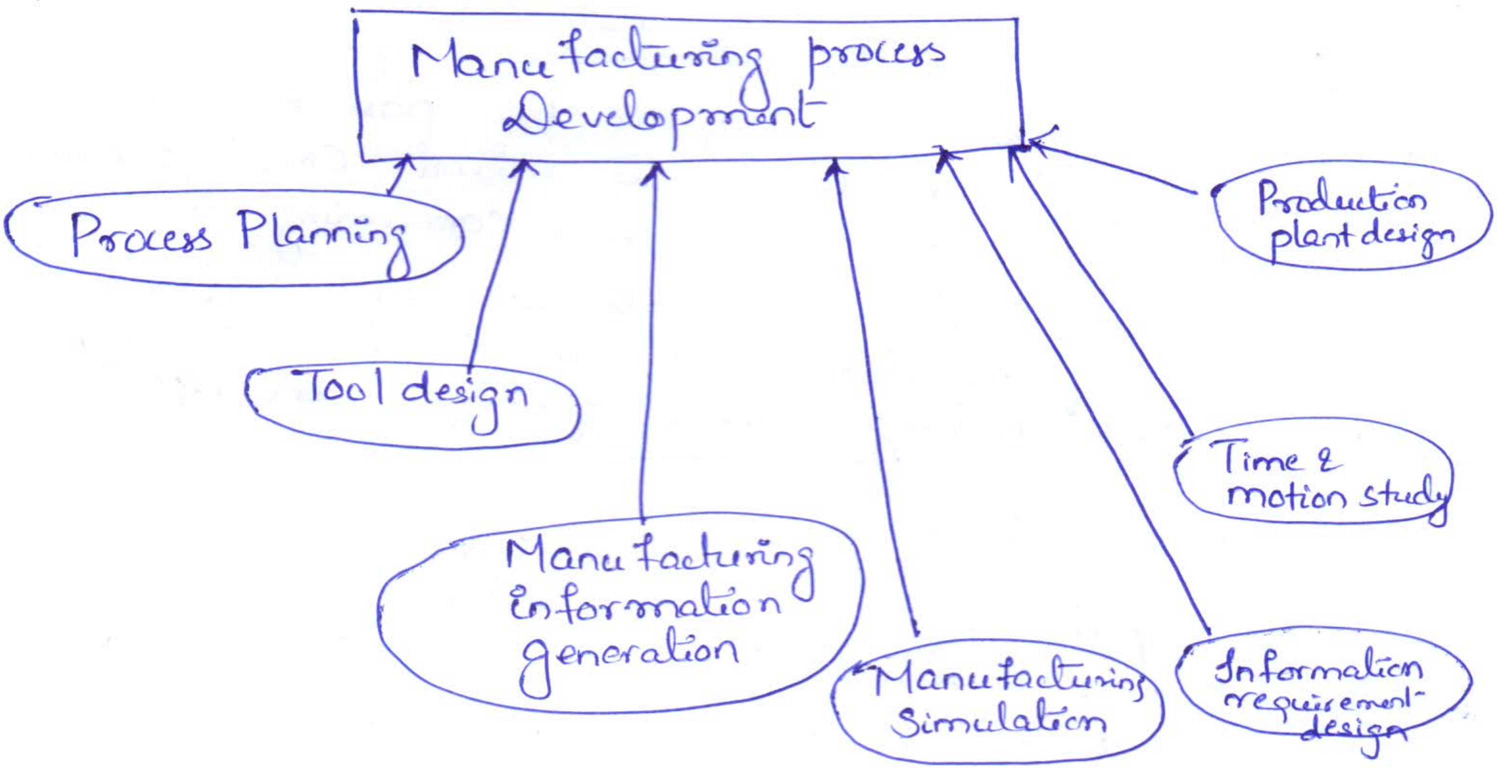
- Having identified the final solution for the design, this stage helps in fine-tuning the design.
- After careful evaluation of each feature & capability embedded in the design, only minor modifications are done at this stage.

c) Working Drawings

- These refer to the final hard copies of the drawings of the components & assemblies, describing the dimensional details, along with the assembly procedures.

STEP VI MANUFACTURING PROCESS DEVELOPMENT

- After finalising the product design, it is important to more the product to the manufacturing stage.
- The typical components present are shown in Figure.



Manufacturing-process-development stage in the design process.

(1) Process planning:-

It is the function of determining exactly how a product will be made to satisfy the requirements specified at the most economical cost.

(2) Tool Design:-

Since the geometric model is available, it is possible to develop tooling designs such as fixtures, injection mould cavities, mould cores, mould bases & other tooling.

(3) Manufacturing Information Generation

- This relates to the various part programs required during the manufacturing. They could be directly generated using the part model data.

Ex:- CNC part programs.

(4) Manufacturing Simulation :-

- Many times, the proving of the NC part programs has to be carried out using the actual CNC m/c tools, which is an expensive & time-consuming option.
- In such cases, it is desirable to carry out the actual simulation of machining on the computer screen, which saves a large amount of time & money.

(5) Information Requirement Design :-

- This aspect relates to the information pertinent to the manufacturing of the part that could be directly generated using the part model data.

Ex:- Production planning, Bill of materials, Material Requirement planning.

(6) Time & Motion Study :-

- This aspect needs to be done to see that the product's manufacturing cycle is optimised.
- Include's Manufacturing time, M/c-tool setup time, etc.

(7) Production plant Design :-

- The actual plant to produce the design for the Production volumes forms part of this.

Computer Aided Design (CAD)

- CAD utilises computer as a tool for all functions that are involved in the design process.
- The main functions that would utilise the computer are :-
    * Layout design for the overall assembly
    * Individual component modelling
    * Assembly modelling
    * Interference & tolerance stack checking
    * Engineering drawings

Advantages of CAD

(1) CAD is faster and more accurate than conventional methods.

(2) The various construction facilities available in CAD would make the job of developing the model & associated drafting a very easy task.

(3) Under CAD, it is possible to manipulate various dimensions, attributes and distances of the drawing elements.

(4) Modification of a model is very easy & would make the designer's task of improving a given product simple to take care of any future requirement

(5) Professional CAD Packages provide 3D visualisation capabilities so that the designers can see the products being designed from several different orientations.

(1) Define CAD & Explain the reasons for adopting CAD in an engg. ~~op~~ organisation.

(2) Briefly describe the role of engg. analysis process in the product design cycle.

(3) Specify the various stages present in a Conventional design process.

(4) Write about prototype development as a part of design process.

Hardware in CAD

CAD Workstation:- is the system interface with the outside world.

- The workstation must accomplish 5 functions:-

1) It must interface with the CPU.
2) It must generate a steady graphic image for the user.
3) It must provide digital descriptions of the graphic image.
4) It must translate computer commands into operating functions.
5) It must facilitate communication betn the user and the system.

Input devices:-

- These are the devices through which the user/operator communicates with the computer for feeding it with the necessary information.
- These devices are:-

1) Keyboard
2) Mouse
3) Light pen
4) Joystick
5) Digitiser
6) ~~Tablet~~
7) Scanner

(1) Keyboard:-

- The keyboard is the most basic input medium for all computers.
- The layout of keys on a keyboard generally consists of the traditional typewriter keys together with some special keys, which are used for controlling the execution of the program or the screen display (cursor movement).

2) Mouse:-

- The mouse is a pointing device. The mouse operates on three basic principles - mechanical, optical and opto-mechanical.
- The mechanical mouse contains a free floating ball with rubber coating on the underside, which when moved on a firm plane surface would be able to follow the movement of the hand.
- The motion of the ball is resolved into X and Y motions by means of the two rollers pressed against the ball. They in turn control the cursor on the screen, which can then be utilised for any desired applications by means of clicking the buttons on the mouse.
- In optical mouse, a special reflective plane surface with etched fine grids is required. The LEDs present inside the mouse would reflect the no of gridlines crossed in X and Y dir^ns, showing the distance moved.
- The operation of the opto-mechanical mouse is similar to that of the mechanical mouse, but the position resolvers used are based on the optical principle.

3) Light pen:-

The light pen is a pointing device in which the computer seeks to identify the position, where the light pen is in contact with the screen.

4) Joystick :-

- A joystick can also be used to control the on-screen cursor movement as a mouse does.
- A joystick can indicate the dirn, speed & duration of the cursor motion by the movement of the stick, which contains a ball seated in a spherical cavity, held in position by the operator. (Videogames)

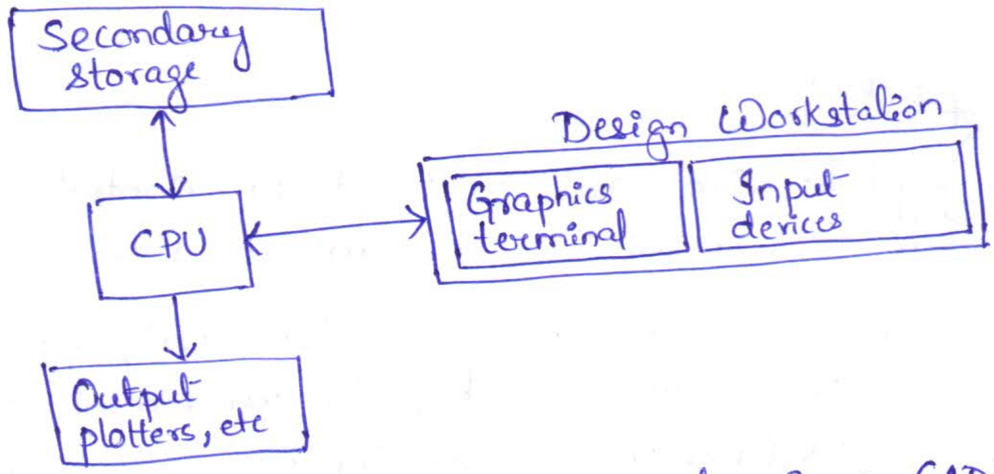
5) Digitiser:- (Tablet is a low-resolution digitiser)

- It is used for converting the physical locations into coordinate values so that accurate transfer of data can be acheived.
- It consists of a large, smooth board and an electronic tracking device, which can be moved over the surface to follow existing lines.
- It is a common technique in CAD systems for taking x, y coordinates from a paper drawing.

6) ~~Digitiser~~:- ~~Tablet~~:-

6) Scanner:-

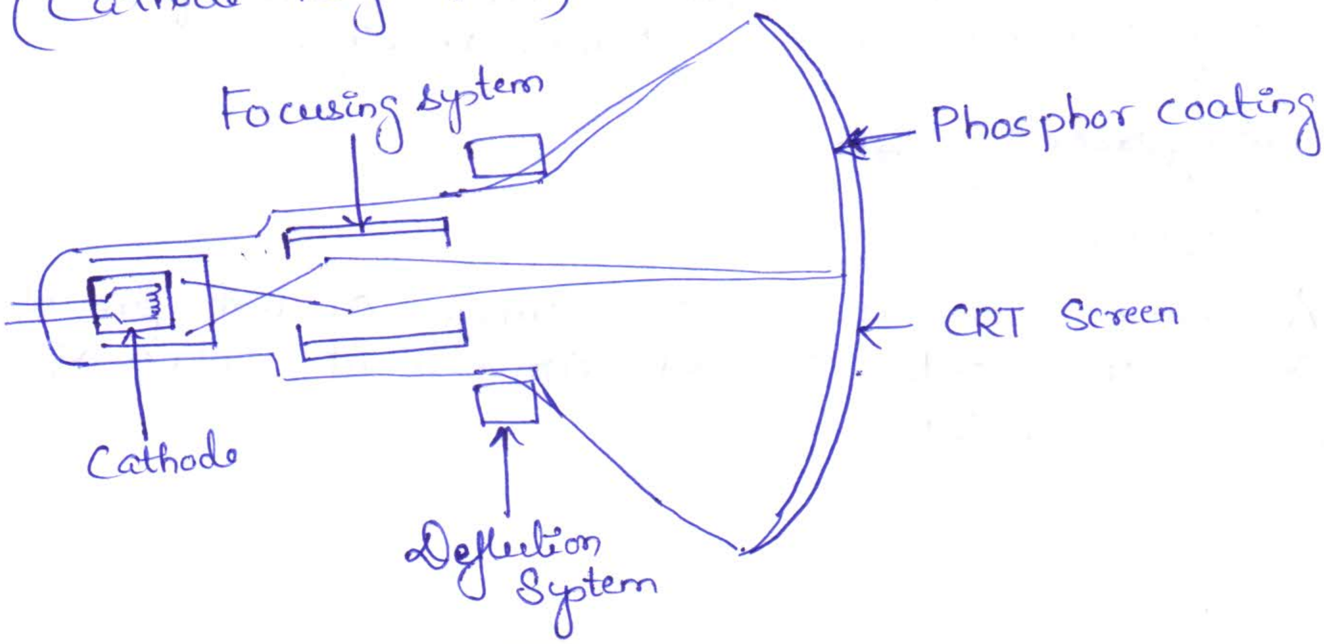
- A scanner digitally scans images or text present on a paper optically and converts it into a digital image as a bit map.



Configuration of hardware components in a CAD system

Display devices / Graphics terminal

- The display device forms the most important element in a CAD/CAM system, since on this most of the design work and simulation of manufacturing can be graphically displayed.
- The most common display medium is CRT (Cathode-Ray-Tube)



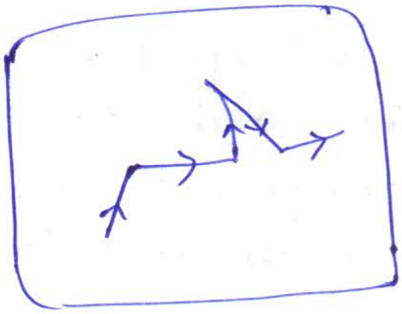
- A heated Cathode emits a high-speed electron beam onto a phosphor-coated glass screen. The electrons energize the phosphor coating, causing it to glow at the points where the beam makes contact.

- By focusing the electron beam, changing its intensity and controlling its point of contact against the phosphor coating through the use of a deflector system, the beam can be made to generate a picture on the CRT screen.

- There are two basic techniques used in current computer graphics terminals for generating the image on the CRT screen. They are
  (1) Stroke-writing
  (2) Raster scan

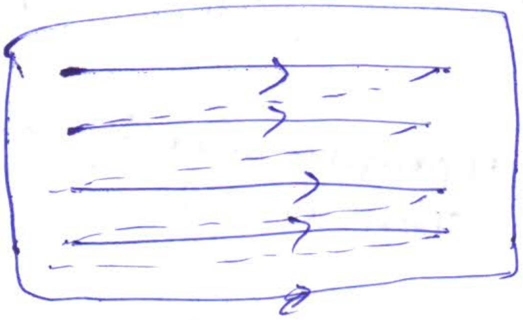
<u>Stroke-writing :-</u>

- The stroke writing system uses an electron beam which operates like a pencil to create a line image on the CRT screen.
- The image is constructed out of a sequence of straight-line segments.
- Each line segment is drawn on the screen by directing the beam to move from one point on the screen to the next, where each point is defined by its x and y coordinates.
- Smooth curves can be approximated by making the connecting line segments short enough.



Raster scan approach :-

- The viewing screen is divided into a large no. of discrete phosphor picture elements, called pixels.
- The matrix of pixels constitutes the raster.
  The no. of separate pixels in the raster display might typically range from 256 X 256 to 1024 x 1024.
- Each pixel on the screen is made to glow with a different brightness. Color screens provide for the pixels to have different colors as well as brightness.
- During operation, an electron beam creates the image by sweeping along a horizontal line on the screen from left to right and energizing the pixels in that line during the sweep.
- When the sweep of one line is completed, the electron beam moves to the next line below and proceeds in a fixed pattern.
- After sweeping the entire screen the process is repeated at a rate of 30 to 60 entire scans of the screen per second.



Raster scan.

Hard-Copy devices

Once the output is finalised on the display device, it can be transformed into hard copy using:-

* Graphical printers
* Plotters
* Photographic devices

(1) Graphical printers

This is the fastest way of getting graphical output at low cost.

Types:- - Dot-Matrix printer
- Inkjet printer
- Laser printer

a) Dot-Matrix printer:-

- The print head consists of a vertical bank of needles, which move horizontally over the paper. At each of the horizontal positions, any of the pins in the print head makes ink marks by hitting the paper through a ribbon.
- Cost low, but creates noise due to impact of pins on the paper.

b) Inkjet printer:-

- It shoots a jet of ink directly onto the paper, ~~as the pin impact~~ of the The rest of the mechanism is identical to the impact dot-matrix printer.
- The only requirement is that the paper used should be sufficiently absorbent, so that the droplet dries quickly upon reaching the surface of the paper.

c) Laser printer

- A semiconductor laser beam scans the electrostatically charged drum.
- The toner powder sticks to the charged portion of the drum which is then transformed to a sheet of paper & bonded to it by heat.
- Only A3 or A4 size can be used.

(2) PLOTTERS

- The plotter is the widely accepted output device for the final output.
- Various sizes for plotters are:-

Designation	Size of drawing, mm
A0	841 x 1189
A1	594 x 841
A2	420 x 594
A3	297 x 420
A4	210 x 297.

- Normally, all plotters have a range of pens available, which can be changed under program control.
- The types of pens used are fibre tip, roller ball or liquid ink.

a) Pen plotters:-

- The pen plotters uses a mechanical ink pen to write on paper through relative movement of the pen & paper.
- There are two basic types of pen plotters in use
  * Drum plotters
  * Flat-bed plotters

(i) <u>Flat-bed plotter</u> :- It is more expensive.

- It uses a flat drawing surface to which the paper is attached.
- The paper is held in a fixed position by means of a vacuum or electrostatic force.
- The pen carriage moves in both X and Y-axes for making the necessary plot.

(ii) <u>Drum plotter</u> :- It is less expensive.

- It uses a rotating drum, usually mounted horizontally and a slide which can be moved along a track mounted axially w.r.t drum.
- The paper is attached to the drum and pen is mounted on the slide.
- The relative motion betn pen & paper is acheived by coordinating the rotation of the drum with the motion of the slide.

(b) <u>Electrostatic plotters</u>

- The electrostatic plotter uses the pixel as a drawing means like raster display device.
- The plotter head consists of a large no. of tiny styluses embedded into it.
- This head traverses over the width of the paper as it rolls past the head to make the drawings. These styluses cause electrostatic charges at the required dot positions to make the drawing
- They are normally very fast with plotting speeds of 6 to 32mm/s.

Photographic devices

- These are essentially cameras in front of a CRT display.
- They normally have a smaller built-in-screen inside the recorder, which is connected to the CPU through the serial communication port.

STORAGE DEVICES

- Permanent storage of programs & of data generated during various sessions of CAD/CAM requires a large amount of storage space.
- The various devices used are
  * Floppy disks (Not in use today)
  * Magnetic ~~tapes~~ disks
  * " tapes.

Magnetic disks → typically used for the CAD system software & the CAD data base. (CD, DVD)

Magnetic tapes → Stores programs & files (Audio cassette)

Assignment

1) What do you understand by CPU? State its importance?
2) What are the input devices more commonly employed for general graphics applications? Explain all?
3) What are the various methods employed in making display devices that are used for displaying graphic information?

MODULE II

Chapter-3

Computer Graphics Software & Data base

- The graphics software is the collection of programs written to make it convenient for a user to operate the computer graphics system.
- It includes programs to generate images on the CRT Screen, to manipulate the images, and to accomplish Various types of interaction betn the user & the system.

Features of graphics software:-

(1) Simplicity :- Should be easy to use.

2) Consistency :- The package should operate in a consistent and predictable way to the user.

(3) Completeness :- There should be no inconvenient omissions in the set of graphics functions.

(4) Robustness :- The graphics system should be tolerant of minor instances of misuse by the operator.

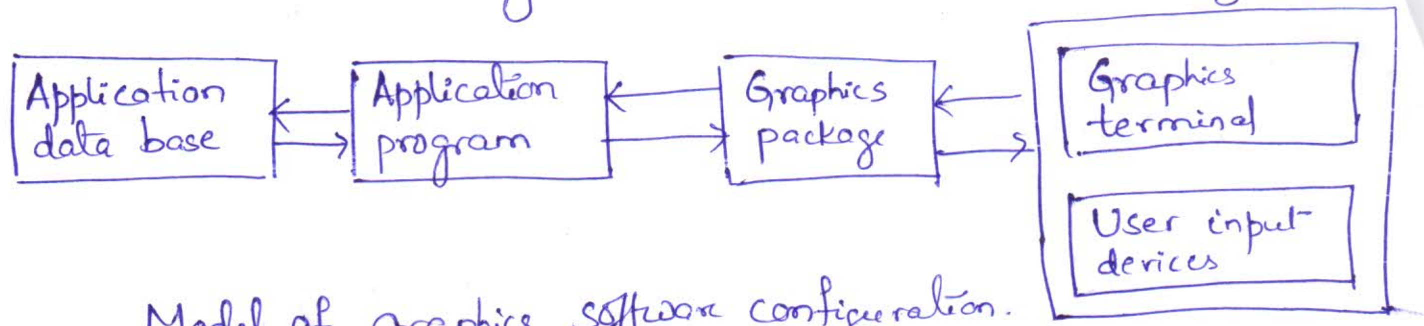
(5) Performance :- The performance should be exploited as much as possible by software.

(6) Economy :- Graphics programs should not be so expensive to make their use prohibitive.

The graphics software is divided into 3 modules

1) The graphics package
2) The application program
3) The application data base

This software configuration is illustrated in Figure.



Model of graphics software configuration.

Application program

- Application program controls the storage of data into & retrieves data out of the application data base.
- The application program is implemented by the user to construct the model of a physical entity whose image is to be viewed on the graphics screen.

Graphics package

- It is the software support betn the user and the graphics terminal.
- It manages the graphical interaction betn the user & the system. It also serves as the interface betn the user & the application software.
- It consists of input subroutines and output subroutines. The input subroutines accept input commands and data from the user and forward them to the application program.

  The output subroutines control the display terminal & converts the application models into two-dimensional or three-dimensional graphical pictures.

Database

- It contains mathematical, numerical, and logical definitions of the application models, such as electronic circuits, mechanical components, etc.
- The contents of the database can be readily displayed on the CRT or plotted out in hard-copy form.

Functions of a graphics package

Some common function sets are :-

1) Generation of graphic elements
2) Transformations
3) Display control and windowing functions
4) Segmenting functions
5) User input functions

(1) Generation of graphic elements :-

- A graphic element in computer graphics is a basic image entity such as a dot, line segment, circle, etc.
- The collection of elements in the system could also include alphanumeric characters & special symbols.
- The user can construct the application model out of a collection of elements available on the system.

(2) Transformations :-

- Transformations are used to change the image on the display screen & to reposition the item in the database.
- They are applied to the graphic elements to aid the user in constructing an application model.
- These transformations include enlargement & reduction of the image by a process called 'Scaling', repositioning the image or translation and rotation.

(3) Display control and windowing functions

- It provides the user with the ability to view the image from the desired angle and at the desired magnification.
- This is sometimes referred to as windowing because the graphics screen is like a window being used to observe the graphics model.
- Another aspect of display control is hidden-line removal.

(4) Segmenting functions

- It provide users with the capability to selectively replace, delete or otherwise modify portions of the image.
- The term 'segment' refers to a particular portion of the image which has been identified for purposes of modifying it.

(5) User input functions

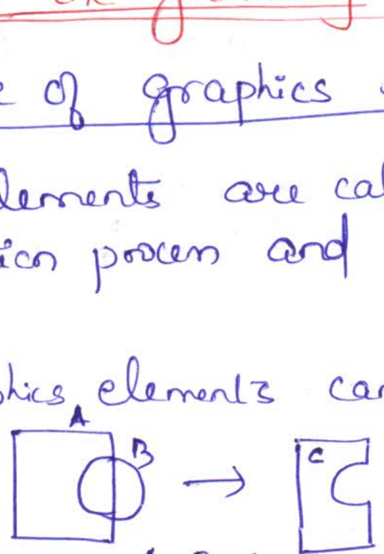
- They permit the operator to enter commands or data to the system.
- The entry is done by means of operator input devices.

Constructing the geometry

(1) The use of graphics elements

- These elements are called by the user during the construction process and added one by one to create the model.
- The graphics elements can be subtracted as well as added.

Ex:-



A - B = C

Rotation:-

For a +ve angle, the rotation is in the counterclockwise dirn.
In matrix notation, the procedure is

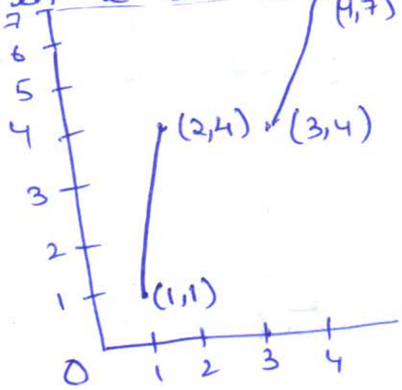
$$(x', y') = (x, y) R$$

where $R = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}$ the rotation matrix

Ex.1 Line is defined by

$$L = \begin{bmatrix} 1 & 1 \\ 2 & 4 \end{bmatrix}$$

Translate the line by 2 units in x dirn & 3 units in y dirn.



$$\begin{bmatrix} 1 & 1 \\ 2 & 4 \end{bmatrix} + \begin{bmatrix} 2, & 3 \\ 2, & 3 \end{bmatrix} = \begin{bmatrix} 3 & 4 \\ 4 & 7 \end{bmatrix}$$

The new line has end points (3,4) & (4,7)

Ex.2 For the previous problem, apply a scaling factor of 2 to the line.

$$T = \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 1 \\ 2 & 4 \end{bmatrix} \cdot \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix} = \begin{bmatrix} 2 & 2 \\ 4 & 8 \end{bmatrix}$$

Ex.3 Rotate the line about the origin by 30°

$$R = \begin{bmatrix} \cos 30 & \sin 30 \\ -\sin 30 & \cos 30 \end{bmatrix} = \begin{bmatrix} 0.866 & 0.5 \\ -0.5 & 0.866 \end{bmatrix}$$

The new line is

$$\begin{bmatrix} 1 & 1 \\ 2 & 4 \end{bmatrix} \cdot \begin{bmatrix} 0.866 & 0.5 \\ -0.5 & 0.866 \end{bmatrix} = \begin{bmatrix} 0.366 & 1.366 \\ -0.268 & 4.464 \end{bmatrix}$$

Translation matrix in 3-dimensions

$$T = (m, n, p)$$

Scaling transformation, S

$$S = \begin{bmatrix} m & 0 & 0 \\ 0 & n & 0 \\ 0 & 0 & p \end{bmatrix}$$

$$R_z = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$ Rotation about Z-axis by an angle θ

$$R_y = \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix}$$ Rotation about y-axis by an angle

$$R_x = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix}$$ Rotation about x-axis by an angle

Concatenation

Let the point is (3, 1). It is scaled by a factor of 2 and rotated by 45°.

$$(x', y') = (x, y) \cdot S$$
$$= (3, 1) \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix} = (6, 2)$$

$$(x'', y'') = (x', y') R = (6, 2) \begin{bmatrix} \cos 45 & \sin 45 \\ -\sin 45 & \cos 45 \end{bmatrix}$$
$$= (6, 2) \begin{bmatrix} 0.7071 & 0.7071 \\ -0.7071 & 0.7071 \end{bmatrix} = (2.828, 5.657)$$

OR

$$SR = \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix} \begin{bmatrix} 0.7071 & 0.7071 \\ -0.7071 & 0.7071 \end{bmatrix} = \begin{bmatrix} 1.414 & 1.414 \\ -1.414 & 1.414 \end{bmatrix}$$

$$(x'', y'') = (3, 1) \begin{bmatrix} 1.414 & 1.414 \\ -1.414 & 1.414 \end{bmatrix} = (2.828, 5.657)$$

CONCATENATION

The single transformations can be combined as a sequence of transformations. This is called concatenation & the combined transformations are called concatenated transformations.

Scaling :- Scaling of an element is used to enlarge it or reduce its size.

Ex:- The points of an element can be scaled by the scaling matrix as follows :-

$$(x', y') = (x, y) \cdot S$$

when $S = \begin{bmatrix} m & 0 \\ 0 & n \end{bmatrix}$ the scaling matrix

- This would produce an alteration in the size of the element by a factor m in the x dir^n and by a factor n in the y dir^n.

Rotation :- In this transformation, the points of an object are rotated about the origin by an angle θ.

- For a +ve angle, this rotation is in the counterclockwise dir^n. This accomplishes rotation of the object by the same angle, but it also moves the object.

- In matrix notation,

$$(x', y') = (x, y) R$$

when $R = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}$ the rotation matrix

(2) Defining the graphic elements

- The user has a variety of different ways to call a particular graphic element and position it on the geometric model.
- Ex:- A point would be defined as by its x, y & z Coordinates.

(3) Editing the geometry

- CAD System provides editing capabilities to make Corrections and adjustments in the geometric model.
- When developing the model, the user must be able to delete, move, copy and rotate components of the model.
- The editing procedure involves selecting the desired portion of the model and executing the appropriate ~~demand~~ command.
- The method of selecting the segment of the model to be modified varies from system to system.

TRANSFORMATIONS

1) Two-dimensional transformations

- To locate a point in a two-axis cartesian system, the x and y coordinates are specified.
- These coordinates can be treated together as a 1×2 matrix: (x, y)
- These coordinates would be interpreted to be a point Ex:- the matrix $(2,5)$ which is 2 units from the origin in the x-dir^n & 5 units from the origin in the y-direction.

Translation

$$x' = x + m, \quad y' = y + n$$

where $x', y' \longrightarrow$ Coordinates of the translated point
$x, y \longrightarrow$ Coordinates of the original point
$m, n \longrightarrow$ movements in the x and y directions.

In matrix notation, it can be represented as

$$(x', y') = (x, y) + T$$

where $T = (m, n)$ the translation matrix.

Data base structure

- The CAD data-base contains the application models, designs drawings, assemblies, etc.
- The data base resides in computer memory (primary storage) & Secondary storage.

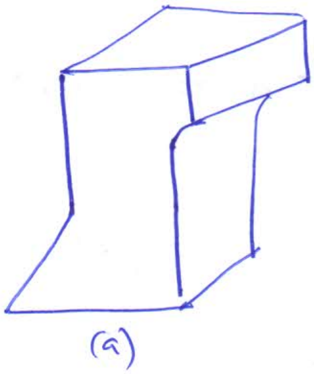
The basic ingredients of the application model :-

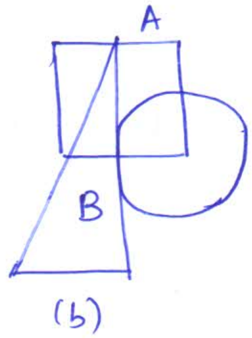
(1) Basic graphic elements (points & other elements)
(2) Geometry (shape) of the model components & their layout in space.
(3) Topology or structure of the models — how the various components are connected to form the model.
(4) Application-specific data, such as material properties.
(5) Application-specific analysis programs, such as finite-element analysis programs.

- The list represents a building-block approach to model formulation. The model structure consists of both data and procedures to connect, describe and analyze the model.

- One possible data structure involves storing the coordinates of the geometry, together with other information which might be required to completely define the model.
There are disadvantages to this type of data structure.
Ex:- Let us consider a cylinder. It consist of a line segment parallel to the y-axis & rotated about that axis to form the cylinder. (We require line segment (points) & axis of rotation)
→ We have to feed solid cylinder.

- Boolean operations can be used to construct the geometric model.





- The solid model in part (a) of the figure is formed by the intersection of the compliment of the cylinder C with the union of rectangular solid A and triangular prism B.

$$\bar{C}(A+B)$$

- Part (b) of the figure shows the three elements A, B & C in cross-sectional view

WIRE-FRAME VERSES SOLID MODELING

- In the construction of the wire-frame model, the edges of the objects are shown as lines.
- For objects in which there are curved surfaces, contour lines can be added, to indicate the contour.
- The image assumes the appearance of a frame constructed out of wire - hence the name 'Wire frame' model.
- Wire-frame models are quite adequate for 2-dimensional representation.
- Many 3-dimensional wire-frame systems donot possess an automatic hidden-line removal feature.
  Consequently, the lines that indicate the edges at the rear of the model is seen, which can cause the image to be somewhat confusing to the viewer.
- Another limitation:- CAD system define the model in their databases. Ex:- There may be doubt in case of a surface definition as to which side of the surface is solid.

Solid models

- An improvement over wire-frame models → is the solid modelling approach.
- In this approach, the models are displayed as solid objects to the viewer, with very little risk of mis interpretation.
- When colour is added to the image, the resulting picture becomes strikingly realistic.
- Applications :- Colour illustrations in magazines & technical publications, animation in movie films & training simulators.

- There are two factors which promote widespread use of Solid modelers. The first is the increasing awareness among users of the limitations of wire-frame systems.
- The 2nd reason is the continuing development of computer hardware & software which make solid modeling possible.
- Solid modelers require a great deal of computational power in terms of both speed & memory, in order to operate.
- Two basic approaches to the problem of solid modeling have been developed:

(1) Constructive solid geometry (CSG), also called the building block approach.

(2) Boundary representation (B-rep)

CSG Systems:- allow the user to build the model out of solid graphic primitives, such as rectangular blocks, cubes, spheres, cylinders.

- The boundary representation approach requires the user to draw the outline or boundary of the object on CRT screen.
- The user would sketch the various views of the object, drawing interconnecting lines among the views to establish their relationship.

The two approaches have their relative advantages & disadvantages.

1. The CSG systems have a significant procedural advantage in the initial formulation of the model.
   - It is relatively easy to construct a precise solid model out of regular solid primitives by adding, subtracting, and intersecting the components.

   B-rep systems become evident when unusual shapes are encountered that is not included in CSG systems.

   Ex:- Wing shapes

2. Another point of comparison betn the two approaches is the diffn in the way, the model is stored in the data base for the two systems.
   - The CSG system generally requires less storage, but more computation to reproduce the model & its image. However, B-rep system requires more storage space & ~~but~~ less computation effort to reproduce the image.
   - A related benefit of B-rep systems is that it is relatively simple to convert back & forth betn a boundary representation and a corresponding wire-frame model.

- The reason is that the model's boundary definition is similar to the wire-frame definition, which facilitates conversion of one form to the other.

- Because of the relative benefits and weaknesses of the two approaches, hybrid systems have been developed which combine CSG & B-rep approaches.

- With these systems, users have the capability to construct the geometric model by either approach, whichever is more appropriate to the particular problem.

Most CAD Systems currently available offer extensive capabilities for developing engineering drawings. These capabilities are:-

(1) Automatic cross hatching of surfaces in drawing from wire-frame models.

(2) Capability to write text on the drawings

(3) Semi automatic dimensioning:-
The dimensions can be obtained from the database.
Dimensioning features include

- Linear or angular conventions, depending on which is more appropriate.

- Dimensions displayed in decimal or fractional notation.

MODULE III

CAM – NUMERICAL CONTROL

Numerical control :- defined as a form of programmable automation in which the process is controlled by numbers, letters and symbols.

- In NC, a program of instructions is designed for a particular job. When the job changes, the program of instructions is changed.
- This capability to change the program for new job gives flexibility to NC.
- NC technology has been applied to a wide variety of operations (e.g. Inspection, sheet metal press working, welding, etc) But principal applications in metal machining process.

Basic Components of an NC System

(1) Program of instructions
(2) Controller unit, (Machine Control Unit, MCU)
(3) M/C tool or other controlled process

- The program of instructions serves as input to the controller unit, which in turn commands the machine tool or other process to be controlled.

Program of instructions :-

- The program of instructions is the detailed step-by-step set of directions, which tells m/c tool what to do.
- It is coded in numerical/symbolic form on some type of input medium (Punched cards, magnetic tape) that can be interpreted by the controller unit.
- There are two other methods of input to the NC system

- The first is by manual entry of instructional data to the controller unit. This method is called manual data input, abbreviated MDI.
This is appropriate only for relatively simple jobs where the order will not be repeated.

- The second other method of input is by means of a direct link with a computer. This is called direct numerical control or DNC.

- The program of instructions is prepared by Part-programmer. The programmer's job is to provide a set of detailed instructions by which the sequence of processing steps is to be performed. For the machining operation, the processing steps involve the relative movement betn the cutting tool & the W/P.

Controller unit

- The second basic component of the NC system is the controller unit.
- It consists of the electronics and hardware that read and interpret the program of instructions and convert it into mechanical actions of the machine tool.

- The typical elements of a conventional NC controller unit include the <u>tape reader</u>, a data buffer, signal output channels to the m/c tool, feedback channels from the m/c tool and sequence controls to coordinate the overall operation of the foregoing elements.

Tape reader:- is an electromechanical device for winding and reading the punched tape containing the program of instructions.
- The data contained on the tape are read into the data buffer.

Data buffer:- The purpose of data buffer is to store the input instructions in logical blocks of information. (A block of information represents one complete step in the sequence of processing elements.) Ex:- A block may be the data required to move the m/c table to a certain position & drill a hole at that location)

Signal output channels:- are connected to the servomotors and other controls in the m/c tool. Through these channels, the instructions are sent to the m/c tool from the controller unit.

Feedback channels:- To make certain that the ~~m/c tool from~~ instructions ~~are sent to the~~ have been properly executed by the m/c, feedback data are sent back to the controller via the feedback channels.

- The most important function of this return loop is to assure that the table and workpart have been properly located w.r.t the tool.

Sequence controls:- It coordinate the activities of the other elements of the controller unit.

- The tape reader is actuated to read data into the buffer from the tape, signals are sent to & from the m/c tool and so on. These types of operations must be synchronized and this is the function of the sequence controls.

Control panel:- Contains the dials and switches by which the m/c operator runs the NC system.

- It may also contain data displays to provide information to the operator.

- Although the NC system is an automatic system, the human operator is still needed to turn the m/c on and off, to change tools, to load & unload the m/c and to perform various other duties.

M/c tool or other controlled process

- The 3rd basic component of an NC system is the m/c tool or other controlled process.
- It is the part of the NC system which performs useful work.
- The m/c tool consists of the worktable and spindle, motors and controls necessary to drive them.
- It also includes cutting tools, work fixtures and other auxillary equipment needed in the machining operation.

The NC procedure :-

(1) Process planning :-

- It is concerned with the preparation of a route sheet. The route sheet is a listing of the sequence of operations which must be performed on the workpart.
- It also lists the machines through which the part must be routed in order to accomplish the sequence of operations.

(2) Part programming :-

- A part programmer plans the process for the portions of the job to be accomplished by NC.
- They plan the sequence of machining steps to be performed by NC.

There are two ways to program for NC:-

- Manual part programming
- Computer-assisted part programming

MPP:- the machining instructions are prepared on a form called a part program manuscript.
- The manuscript is a listing of the relative cutter/workpiece positions, which must be followed to m/c the part.

CAPP:- Tedious computational work required in manual part programming is transfered to the computer.
- This is especially appropriate for complex workpiece geometrics and jobs with many machining steps.
- Use of computer results in significant savings in part-programming time.

(3) Tape preparation:-
- In MPP, the punched tape is prepared directly from the part program manuscript on a typewriter like device, equipped with tape punching capability.

- In CAPP, the computer interprets the list of part programming instructions, performs the necessary calculations to convert this into a detailed set of m/c tool motion commands, & then controls a tape punch device to prepare the tape for the specific NC machine.

(4) Tape verification:-
- After the punched tape has been prepared, the accuracy of the tape is checked.
- Sometimes, the tape is checked by running it through a computer program which plots the various tool movements on paper.

- In this way, major errors in the tape is discovered

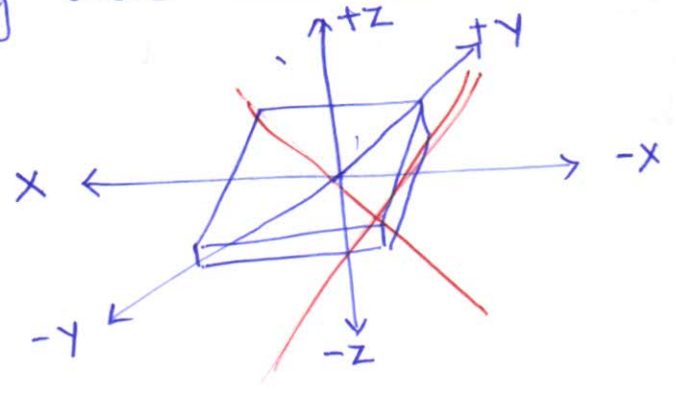
(5) Production

- The final step in the NC procedure is to use the NC tape in production.
- The m/c tool operator loads the raw workpart in the m/c and establish the starting position of the cutting tool relative to the W/P.
- The NC system then takes over and machines ~~m/cins~~ the part according to the instructions on tape.

When the part is completed, the operator removes it from the m/c.

NC COORDINATE SYSTEMS

- The purpose of the coordinate system is to provide a means of locating the tool in relation to the W/P.
- In order to plan the sequence of positions & movements of the cutting tool relative to the W/P, it is necessary to establish a standard axis system by which the relative positions can be specified.
- In NC m/c tool axis system for milling and drilling operations, two axes 'x' and 'y' are defined in the plane of the table. The 'Z' axis is ⊥ to this plane and the movement in the 'Z' dirⁿ is controlled by the vertical motion of the spindle.
- The +ve and -ve directions of motion of tool relative to table along these axes is shown in Figure.



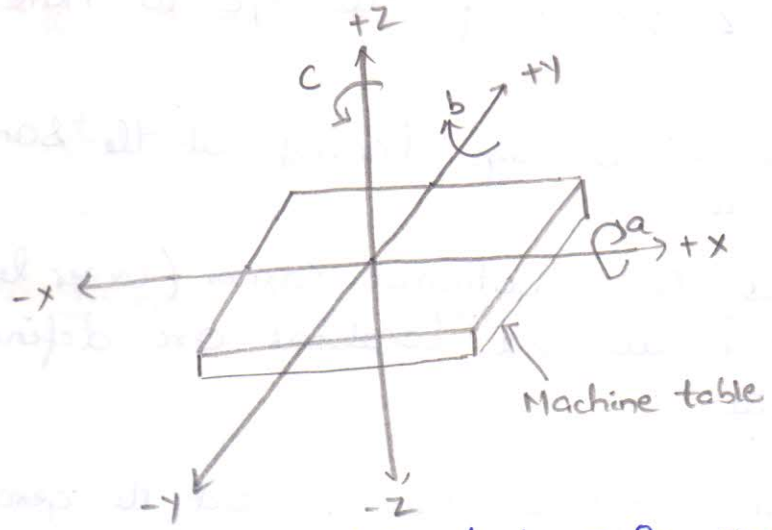
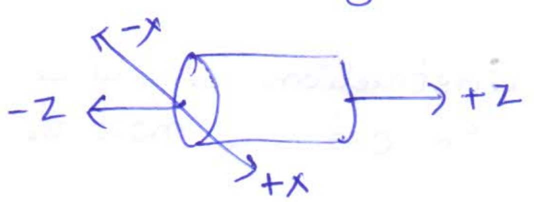


Fig. 1 NC machine tool axis system for milling & drilling operations.

- In addition to the 3 linear axes, these machines may possess the capacity to control one or more rotational axes.
- 3 rotational axes in NC: a, b, c axes. These axes specify angles about the x, y and z axes.
- 'Right-hand rule' is used to distinguish +ve from -ve angular motions.

(Using the right hand with the thumb pointing in the +ve linear axis dirn, the fingers of the hand are curled to point in the +ve rotational dirn)

- For turning operation, z-axis ~~are~~ is the axis of rotation of the workpart & x-axis defines the radial location of the cutting tool.



Fixed zero and Floating zero

Fixed zero:- ~~M/c~~ The programmer must determine the position of the tool relative to the origin (Zero point) of the coordinate system.

- The 1st possibility (Fixed Zero):- is for the m/c to have a fixed zero.
- In this case, the origin is always located at the same position on the m/c table.
- Usually, that position is the southwest corner (lower left-hand corner) of the table and all tool locations are defined by +ve 'x' and 'y' coordinates.

Floating zero :- allows the m/c operator to set the zero point at any position on the m/c table. This feature is called floating zero.

- depends on post programming convenience

Absolute positioning and Incremental positioning

ABSOLUTE POSITIONING:- The tool locations are always defined in relation to the zero point.

- If a hole is to be drilled at a spot (8" above x axis & 6" to the right of y axis, the coordinate location of the hole would be specified as $x = +6$, $y = +8$.

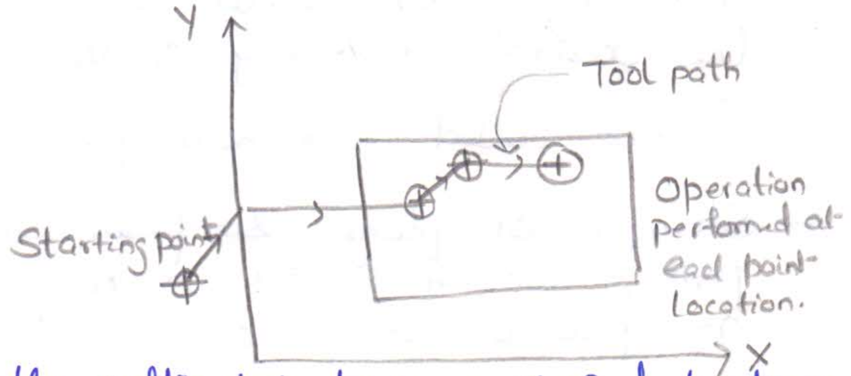
INCREMENTAL POSITIONING :- The next tool location must be defined w.r.t the previous tool location.

- If previous hole had been drilled at an absolute position of $x = +4$ and $y = +5$.
- Accordingly, the incremental position instructions would be specified as $x = +2$ and $y = +3$ in order to move the drill to the desired spot.

NC MOTION CONTROL SYSTEMS

- In order to do the machining process, the cutting tool and workpiece must be moved relative to each other.
- In NC, there are 3 basic types of motion control systems:

1) Point-to-point (PTP)
2) Straight cut
3) Contouring



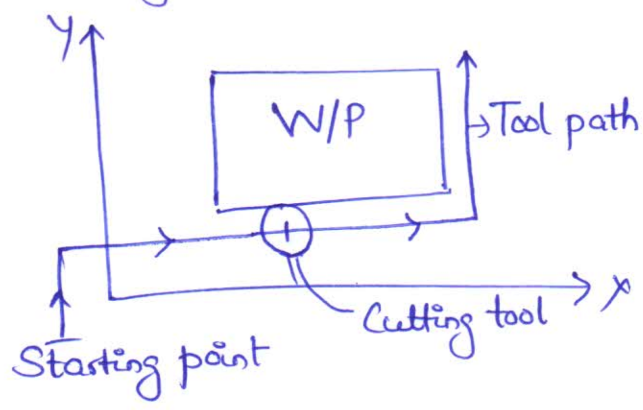
Point-to-point NC

- Also called 'Positioning System'.
- The objective is to move the cutting tool to a predefined location.
- The path or speed by this movement is done is not important in PTP.
- Once the tool reaches the desired location, the machining operation is performed at that position.

Ex:- NC drill press.

Straight-cut NC

- Straight-cut control systems are capable of moving the cutting tool parallel to one of the major axes at a controlled rate.
- It is appropriate for milling operations to fabricate workpieces of rectangular configurations.

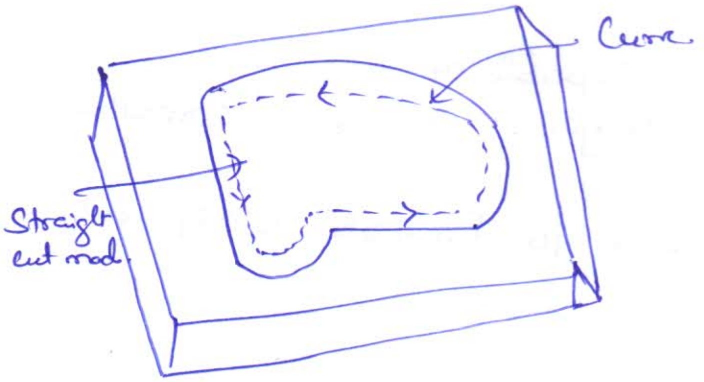


Contouring NC

- Contouring is the most complex, the most flexible and the most expensive type of m/c tool control.
- Capable of performing both PTP and Straight-cut Operations.
- Capable of controlling more than one axis movement of the m/c tool.
- The path of the cutter is continously controlled to generate the desired geometry of the workpiece.

(Thus called Continous-path NC System)

- Straight or plane surfaces at any orientation, circular paths, conical shapes or any mathematically definable form are possible under contouring control.
- In order to machine a curved path in NC contouring system, the dirn of the feed rate must continously be changed so as to follow the path.
- This is accomplished by breaking the curved path into very short straight-line segments that approximate the curve. Then the tool is commanded to machine each segment in succession.



Applications of NC :-

- Milling
- Drilling
- Turning
- Grinding
- Sawing
- Boring

Where NC should be used :-

(1) Parts are processed frequently and in small lot sizes.
(2) The part geometry is complex.
(3) Many operations must be performed on the part in its processing.
(4) Much metal needs to be removed.
(5) Engineering design changes are likely.
(6) Close tolerances must be held on the workpart.
(7) The parts require 100% inspection.
(8) It is an expensive part where mistakes in processing would be costly.

Advantages of NC

(1) Reduced non-productive time :- Fewer setups, less time in setting up, reduced workpiece handling time, automatic tool changes on some machines, etc.

(2) Reduced fixturing :-
NC requires fixtures which are simpler and less costly to fabricate. ~~because the positioning is done~~

(3) Greater manufacturing flexibility :-
With NC, it is easy to adapt to engg. design changes, alterations of the production schedule, etc.

(4) Improved quality control :-
NC produces parts with greater accuracy, reduced scrap, & lower inspection requirements.

(5) Reduced inventory :- Owing to fewer setups & shorter lead times, with NC, the amount of inventory is reduced.

(6) Reduced floor space requirements :-
Since one NC machining center can do the production of several conventional machines, the amount of floor space required is less than in a conventional shop.

DISADVANTAGES OF NC

(1) Higher Investment cost

(2) Higher maintenance cost

(3) Training NC personnel:- (Requires higher skills level than Conventional operations)

NC PART PROGRAMMING

NC part programming :- is the procedure by which the sequence of processing steps to be performed on the NC m/c is planned and documented.

- It involves the preparation of a punched tape to transmit the processing instructions to the machine tool.

Punched tape in NC

- The part program is converted into a sequence of m/c tool actions by ~~mean~~ input medium, which contains the program, and the controller unit, which interprets the input medium.
- The controller unit and the input medium must be compatible.

  (The input medium uses coded symbols which represent the part program and the controller unit must be capable of reading those symbols.)

- The most common input medium is punched tape. It is 1 inch wide.
- There are 2 basic methods of preparing the punched tape. The 1st method is associated with manual part programming and involves the use of type writer-like device.

  The operator types directly from the part programmer's hand written list of coded instructions.

  This produces a typed copy of the program as well as the punched tape.

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This produces a typed copy of the program as well as the punched tape.

- A binary digit is called 'bit'.
  It has a value of 0 or 1

bit ⟶ Character ⟶ Word ⟶ blocks ⟶ Complete NC instruction
(Combination of bits)
Letter/No./Symbol

- Typical NC words are x-position, y-position, cutting speed, & so on.

- block ⟶ X & Y coordinates of the hole location, speed & feed at which cut should be run.

- To separate blocks ⟶ 'EOB' (End-of-block) symbol is used.
  (Hole in column 8)

NC Words

(1) Coordinates (x-, y- & z words):- gives the coordinate positions of the tool.
- In 2-axis system, only 2 of the words can be used. In 4 or 5 axis system, additional a-words and/or b-words would specify the angular positions.

(2) Feed rate (f-word):- Specifies the feed in a machining operation. (inch/min)

(3) Cutting speed (s-word):- Specifies the cutting speed, the rate at which the spindle rotates.

(4) Miscellaneous func^n (m-word):- Ex m03 to start the spindle rotation.

Manual Part Programming (For simple jobs)

- To prepare a part program using the manual method, the programmer writes the machining instructions on a special form called a part programming manuscript.
- The instructions must be prepared in a very precise manner because the typist prepares the NC tape directly from the manuscript.
- The manuscript is a listing of the relative tool & W/P locations.
- It also includes other data such as preparatory commands, miscellaneous instructions, and speed/feed specifications.

Computer-assisted part programming

- Most parts machined on NC systems are complex. Thus, high speed digital computer is used in part programming process.
- 2 stages :- (1) The part programmer's job
  (2) The computer's job

The part programmer's job

- In computer-assisted part programming, the machining instructions are written in English statements of the NC programming language, which are then processed by the computer to prepare the tape.
- The computer automatically punches the tape in the proper tape format for the particular NC machine.

The part programmer's responsibility in computer-assisted part-programming consists of 2 basic steps:—

(1) Defining the work part geometry
(2) Specifying the operation sequence & tool path

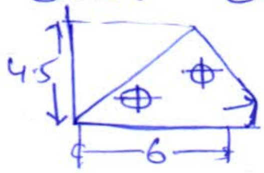
- Workpart geometry is composed of basic geometric elements such as points, straight lines, planes, circles, cylinders and other mathematically defined surfaces.

- Each geometric element must be identified & the dimensions & location of the element should be defined.

- After defining the work part geometry, the programmer must next construct the path that the cutter will follow to m/c the part.

- This tool path specification involves a detailed step-by-step sequence of cutter moves.

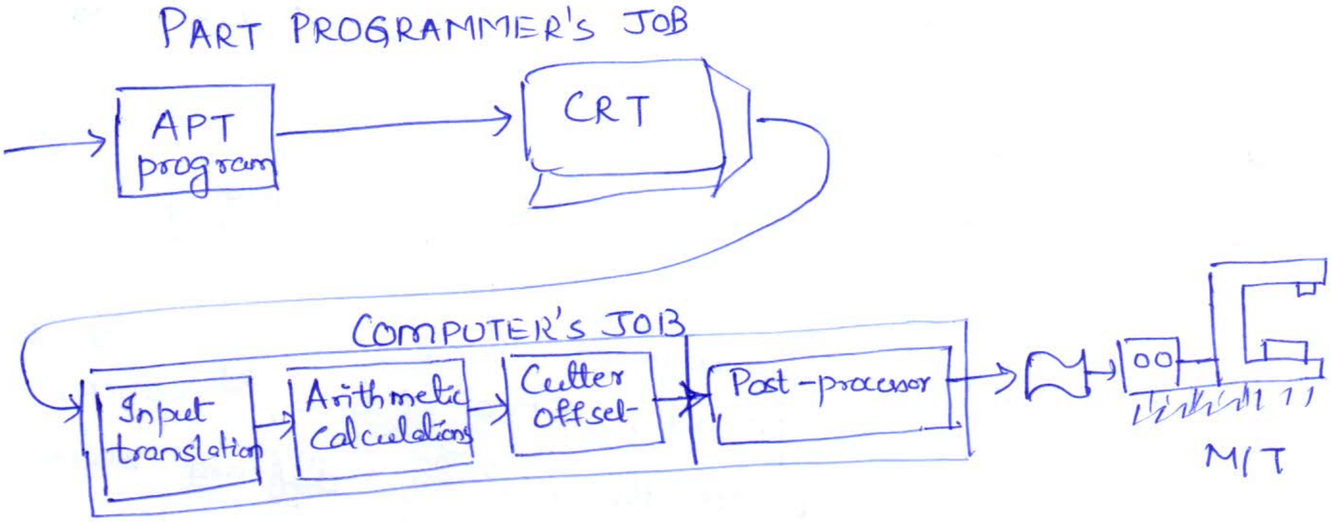
- The moves are made along the geometry elements, which have previously been defined.



The Computer's job

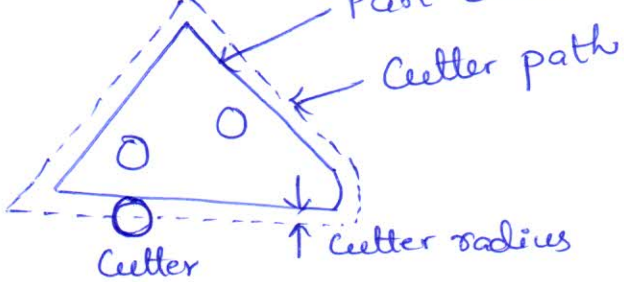
1) Input translation
2) Arithmetic calculations
3) Cutter offset computation
4) Post-processor

Part programmer's job



Steps in Computer-assisted part programming

- The part programmer enters the program written in the APT or other language.
- The input translation component converts the program into computer-usable form for further processing.
- The arithmetic calculations unit of the system consists of a comprehensive set of subroutines for solving the mathematics required to generate the part surface. These subroutines are called by the various part programming language statements.
  The arithmetic unit frees the programmer from the time-consuming geometry and trigonometry calculations to concentrate on the work part processing.



- Actual tool path is different from the part outline because the tool path is defined as the path taken by the center of the cutter.

- The purpose of the cutter offset computations is to offset the tool path from the desired part surface by the radius of the cutter.

- Post processor :-

* NC m/c tool systems are different, having different features and capabilities. They use different NC tape formats.

* All part programming languages including APT are designed to be general purpose languages (for all m/c tool types) The final task of the computer in computer-assisted part programming is to take the general instructions and make them specific to a particular m/c tool system. → done by post processor.

- The post processor is a separate computer program that has been written to prepare the punched tape for a specific m/c tool.

- The input to the post-processor is the output from the other three components : a series of cutter locations and other instructions.

- The output of the post processor is the NC tape written in the correct format for the m/c on which it is to be used.

NC part programming language

- Purpose is to make it convenient for a part programmer to communicate the necessary part geometry and tool motion information to the Computer so that the desired part program can be prepared.

- includes vocabulary words, conventions, special rules.

- Some of the NC languages are :-

(1) APT:{ Automatically Programmed Tools):-

(2) ADAPT:- Adaption of APT

(3) EXAPT:- Extended Subset of APT

Automatically Programmed Tools (APT)

- used for both positioning & Continuous-path programming up to 5 axes.

- It is not only an NC language, it is also the Computer program that performs the calculations to generate cutter positions based on APT statements.

- used to control a variety of different machining Operations.

There are four types of statements in the APT language :-

(1) Geometry statements :

- These define the geometric elements that comprise the workpart.
- They are also called 'definition statements'.

(2) Motion statements :-

These are used to describe the path taken by the cutting tool.

(3) Postprocessor statements :-

These apply to the specific m/c tool & control system. They are used to specify feeds & speeds and to actuate other features of the m/c.

(4) Auxiliary statements :-

These are miscellaneous statements used to identify the part, tool, tolerances & so on.

GEOMETRY STATEMENTS

- The general form of an APT geometry statement is

Symbol = geometry type/descriptive data

Ex:- P1 = POINT/5.0, 4.0, 0.0

- The statement is made up of three sections. The 1st section is the symbol used to identify the geometric element.
- Symbol (Combination of 6 or fewer alphabetic & numeric characters)

- atleast ~~one~~ of the 6, must be an alphabetic character.

- The 2nd Section of the geometry statement is an APT vocabulary word that identifies the type of geometry element.
  Besides POINT, other geometry elements in the APT vocabulary include LINE, PLANE & CIRCLE.

- The 3rd Section of the geometry statement comprises the descriptive data that define the element precisely, completely and uniquely.

- To specify a line, the easiest method is by two points through which the line passes :-

  L3 = LINE/P3, P4

- To define a new line parallel to another line which has previously been defined.

  L4 = LINE/P5, PARLEL, L3

  This states that line L4 must pass through point P5 and parallel to line L3.

- A plane is defined by specifying three points through which it passes

  PL1 = PLANE/P1, P4, P5

  Three points must not lie along a straight line.

- A plane can also be defined as being parallel to another plane.

  PL2 = PLANE/P2, PARLEL, PL1

  Plane PL2 is ||l to plane PL1 & passes through point P2.

- A circle may be specified by its center and radius.

C1 = CIRCLE / CENTER, P1, RADIUS, 5.0

There are several ground rules that must be followed in formulating an APT geometry statement.

(1) The coordinate data must be specified in the order of x, y & z.

Ex: P1 = POINT/5.0, 4.0, 0.0

x = 5.0, y = 4.0, z = 0.0

(2) Any symbols used as descriptive data must have been previously defined.

P2 = POINT/INTOF, L1, L2

the two lines L1 and L2 must have been previously defined.

(3) A symbol can be used to define only one geometry element. The same symbol cannot be used to define two different elements.

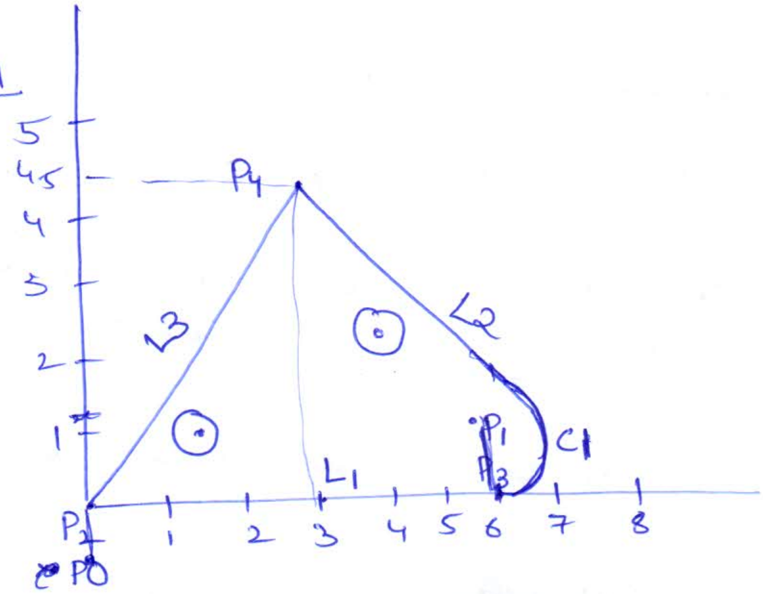
Ex: P1 = POINT/1.0, 1.0, 1.0
P1 = POINT/2.0, 3.0, 4.0

(4) Only one symbol can be used to define any given element.

Ex: P1 = POINT/1.0, 1.0, 1.0
P2 = POINT/1.0, 1.0, 1.0

(5) Lines defined in APT are considered to be of infinite length in both directions.
Similarly, planes extend indefinitely and circles defined in APT are complete circles.

Ex.1



P0 = POINT/0, -1.0, 0

P1 = POINT/6.0, 1.125, 0

P2 = POINT/0.0, 0.0, 0.0

P3 = POINT/6.0, 0, 0

P4 = POINT/3.0, 4.5, 0

L1 = LINE/P2, P3

~~L2 =~~

C1 = CIRCLE/CENTER, P1, RADIUS, 1.125

L2 = LINE/ P4, TANTO, C1

L3 = LINE/P2, P4

PL1 = PLANE/P2, P3, P4

MOTION STATEMENTS

The general form of a motion statement is

motion command/descriptive data

Ex:- GOTO/P1

1st section (motion command) which tells the tool what to do

2nd section (Descriptive data, which tell the tool where to go)

- The tool is commanded to go to point P1, which has been defined in a preceding geometry statement.

- At the begining of the motion statements, the tool must be given a starting point, called as Target point, the location where the operator has positioned the tool at the start of the job.

FROM/TARG

Ex:- FROM/-2.0, -2.0, 0.0

GOTO/P2
GOTO/2.0,7.0,0.0

- In the 1st statement, P2 is the destination of the tool point.
  In the 2nd " , tool is instructed to go to x=2, y=7, z=0

- GODLTA Command → Specifies an incremental move for the tool.

Ex:- GODLTA/2.0, 7.0, 0.0

GODLTA Command → Useful for drilling.

Ex:-
P1 = POINT/1.0, 2.0, 0
P2 = POINT/1.0, 1.0, 0
P3 = POINT/3.5, 1.5, 0
P0 = POINT/-1.0, 3.0, 2.0
FROM/P0
GOTO/P1
GODLTA/0, 0, -1.0
GODLTA/0, 0, +1.0
GOTO/P2
GODLTA/0, 0, -1.0
GODLTA/0, 0, +1.0
GOTO/P3
GODLTA/0, 0, -1.0
GODLTA/0, 0, +1.0
GOTO/P0

Contouring motions :- Tool's position must be continously Controlled throughout the move.

- To accomplish this control, the tool is directed along two intersecting surfaces.

(1) Drive Surface :-

This is the surface that guides the side of the cutter.

(2) Part surface :-

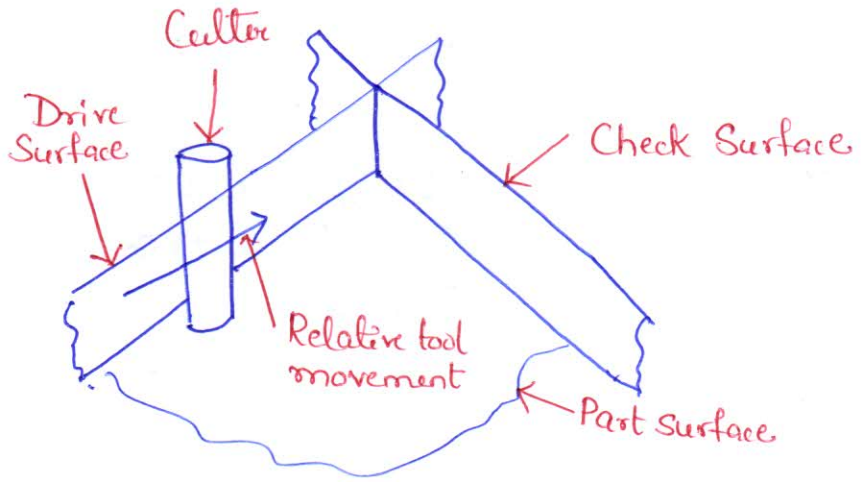
- This is the surface on which the bottom of the cutter rides.

One additional surface in APT

(3) Check Surface :-

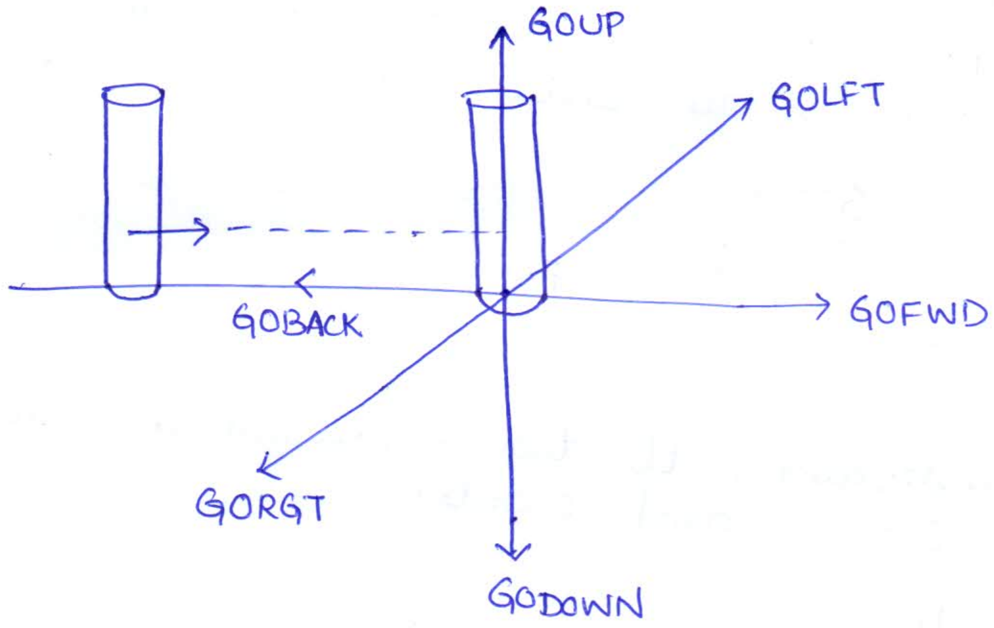
- This is the surface that stops the movement of the tool in its current direction.

- (Checks the forward movement of the tool)

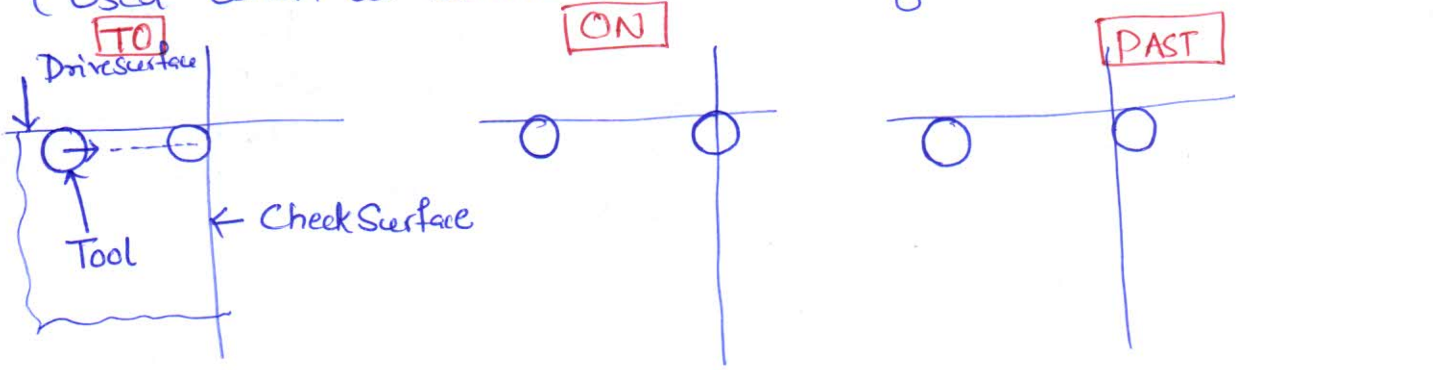


- The APT Contour motion statement commands the cutter to move along the drive surface & part surface.
- The movement ends when the tool is at the check Surface.
- There are 6 motion command words:

GOLFT GOFWD GOUP
GORGT GOBACK GODOWN



- There are several ways in which the check surface can be used.
  * The 3 main modifier words are TO, ON & PAST & their use with regard to the check surface.
  * Another modifier word is TANTO (Used when the drive surface is tangent to circular checksurface



- To begin the sequence of motion commands, 'FROM' Statement is used.

FROM / TARG

① GO/TO, PL1, TO, PL2, TO, PL3

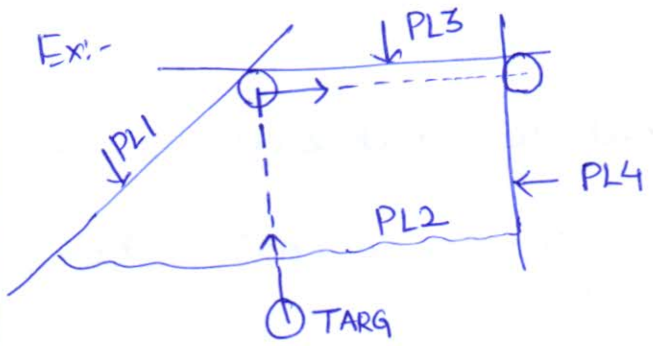
- The Symbol 'TARG' represents the target point where the operator has set up the tool.
- 'GO' command instructs the tool to move to the intersection of the drive surface (PL1), the part surface (PL2) and the check surface (PL3).
- The periphery of the cutter is tangent to PL1 & PL3 and bottom of the cutter is touching PL2.

GO/ TO → used to initialize the sequence of contouring motions

GOTO → For PTP motions.

- After initialization, the tool is directed along its path by one of the 6 command words.

Ex:-



② GORGT/PL3, PAST, PL4

- Tool is directed to move along PL3, using it as the drive surface.
- The tool would continue until past surface PL4, which is the new check surface.
- The part surface (PL2) remain same throughout the motion sequence, the drive surface & check surface are redefined in each new command.

GORGT/L3, PAST, L4

- The lines L3 & L4 have been substituted for planes PL3 & PL4. The sides of the part appear as lines. So, in APT, it is more convenient for the part programmer to define these surfaces as lines & circles rather than planes & cylinders.

Ex:-1

```
FROM/PO
GO/TO, L1, TO,PL1, TO, L3
GORGT/L1, TANTO,C1
GOFWD/C1, PAST, L2
GOFWD/L2, PAST, L3
GOFWD/L3, PAST, L1
GOTO/PO
```

GOTO / Point to point command.
GO/TO → initiate the sequence of contouring motion
PAST, Surface → drive surface.

PL1 → part surface is defined below the bottom plane of the W/P so that the cutter machines the entire thickness of the W/P.

POSTPROCESSOR Statements

- To write a complete part program, statements must be written that control the operation of the spindle, the feed and other features of the m/c tool. These are called postprocessor statements.

Ex:-

COOLNT/	RAPID
END	SPINDL/
MACHIN/	TURRET/

- The statements without slash are self-contained. No additional data needed.
- With slash → requires descriptive data after the slash.

Auxilliary statements

- The complete APT program must also contain various other statements, called auxilliary statements.
- These are used for cutter size definition, part identification, etc.
  e.g.

  CUTTER/0.5 (i.e cutter diameter is 0.5 inch)

NC programming with interactive graphics

- The use of interactive graphics in NC part programming is the integration of computer-aided design & computer-aided manufacturing.
- The programming procedure is carried out on the graphics terminal of a CAD/CAM System.
- Using the same geometric data, which defined the part during the ~~computer~~ CAD process, the programmer constructs the tool path using high level commands to the system.
- In many cases, the tool path is automatically generated by the software of the CAD/CAM system.
- The output resulting from the procedure is a listing of the APT program, which can be post processed to generate the NC punched tape.

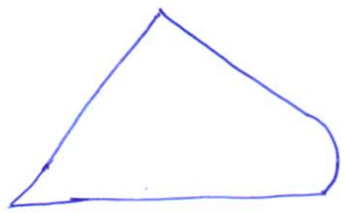
(1) Geometric definition of the part & geometric model creation on graphics terminal

(2) Tool Selection

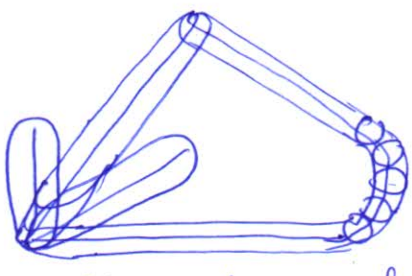
The CAD/CAM System has a tool Library with various tools used in the Shop Catalogued according to the type.

(3) Create the Cutter path, using interactive graphics
It depends on type of Operation (milling, turning, sheet metal) & Complexity of the part.

- Interactive approach permits the programmer to generate the tool path in a step-by-step manner with visual verification on the graphics display.
- The procedure begins by defining a starting position for the cutter.
- The programmer then commands the tool to move along the defined geometric surfaces of the part.
- As the tool is moved on the CRT Screen, the corresponding APT motion commands are automatically prepared by the CAD/CAM System.
- The interactive mode provides the user with the opportunity to insert post processor statements at appropriate points during program creation.
- (includes Feed rates, Speeds & control of the cutting fluid)



Workpart



Cutter path generated automatically

Manual data Input (MDI)

- It involves the entry of part programming data through a CRT display at the m/c site. Hence, the use of punched tape is avoided.

- The programming process is usually carried out by the m/c operator.

- NC systems equipped with MDI capability posses a Computer as the control unit.

- MDI units use shop language rather than alphanumeric Codes.

- The great advantage of MDI is its simplicity.
- Limitation:- Programs are relatively short and Simple

MODULE IV

Computer Controls in NC (3 types)

1. Computer numerical control (CNC)
2. Direct numerical control (DNC)
3. Adaptive control

- CNC involves the replacement of the conventional hard-wired NC controller unit by a small computer (micro-computer).
- The micro-computer performs some or all of the basic NC functions by programs stored in its read/write memory.
- 1 computer is used to control 1 m/c tool.

(DNC uses a larger computer to control a no. of separate NC m/c tools.)

Adaptive control:- doesnot require a digital computer for implementation.

- Control system that measures one or more process variables (cutting force, temp, horsepower, etc) & manipulates feed or speed.
- Objective is to optimize the machining process,

Problems with Conventional NC

1. Part programming mistakes

In preparing the punched tape, part programming mistakes are common.

② Non-optimal speeds and feeds

- In conventional NC, the control system doesnot provide the opportunity to make changes in speeds and feeds during the cutting process.

③ Punched tape :-

- Paper tape is especially fragile & susceptable to wear & tear causes it to be unreliable NC component for repeated use in the shop.
- More durable tape materials, such as Mylar are utilized to help overcome this difficulty. However, these materials are relatively expensive.

④ Tape reader :-

The tape-reader that interprets the punched tape is considered as least reliable hardware component of the m/c.

⑤ Controllers :-

- The conventional NC controller unit is hard wired. This means that its control features cannot be easily altered to incorporate improvement into the unit.

⑥ - The use of a computer as the control device would provide the flexibility to make improvements ~~in the~~

⑥ NC Controller technology

- The hardware technology in NC controls has changed over the years.
- Atleast 7 generations of controller hardware can be identified :-

(1) Vacuum tubes (Circa 1952)
(2) Electromechanical relays (Circa 1955)
(3) Discrete semi-conductors (Circa, 1960)
(4) Integrated circuits (Circa 1965)
(5) Direct numerical Control (Circa, 1968)
(6) Computer numerical control (Circa, 1970)
(7) Micro-processors & micro-computers (Circa, 1975)

- Vacuum tubes:- These components were so large that the control unit consumed more space than the m/c tool.

- Electromechanical relays:- These were substituted for vacuum tubes. The problem with these relay-based controls was their large size and poor reliability. The relays were susceptible to wear.

- The use of transistors based on discrete semiconductor technology formed the next generation of NC Controllers. The use of transistors helped to reduce the no. of electromechanical relays required.

- Size & reliability still remained as problems with NC controls which used discrete semi-conductors. The electronics were sensitive to heat, & fans or ACs were required in the cabinets to operate under factory condition. Thus, integrated circuits were introduced for use in NC controls. This type of electronic hardware brought significant improvements in size & reliability.

- The next development in NC control marked the introduction of digital computers in NC Controller technology. All of the previous controls were made up of hard-wired components. The functions that were performed by these control systems could not be easily changed due to the fixed nature of the hard-wired design.

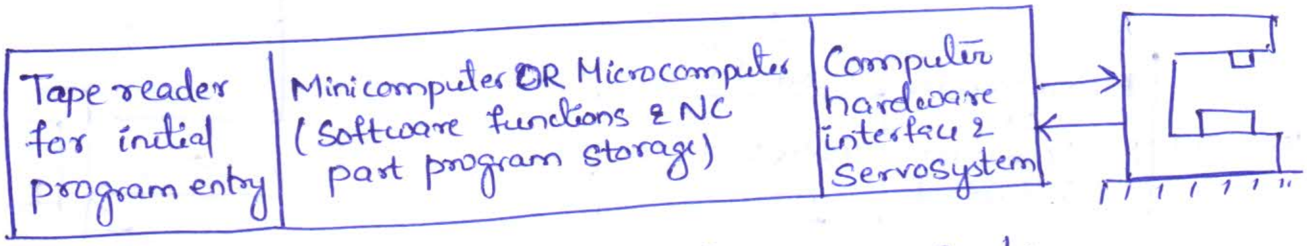
- DNC was the 1st computer control systems to be introduced in 1968. Computers were quite large & expensive. The advantage of DNC was it established a direct control link betn the computer & the m/c tool, hence eliminating the necessity for using punched tape input.

  (The tape & tape reader most unreliable components in Conventional NC systems)

- Demand for smaller & less expensive computers, ~~led~~ to apply a single small computer to one m/c tool, led to the development of CNC. CNC systems ~~They~~ applied the soft-wired controller approach.

Computer Numerical Control

- CNC is an NC system that utilizes a ~~d~~ stored program computer to perform some or all of the basic numerical control functions.
- Because of the trend toward downsizing in computers, most of the CNC systems use a micro-computer based controller unit.
- Punched tape readers are still the common device to input the part program into the system. With Conventional NC, the punched tape is cycled through the reader for every workpiece in the batch. With CNC, the program is entered once & then stored in the computer memory. Thus, the tape reader is used only for the original loading of the part program and data.
- CNC offers additional flexibility & computational capability.



General Configuration of CNC System

Functions of CNC

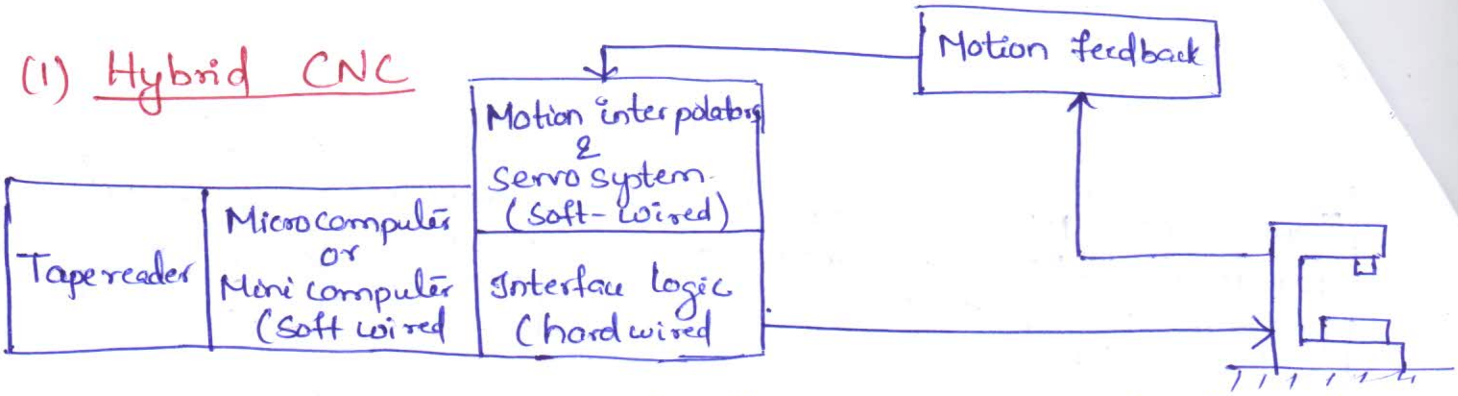
(1) M/c tool control
(2) In-process compensation
(3) Improved programming & operating features
(4) Diagnostics

M/c tool control :-

- The primary function of the CNC System is control of the m/c tool. It involves conversion of the part program instructions into m/c tool motions through the computer interface and servosystem.
- Main advantage of CNC :- to conveniently incorporate a variety of control features into the soft-wired controller unit.
- Some of the control functions (such as circular interpolation) can be done more efficiently with hard-wired circuits than with the computer.
- This led to development of two alternative controller designs in CNC:

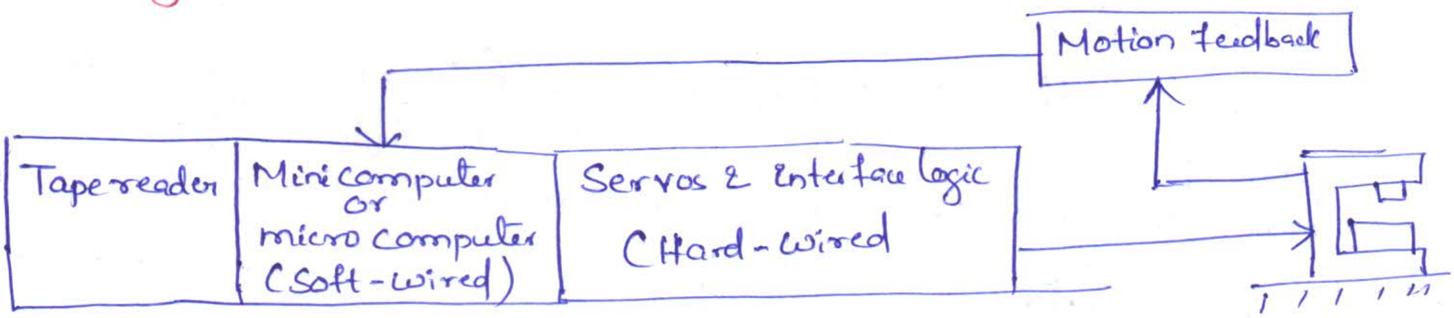
  (1) Hybrid CNC
  (2) Straight CNC

(1) Hybrid CNC



- The controller consists of the soft-wired & hard-wired logic circuits.
- The hard-wired components perform ~~those~~ perform those functions, which they do best (feed rate generation, circular interpolation).
- The computer performs the remaining control functions and other duties, not normally associated with a conventional hard-wired controller.
- Certain NC functions can be performed more efficiently with the hard-wired circuits. Therefore, the circuits that perform these functions can be produced in large quantities at relatively low cost. Hence, a less expensive computer is required in the hybrid CNC controller.

Straight CNC :-



- The Straight CNC system uses a computer to perform all the NC functions.
The only hard-wired elements are those required to interface the computer with the m/c tool & operator's console.
- Interpolation, tool position feedback and all other functions are performed by computer software.

- The advantage gained in straight CNC is additional flexibility.

IN-PROCESS COMPENSATION

- A funⁿ closely related to m/c tool control is in-process compensation.

Ex.- - Adaptive control adjustments to speed / feed.
- Adjustment for errors sensed by in-process inspection probes & gauges.

IMPROVED PROGRAMMING AND OPERATING FEATURES

- The flexibility of soft-wired control has led to many convenient programming & operating features, such as:

(1) Editing the part programs at the m/c.
(2) Manual data input (MDI).
(3) Local storage of more than one part program.
(4) Graphic display of tool path.

DIAGNOSTICS

- NC m/c tools are complex & expensive systems. The complexity increases the risk of component failures which lead to system downtime.
- CNC machines are equipped with a diagnostics capability to assist in maintaining & repairing the system.

Advantages of CNC

(1) The part program tape & tape reader (Freyel) are used only once to enter the program into computer memory.

(2) Tape editing at the m/c site:-
(change of tool path, speeds & feeds) at the site of m/c tool.

(3) Metric conversion:- CNC can accomodate conversion of tapes prepared in units of inches into the International System of units.

(4) Greater flexibility:-
provides opportunity to introduce new control options with relative ease at low cost.

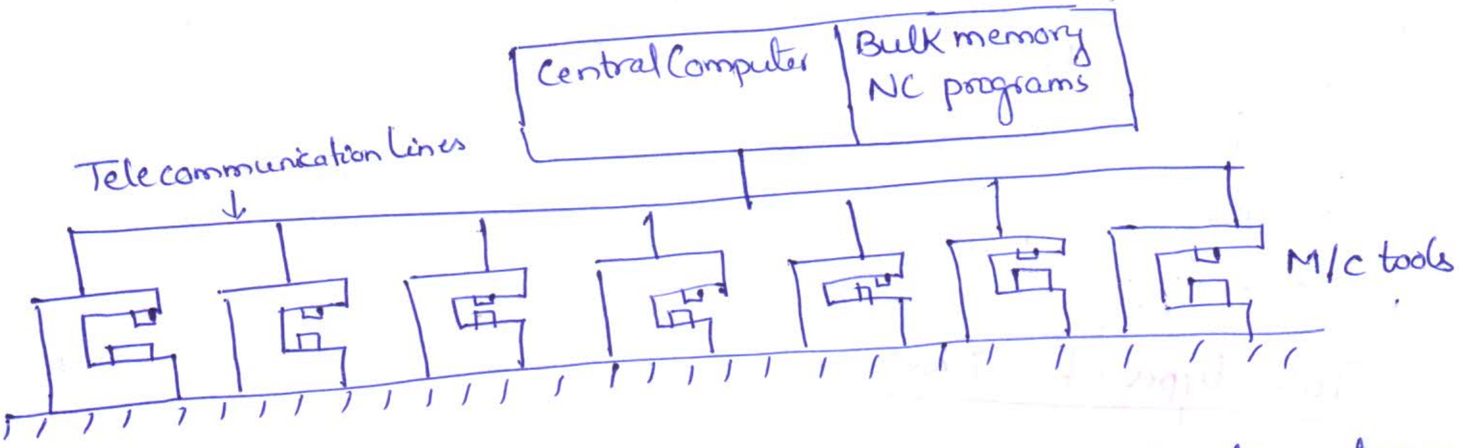
(5)

Direct Numerical Control

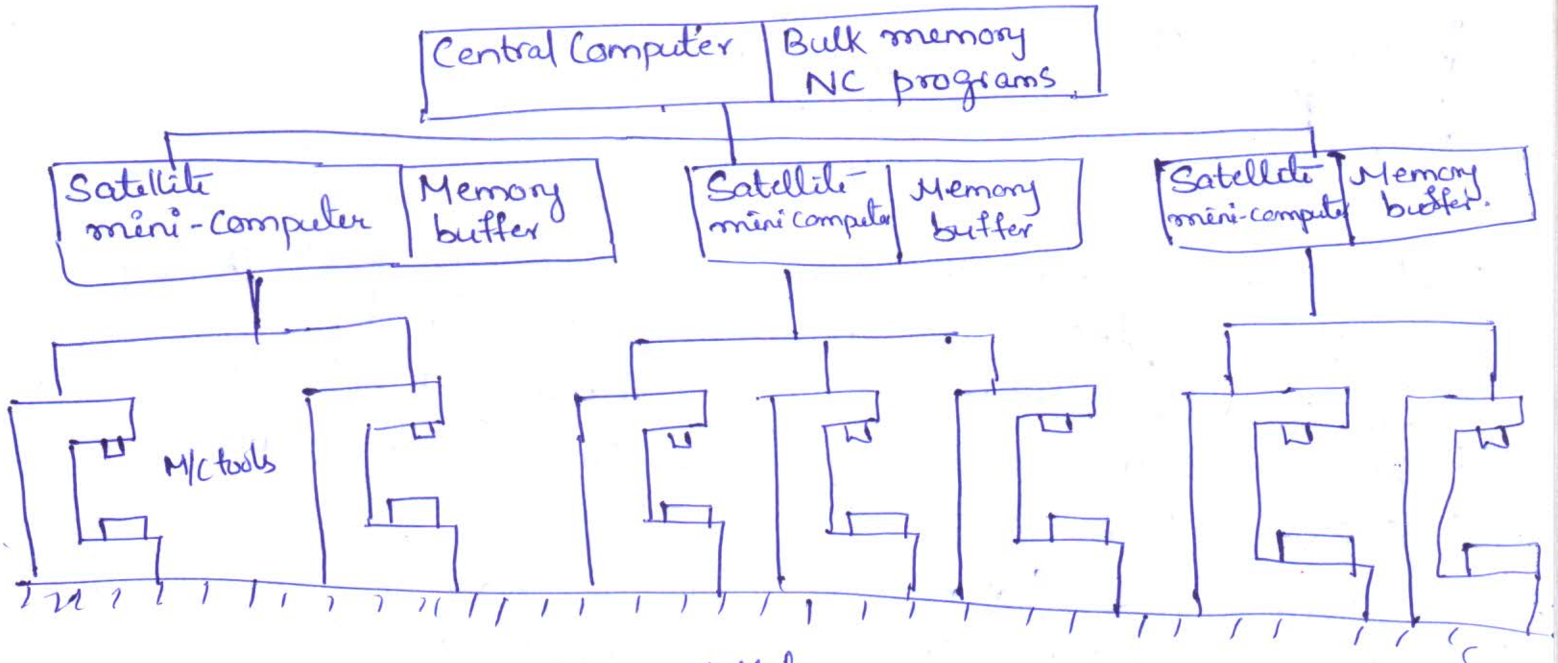
- Manufacturing system in which a no. of machines are controlled by a computer through direct connection & in real time.
- The tape reader is omitted in DNC, thus relieving the system of its least reliable component.
- The part program is transmitted to the m/c tool directly from the computer memory.
- The DNC computer is designed to provide instructions to each m/c tool on demand. DNC also involves data collection & processing from the m/c tool back to the computer.

Components of a DNC System

(1) Central Computer
(2) Bulk memory, which stores the NC part programs
(3) Telecommunication Lines
(4) Machine tools



- The computer calls the part program instructions from bulk storage and sends them to the individual machines as the need arises. It also receives data back from the machines.
- Similarly, the computer must always be ready to receive information from the machines and to respond accordingly.



DNC with satellite mini-computers.

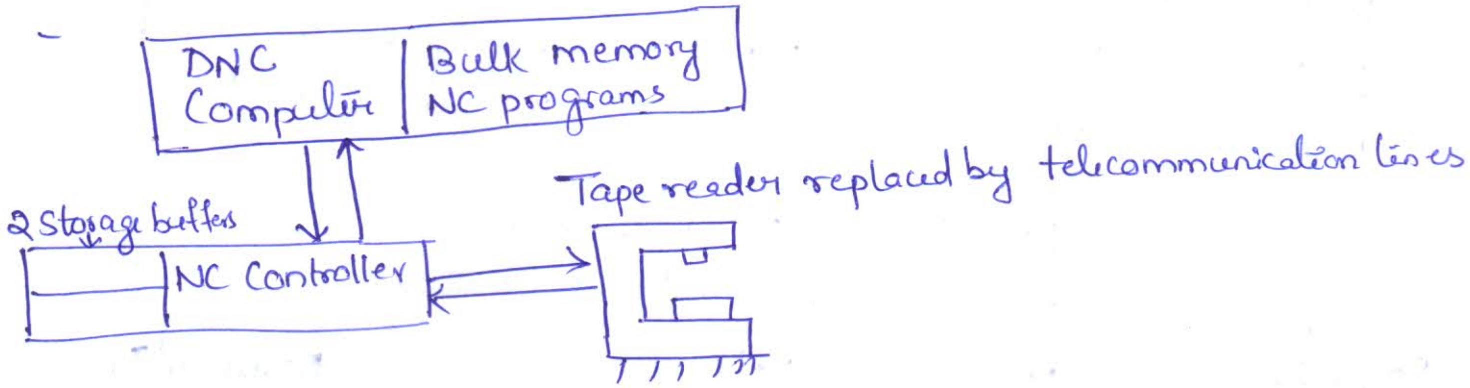
- Sometimes, it is necessary to use satellite computers. These satellites are mini computers and they take some of the burden off the central computer.
- Each satellite controls several machines. Groups of part program instructions are received from the Central Computer and stored in buffers. They are then dispensed to the individual machines as required.
- Feedback data from the machines are also stored in the satellite's buffer before being collected at the central computer.

Two types of DNC

(1) BEHIND-THE-TAPE-READER (BTR) system

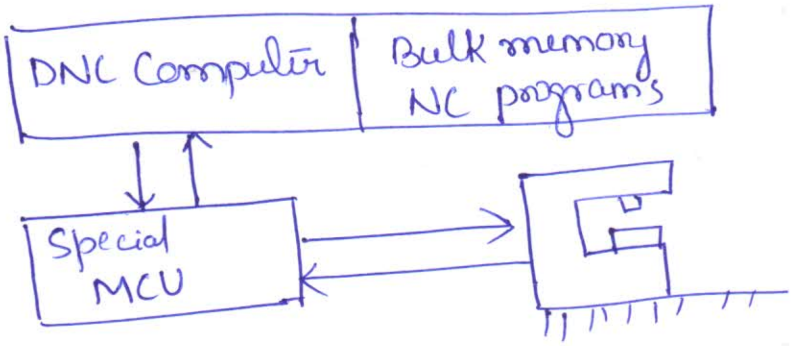
(2) SPECIALIZED MACHINE CONTROL UNIT

(1) BTR System:-



- The connection with the computer is made betⁿ the tape reader and the controller unit - behind the tape reader.
- The controller unit uses two temporary buffers to receive blocks of instructions from the DNC computer and convert them into m/c actions.
- While one buffer is receiving a block of data, the other is providing control instructions to the m/c tool.

2) Special m/c. control unit



DNC with special MCU

- The other strategy in DNC is to eliminate the regular NC controller and replace it with a special MCU.
- This special MCU is a device that is specifically designed to facilitate communication betn the m/c tool and the computer.
- The special MCU configuration acheives a superior balance betn accuracy of the interpolation and fast metal removal rates than is generally possible with the BTR system.
- The special MCU is soft-wired, while the conventional NC controller is hard-wired.
  The advantage of soft-wiring is its flexibility. Its control functions can be altered with relative ease to make improvements. It is much more difficult to make changes in the regular NC controller because rewiring is required.
- BTR Cost is less, since only minor changes are needed in the conventional NC system to bring DNC into the Shop.
- BTR Systems donot require the replacement of the Conventional Control unit by a Special MCU.

Functions of DNC

(1) NC without punched tape
(2) NC part program Storage
(3) Data collection, processing & reporting
(4) Communications

NC without punched tape :-

- Several of the problems with conventional NC are related to the use of punched tape (unreliable tape reader, paper tape, difficulties in making corrections & changes in the program contained on punched tape, etc)
- There is also the expense associated with the equipment that produces the punched tape.

(So it is eliminated)

(2) NC part program storage :-

- A second important fun^n of the DNC system is concerned with storing the part programs.
- First, the programs must be available for downloading to the NC m/c tools.
- Second, the subsystem must allow for new programs to be entered, old programs to be deleted and existing programs to be edited as the need arises.
- Third, DNC software must accomplish the post processing function.
- Fourth, the storage subsystem must be structured to perform data processing & management functions such as file security, display of programs, manipulation of data, etc.

DNC program storage subsystem consists of an active storage & a secondary storage.

- Active storage (Disc) used to store NC programs which are frequently used. The active storage can be readily accessed by the DNC computer to drive an NC m/c in production.

- Secondary storage could be used for NC programs which are not frequently used.
  Ex:- Magnetic tape, floppy disks, punched tape.

3) Data Collection, processing & reporting

- DNC involves the transfer of data from the m/c tools back to the central computer. DNC involves a two-way transfer of data.

- The basic purpose is to monitor production.

4) Communications :-

- A communications network is required to accomplish the previous 3 functions of DNC.

- Communication among the various subsystem is a funⁿ that is central to the operation of any DNC system.

- The essential communication links in DNC are betⁿ the following components of the system.
  Central computer & m/c tools
  Central computer & NC part programmer terminals
  Central computer & bulk memory, which stores the NC programs.

Advantages of DNC

(1) Elimination of punched tapes & tape readers :-
DNC eliminates the punched tapes & tape readers. In some DNC systems, hard-wired control unit is also eliminated, and replaced by a special m/c control unit (designed to be more compatible with DNC operation.

(2) Greater computational capability & flexibility :-
- The DNC system performs the computational & data processing functions more effectively than traditional NC.
- Because these functions are implemented with software rather than hard-wired devices, there exists the flexibility to alter and improve the method.

(3) Convenient storage of NC part programs in computer files :- (punched tapes used in conventional NC)

(4) Reporting of shop performance :-
It collects, processes and reports about the production performance data from the NC machines.

(5) Establishes the framework for the evolution of future computer - automated factory.

Combined DNC/CNC Systems

- The combination of DNC & CNC provides the opportunity to add new capabilities & refine existing capabilities in these computerized manufacturing systems.
- The combination of CNC & DNC $\rightarrow$ resulted in elimination of the use of punched tape as the input media for CNC machines.

The DNC computer downloads the program directly to the CNC computer memory.

- The second advantage of combining CNC & DNC is redundancy. If the central DNC computer fails, this will not necessarily cause the individual machines in the system to be down. It is possible to provide the necessary backup to permit the CNC machines to operate on a stand-alone basis.

  * This backup capability consists of two elements. The first is a file of punched tapes which duplicate the programs contained in the DNC computer files.
  * The second is that each CNC m/c must be equipped with a tape reader for the purpose of entering the program from the punched tape.

- The third improvement that develops from combined DNC/CNC systems is improved communication betn the central computer and the shop floor.
  It is easier for computers to communicate with other computers than with hard-wired devices.

Adaptive Control Machining Systems

- For a machining operation, the term 'adaptive control' denotes a control system that measures certain output process variables and uses these to control speed / feed.
- Some of the process variables that have been used in adaptive control machining systems include spindle deflection or force, torque, cutting temp, vibration amplitude.

Where to use adaptive control

- NC (both DNC & CNC) reduces the non-productive time in a machining operation. This time savings is acheived by reducing such elements as workpiece handling time, tool changes, etc.
- Although NC has a significant effect on downtime, it can do very less to reduce the in-process time. The in-process time can be reduced by the use of adaptive control.
- The NC guides the sequence of tool positions or the path of the tool during machining. The adaptive control determines the proper speeds/feeds during machining as a fun^n of variations in such factors as work-material hardness, width/depth of cut, air gaps in the part geometry & so on.

Situations where AC is beneficially applied

(1) There are significant sources of variability in the job for which adaptive control can compensate. AC adapts feed/speed to these variable conditions.

(2) The typical jobs are ones involving steel, titanium, and high strength alloys.

(3) The cost of operating the m/c tool is high. The high operational cost results mainly from the high investment in equipment.

Sources of variability in machining

The greater the variability, the more suitable the process will be for using adaptive control.

(1) Variable geometry of cut in the form of changing depth/ width of cut :-

In these cases, feed rate is usually adjusted to compensate for the variability.
This type of variability is encountered in profile milling or contouring operations.

(2) Variable workpiece hardness and variable machinability :-

when hard spots or other areas of difficulty are encountered in the W/P, either speed or feed is reduced to avoid premature failure of the tool.

(3) Variable workpiece rigidity :-

If the workpiece deflects as a result of insufficient rigidity in the set up, the feed rate must be reduced to maintain accuracy in the process.

(4) Tool wear :-

It has been observed as the tool begins to dull, the cutting forces increase. The adaptive controller will respond to tool dulling by reducing the feed rate.

(5) Air gaps during cutting :-

- The W/P geometry may contain shaped sections where no machining needs to be performed.
- If the tool were to continue feeding through these air-gaps

at the same rate, time would be lost.
So feed rate is increased by 2 or 3 times, when air gaps are encountered.

Two types of adaptive control

(1) Adaptive control optimization (ACO)
(2) Adaptive Control Constraint (ACC)

Adaptive control optimization (ACO)

- In this form of AC, a performance index is Specified for the system.
- This performance index (PI) is a measure of overall process performance such as prodn rate or Cost/vol of metal removed.
- The objective of Adaptive Controller is to optimize the performance index by manipulating speed/feed in the operation.
- Most ACO Systems attemp to maximize the ratio of material removal rate to tool wear rate.

$$PI = \text{a fun}^n \text{ of } \frac{MRR}{TWR}$$

where, MRR → Material removal rate
TWR → Tool wear rate

- The trouble with 'PI' is TWR cannot be measured on-line with today's measurement technology. Hence, IP cannot be monitored during the process.
- Eventually, sensors will be developed to a level at

which the true process can be measured on-line.

- However, because of the sensor problems encountered in the design of ACO systems, nearly all adaptive control machining is of the 2nd type, adaptive control constraint systems.

Adaptive Control Constraint :- (ACC)

- The production AC systems utilize constraint limits imposed on certain measured process variables.
- Accordingly, these are called adaptive control constraint (ACC) systems.
- The objective in these systems is to manipulate feed/speed so that these measured process variables are maintained at or below their constraint limit values.

Operation of an ACC System

- Adaptive controller (AC) are attached to an NC m/c tool.

Because (1) NC m/c tools possess the required servomotors on the table axes to accept automatic control.

(2) The usual kinds of machining jobs for which NC is used posses the sources of variability that makes AC feasible.

- The adaptive control package consists of a combination of hardware & software components.

The typical hardware components are :-

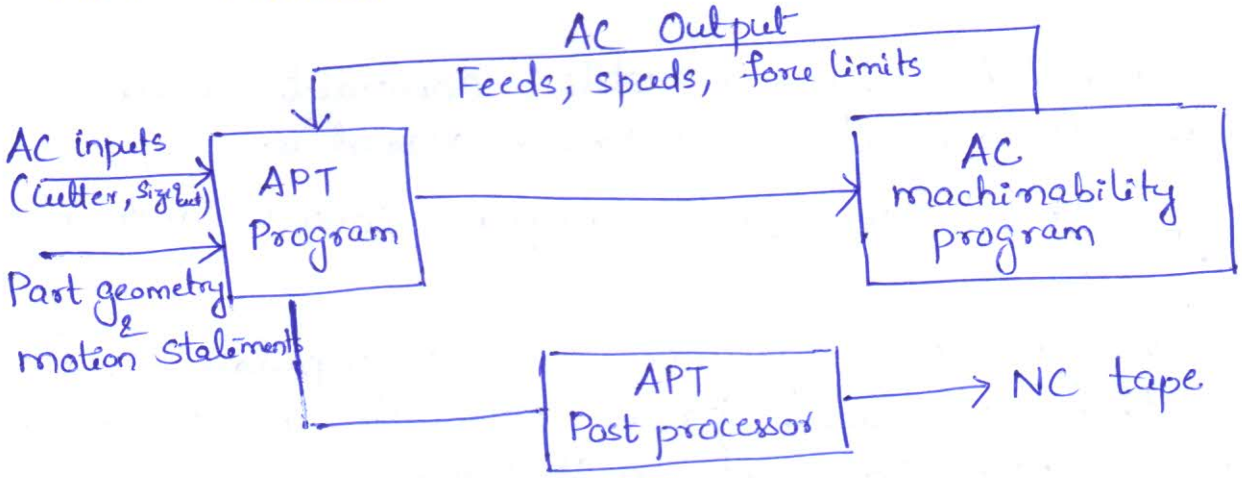
(1) Sensors mounted on the spindle to measure cutter deflection (force).

(2) Sensors to measure spindle motor current. This is used to provide an indication of power consumption.

(3) Control unit & display panel to operate the sys

(4) Interface hardware to connect the AC system to the existing NC or CNC control unit.

- The software in the AC package consists of a machinability program which can be called as an APT MACRO statement.



Relationship of AC Software to APT program

- The inputs to the APT program are:- cutter size & geometry, work material hardness, size of cut and m/c tool characteristics.

- From calculations based on these parameters, the outputs from the program are feed rates, spindle speeds & cutter force limits for each section of the cut.

- The objective in these computations is to determine cutting conditions which will maximize metal removal rates. The NC part programmer have to specify feeds & speeds for the machining job.

- With adaptive control, these conditions are computed by the machinability program based on the input data supplied by the part programmer.

- In machining, the AC system operates at the force value calculated for the particular cutter & m/c tool spindle.

- Maximum production rates are obtained by running the m/c at the highest feed rate consistent with this force level.

- Since force is dependent on factors such as depth of cut, width of cut, the end result of the control action is to maximize metal removal rates within the limitations imposed by existing cutting conditions.

Benefits of Adaptive Control machining

(1) Increased production rates:-

Productivity improvement was the motivating force behind the development of adpative control machining. On-line adjustments to allow for variations in work geometry, material and tool wear provide the m/c with the capability to

COMPUTER-INTEGRATED MANUFACTURING SYSTEMS

CIM:- It is the integration of the total manufacturing enterprise through the use of integrated systems and data communications coupled with new managerial philosophies that improve organisational and personal efficiency.

- CIM basically involves the integration of all the functions of an enterprise.

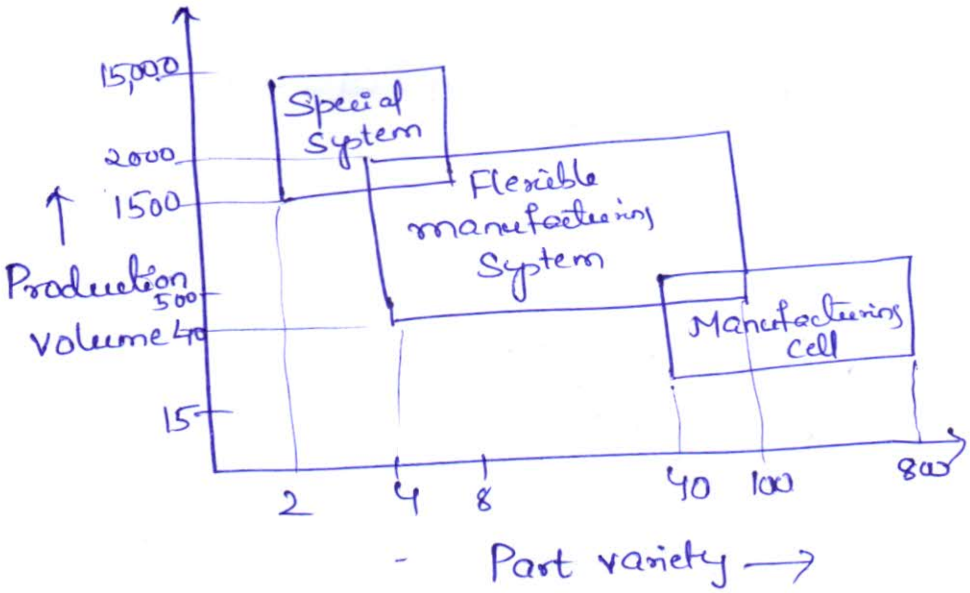
Advantages of CIM:-

1) Improves operational control through
   - reduction in the no. of uncontrollable variables.
   - reducing dependence on human communication.
2) Improves the short-run responsiveness consisting of
   - engineering changes
   - m/c downtime or unavailability
   - Operator unavailability
   - Cutting-tool failure
   - Late material delivery
3) Reduces inventory by
   - reducing lot sizes
   - improving inventory turnovers.
4) increases m/c utilization by
   - eliminating or reducing m/c setup.
   - utilising automated features to replace manual intervention to the extent possible
5) Engg. design costs can be reduced.
6) Overall lead times "
7) Productivity of the manufacturing operation can be increased.

8) Work-in-process can be reduced.

Types of manufacturing systems

(1) Special manufacturing system
(2) Manufacturing cell
(3) Flexible manufacturing system (FMS)



- The special manufacturing system is the least flexible CIM system.
  * It is designed to produce a very limited no. of different parts (2 to 8) in the same manufacturing family.
  * Annual production rate per part → (1500 - 15,000) pieces.

- Manufacturing cell is the most flexible, but generally has the lowest production rate of the three types.
  * The no. of different parts manufactured in the cell might be inbetween 40 & 800 and annual production levels for these parts would be between 15 & 500.

- The FMS covers a wide middle territory within the midvolume, mid variety production range.
  * The no. of different parts manufactured (4 to 100) Production rates per part (40 & 2000) per year.

FMS

- Workparts are loaded and unloaded at a central location in the FMS.
- Pallets are used to transfer workparts betn m/cs.
- Once a part is loaded onto the handling system, it is automatically routed to a particular workstations required in its processing.
- For each different workpart type, the routing may be different and the operations & tooling required at each workstation also differs.
- The coordination & control of the parts handling & processing activities is accomplished under command of the computer.
- One or more computers can be used to control a single FMS.
- The computer system is used to control the m/c tools & material handling system to monitor the performance of the system & to schedule production.
- Human labor is required to operate the CIMS. Among the functions performed are loading & unloading of workparts, changing tools, tool setting & programming the computer system.

Components of CIM

1) M/c tools & related equipment
2) Materials handling system
3) Computer system
4) Human labor.

M/C tools & Related equipment

It includes:-
1) Standard CNC m/c tools
2) Special-purpose m/c tools
3) Tooling for these machines
4) Inspection stations or special inspection probes used with the m/c tools.

- The selection of the particular m/cs that make up a CIMS depend on the processing requirements to be accomplished by the system.
- Some of the factors that define the processing requirements are as follows:-

(1) Part size:- The size of the workparts to be processed on the CIMS influences the size & construction of the machines. Larger parts require larger m/cs.

(2) Part shape:- Machined workparts usually divide themselves naturally into two types according to shape: round & prismatic.

- Round parts (gears, shafts, disks) → require turning & boring operations.
- Prismatic parts (cube shaped & non-rotational) → require milling & drilling operations.

(3) Part variety:- If the part variety is limited, the m/c tools would be more specialized for higher production.

- If a wide variety of parts are to be processed, standard m/c tools (more versatile) should be selected.

(4) Product life cycle :-
If the product life cycle is relatively long, the CIMS can include more specialized & less flexible m/c tools.

(5) Definition of future parts:-
- Another factor that affects the versatility of CIMS is the level of knowledge about parts which are to be processed.
- 1st case: where the manufacturing system is designed to process a family of parts that are completely known in advance.
- Othe case:- where the future parts are not known in advance. New part designs must be accommodated by the system. Thus, its m/c tools must possess a significant degree of flexibility.

(6) Operations other than machining:-
Most computer-integrated manufacturing (CIM) systems are designed for machining exclusively. In some cases, the processing requirements include other operations, such as assembly or inspection.

Material handling System

- The material handling system in a CIMS must be designed to serve two functions.
The 1st function is to move workparts betn m/cs → Primary MHS
The 2nd function is to orient and locate the workparts for processing at the machines → Secondary handling system
- These two functions are often accomplished by means of two different, but connected material handling systems.

- The requirements usually placed on the primary material handling system are :-

* It must be compatible with computer control.
* It must provide random, independent movement of palletized workparts betn m/c tools in the system.
* It must permit temporary storage of parts.
* It should allow access to the m/c tools for maintenance, tool changing & so on.
* It must interface with the secondary work handling system.

The Secondary work handling systems generally consists of one transport mechanism for each m/c.
The specifications placed on the secondary materials handling system are :-

(1) It must interface with the primary handling system. Parts must be compatible with computer transferred automatically betn the primary system & the secondary system.

(2) It must be compatible with computer control.

(3) It must permit temporary storage of parts.

(4) It must provide for parts orientation & location at each workstation for processing.

(5) It should allow access to the m/c tool for maintenance, tool changing & so on.

Computer Control System

A digital computer system is used to manage the Operation of a Complex manufacturing system. The functions accomplished by the Computer Control System is divided into 8 Categories.

(1) Machine Control :-

This is usually done by CNC. The advantage of CNC is that it can be conveniently interfaced with the other elements of the computer control system.

(2) DNC :-

Most computer-integrated manufacturing systems operate under DNC. The purpose of DNC is to perform the usual DNC functions, including NC part program storage, distribution of programs to the individual machines in the system, post processing & so on.

(3) Production Control :-

- The computer performs its production control function by routing a pallet to the load / unload area and providing instructions to the operator to load the desired raw part.
- A data entry unit (DEU) is located in the load/unload area for communication betn the operators and the computer.

(4) Traffic Control :-

- This term refers to the regulation of the primary workpiece transport system which moves parts betn workstations.
- This control can be accomplished by dividing the transport system into zones.

- A zone is a section of the primary transport system which is individually controlled by the computer.
- By allowing only one cart or pallet to be in a zone, the movement of each individual workpart is controlled.
- The traffic controller operates the switches, stops workparts at m/c tool loading points & moves parts to operator Load / Unload Stations.

(5) Shuttle control:-

- This is concerned with the regulation of the secondary part handling systems at each m/c tool.
- Each shuttle system must be coordinated with the primary handling system & it must also be synchronized with the operations of the m/c tool it serves.

(6) Work handling system monitoring:-

The computer must monitor the status of each cart / pallet in the primary and secondary handling systems, as well as, the status of each of the various workpart types in the system.

(7) Tool Control:-

- Monitoring & control of cutting tool status is an important feature of computer system.
- There are two aspects to tool control:

a) Accounting for the location of each tool in CIMS

b) Tool life monitoring.

- The 1st aspect of tool control involves keeping track of the tools at each work station.
- If 1 or more tools required in the processing of a particular workpart are not present at the workstation specified in the part's routing, the computer control system will not deliver the part to that station. It will determine an alternative machine to which the part can be routed, or it will temporarily float the part in the handling system.
- In the 2nd case, the operator is notified via the data entry unit what tools are required in which workstation. The operator then manually loads the tools and notifies the computer accordingly.
- Any type of tool transaction (e.g. removal, replacement addition) must be entered into the computer to maintain effective tool control.

The 2nd aspect of tool control is tool-life monitoring. A tool life is specified to the computer for each cutting tool in the CIMS.

- Then a file is kept on the machining time usage of each tool.

When the commulative machining time reaches the life for a given tool, the operator is notified that a replacement is required.

(8) System Performance Monitoring & Reporting

The computer can be programmed to generate various reports desired by management on system performance.

CIMS data files

(1) Part program file:-

- The part program for each workpart processed on the system is maintained in this file.
- For any given workpart, a separate program is required for each station that performs operations on the part.

(2) Routing file:-

The file contains the list of workstations through which each workpart must be processed. It also contains alternate routings for the parts.

(3) Part production file:-

- A file of production parameters is maintained for each workpart.
- It contains data relative to production rates for the various machines in the routing, allowances for in-process inventory, inspections required & so on.

(4) Pallet reference file:-

- A given pallet may be fixtured only for certain parts. The pallet reference file is used to maintain a record of the parts that each pallet can accept.
- Each pallet in the CIMS is uniquely identified and referenced in this file.

(5) Station tool file:-

A file is kept for each workstation, identifying the codes of the cutting tools stored at that station. This file is used for tool control purposes.

(6) Tool life file:- This data file keeps the tool-life value for each cutting tool in the system. The cummulative m/cing time of each tool is compared with its life value so that a replacement can be made before complete failure occurs.

System reports

The data collected during monitoring can be summarized for preparation of performance reports.

(1) Utilization reports:-
These are reports that summarize the utilization of individual workstations as well as overall average utilization for the system.

(2) Production reports:-
It lists the quantity of parts produced from the CIMS.

(3) Status reports:-
It shows the present condition of the CIMS.
It includes status data on workparts, m/c utilization, pallets & other system operating parameters.

(4) Tool reports:-
These reports relate to various aspects of tool control. Reported data might include a list of missing tools at each workstation.

Human labor in the manufacturing system

The CIM is a highly automated production facility. However, human resources are required to operate the system.

1) System manager:- Overall responsibility for the operations of the CIMS.

2) Electrical technician:- Maintenance & repair services on the electrical components of the m/c tools & material handling system.

3) Mechanical / hydraulic technician:-

4) Tool setter :- making the tools ready for production.

5) Fixture set up & lead man:- This person is responsible for setting up the fixtures, pallets & tools for the system.

6) <u>Load / Unload man:-</u>

Loading raw workparts & unloading finished parts.

7) <u>Rover operator :-</u>

The duties of the rover operator include reacting to unscheduled m/c stops, identifying broken tools or tools in need of immediate replacement, tool adjustments, etc.