

CAD / CAM / CIM

ANSWERS

By

Mr. B. Guruprasad

Asst. Professor, Mechanical

# CAD/CAM/CIM

BACHELOR OF MECHANICAL ENGINEERING

Prepared by  
B.GURUPRASAD, M.E.,  
Assistant Professor of Mechanical Engineering

ANNAMALAI



UNIVERSITY

- “People are often unreasonable and self-centered.  
**Forgive them anyway.**

- If you are kind, people may accuse you of ulterior motives.

**Be kind anyway.**

- If you are honest, people may cheat you.

**Be honest anyway.**

- If you kind happiness, people may be jealous.

**Be happy anyway.**

- The good you do today may be forgotten tomorrow.

**Do good anyway.**

- Give the world the best you have and it may never be enough.

**Give your best anyway.**

- For you see, in the end, it is between you and God.
  - **it was never between you and them any way”**

# UNIT - I

- CAD/CAM is a term which means computer-aided design and computer aided manufacturing.
- It is the technology concerned with the use of digital computers to perform certain functions in design and production
- CAD/CAM will provide the technology base for the computer integrated factory of the future.  
“Computer-aided design (CAD) can be defined as the use of computer systems to assist in the creation, modification, analysis, or optimization of a design

- The computer systems consist of the hardware and software to perform the specialized design functions required by the particular user firm. The CAD hardware typically includes the computer, one or more graphics display terminals, keyboards and other peripheral equipment
- Stress-strain analysis of components,
- Dynamic response of mechanisms, heat-transfer calculations, and numerical control part programming

- The collection of application programs will vary from one user firm to the next because their product lines, manufacturing processes, and customer markets are different. These factors give rise to differences in CAD system requirements
- Computer aided manufacturing (CAM) can be defined as the use of computer systems to plan, manage, and control the operations of a manufacturing plant through either direct or indirect computer interface with the plants production resources

- the applications of computer-aided manufacturing fall into two broad categories
- **Computer monitoring and control:**

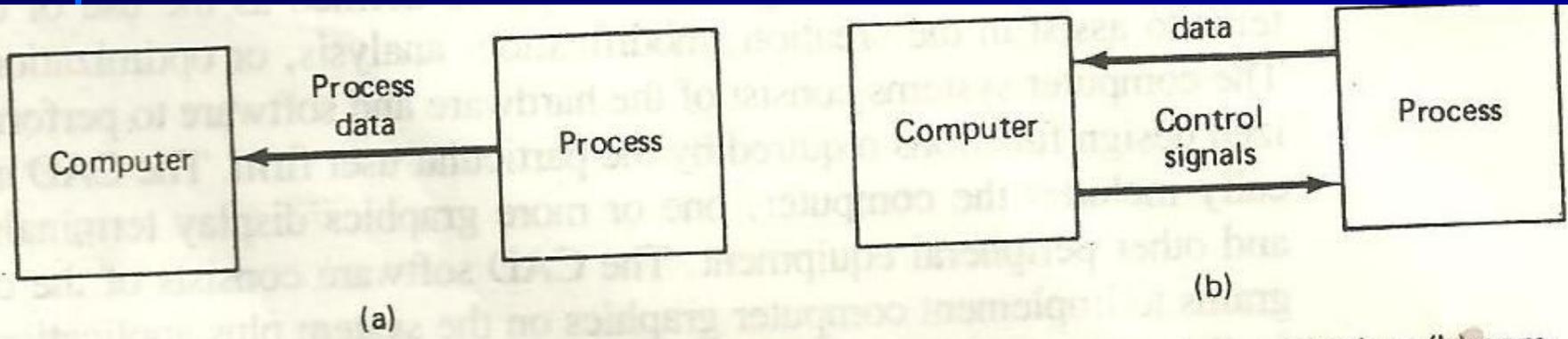


FIGURE 1.1 Computer monitoring versus computer control: (a) computer monitoring; (b) computer control.

- **Manufacturing support applications:**

These are the indirect applications in which the computer is used in support of the production operations in the plant, but there is no direct interface between the computer and the manufacturing process

- **Numerical control part programming by computers:**

Control programs are prepared for automated machine tools.

- **Computer-automated process planning:**

The computer prepares a listing of the operation sequence required to process a particular product or component:

- **Computer generated work standards:** The computer determines the time standard for a particular production operation.
- **Production scheduling:** The computer determines an appropriate schedule for meeting production requirements.
- **Material requirements planning:** The computer is used to determine when to order raw materials and purchased components and how many should be ordered to achieve the production schedule.
- **Shop floor control:** In this CAM application, data are collected from the factory to determine progress of the various production shop orders

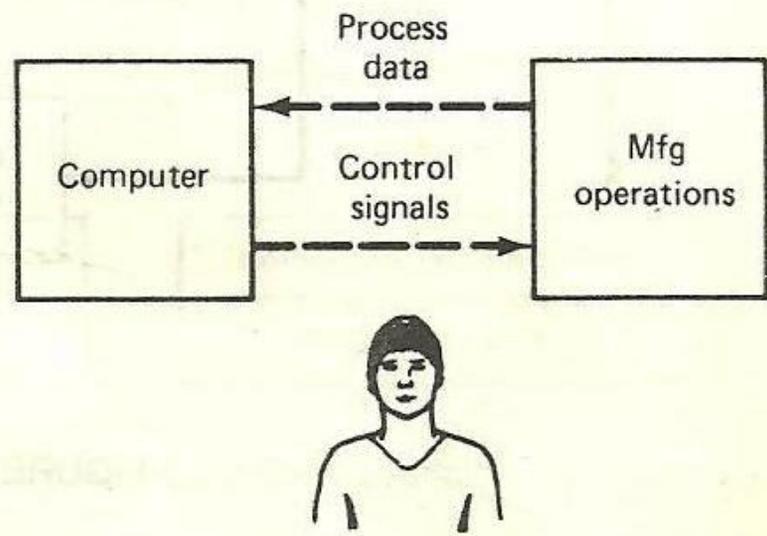


FIGURE 1.2 CAM for manufacturing support.

# Product Cycle and CAD/CAM

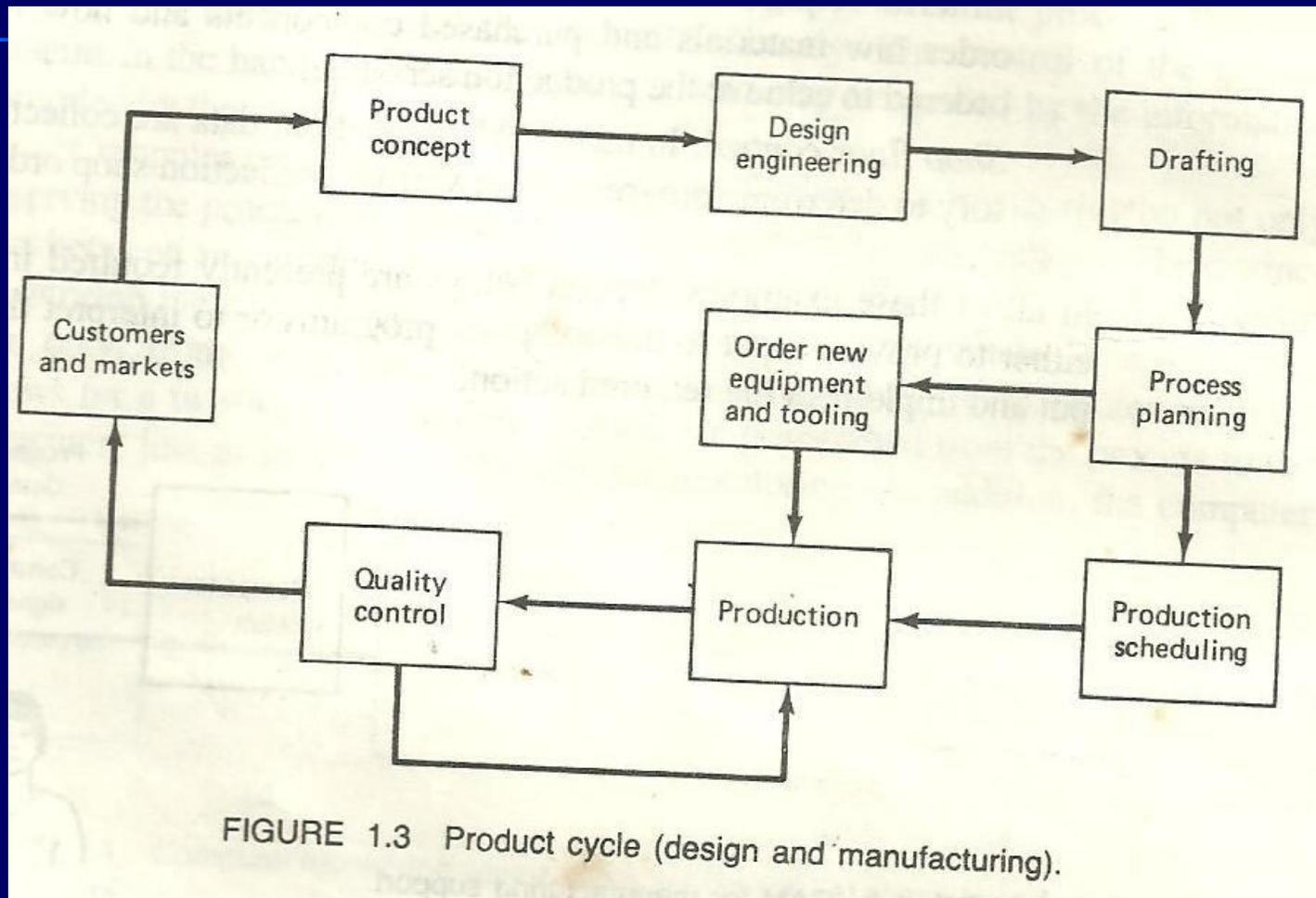


FIGURE 1.3 Product cycle (design and manufacturing).

- The cycle is driven by customers and markets which demand the product.
- It is realistic to think of these as a large collection of diverse industrial and consumer markets rather than one monolithic market.
- Depending on the particular consumer group, there will be differences in the way the product cycle is activated. In some cases, the design functions are performed by the customer and the product is manufactured by a different firm.
- In other cases, design and manufacturing is Accomplished by the same firm. Whatever the case, the product cycle begins with a concept, an idea for a product. This concept is cultivated, refined, analyzed, Improved, and translated into a plan for the product through the design engineering process.
- The plan is documented by drafting a set of engineering drawings showing how the product is made and providing a set of specifications indicating how the product should perform

- The next activities involve the manufacture of the product. A process plan is formulated which specifies the sequence of production operations required to make the product.
- New equipment and tools must sometimes be acquired to produce the new product.
- Scheduling provides a plan that commits the company to the manufacture of certain quantities of the product by certain dates.
- Once all of these plans are formulated, the product goes into production, followed by quality testing, and delivery to the customer

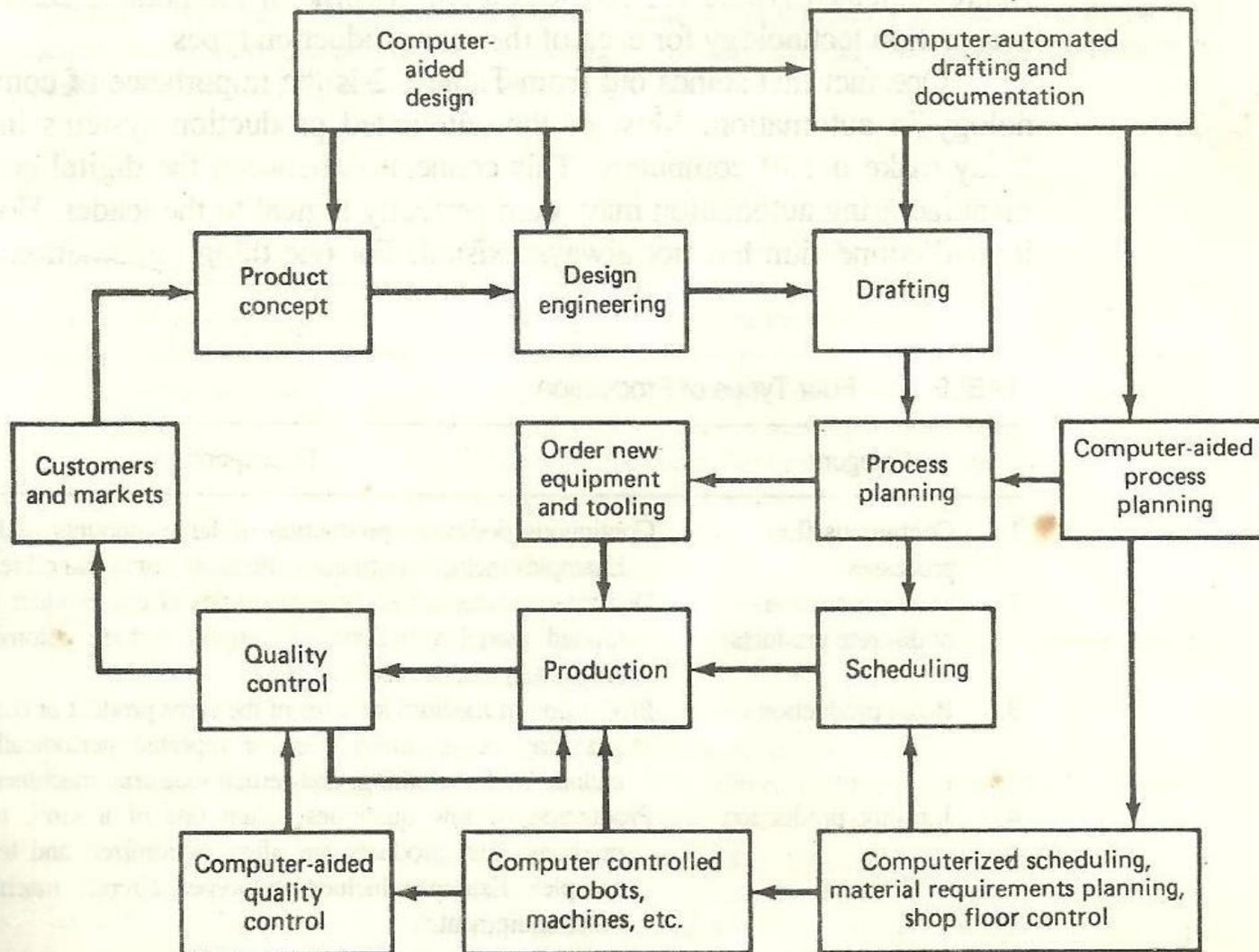
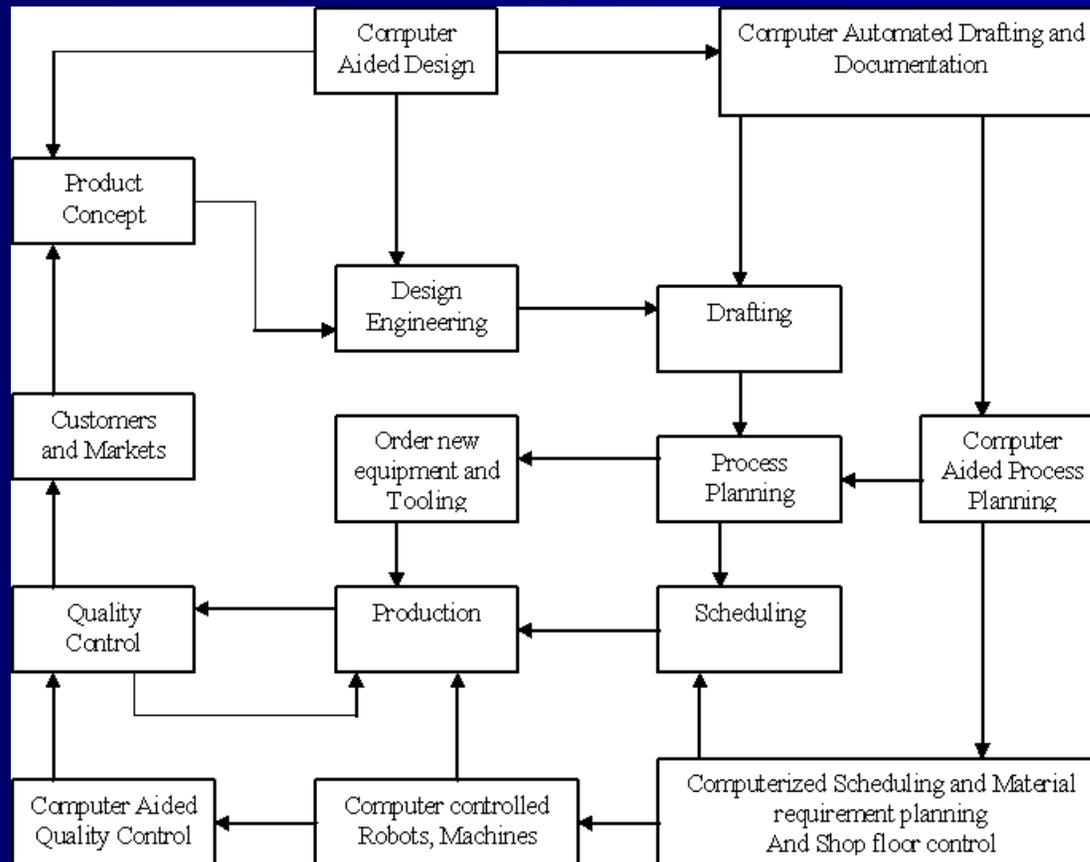


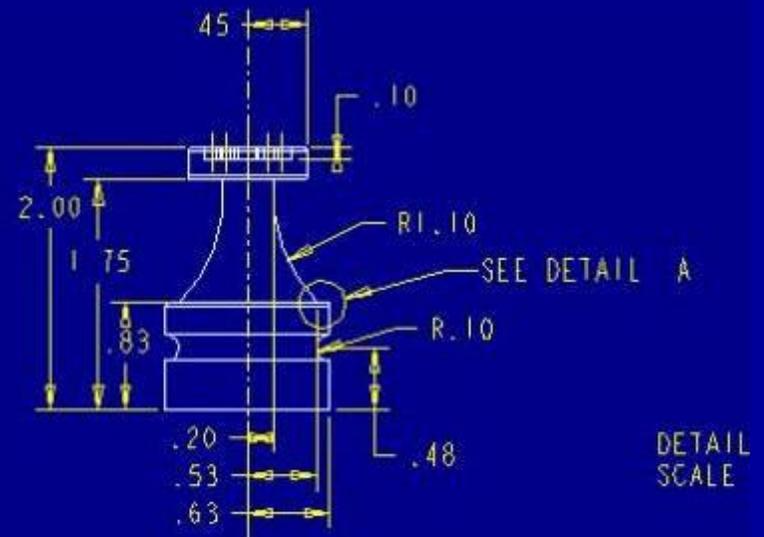
FIGURE 1.4 Product cycle revised with CAD/CAM overlaid.

# CAD/CAM and the new Environment



# How do CAD/CAM systems work?

- Developing NC code requires an understanding of:
  1. Part geometry
  2. Tooling
  3. Process plans
  4. Tolerances
  5. Fixturing
- Most CAD/CAM systems provide access to:
  1. Part geometry
  2. Tooling



# CAD/CAM Support

- AutoCAD 200i
- Pro Engineer 2001
- MasterCAM

- Compute aided design and automated drafting are utilized in the conceptualization, design, and documentation of the product. Computers are used in process planning and scheduling to perform these functions more efficiently.
- Computers are used in production to monitor and control the manufacturing operations. In quality control, computers are used to perform inspections and performance tests on the product and its components

## E 1.1 Four Types of Production

Category	Description
Continuous-flow processes	Continuous dedicated production of large amounts of bulk product. Examples include continuous chemical plants and oil refineries.
Mass production of discrete products	Dedicated production of large quantities of one product (with perhaps limited model variations). Examples include automobiles, appliances, and engine blocks.
Batch production	Production of medium lot sizes of the same product or component. The lots may be produced once or repeated periodically. Examples include books, clothing, and certain industrial machinery.
Job shop production	Production of low quantities, often one of a kind, of specialized products. The products are often customized and technologically complex. Examples include prototypes, aircraft, machine tools, and other equipment.

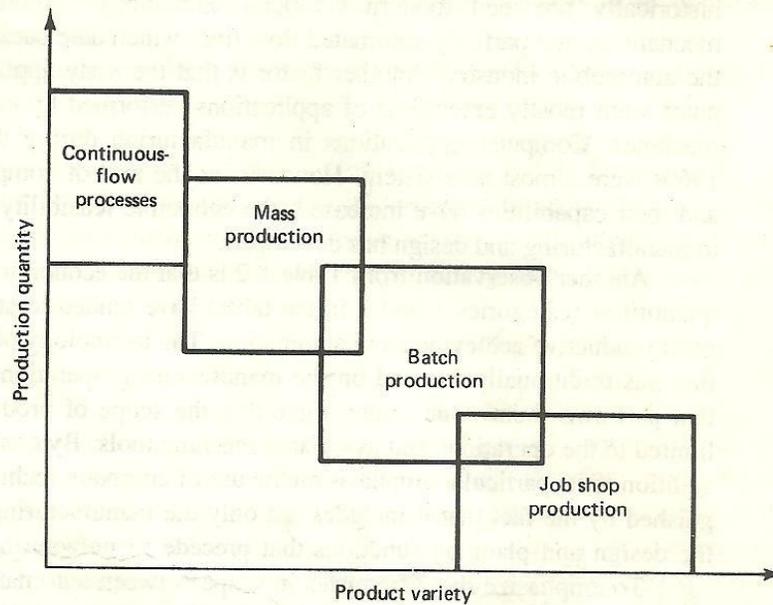


FIGURE 1.5 Four production types related to quantity and product variation. (Reprinted with permission from *Industrial Engineering Magazine*, November, 1981. Copyright ©Institute of Industrial Engineers, 25 Technology Park, Atlanta Norcross, GA 30092.)

- CAD/CAM is the digital computer. its inherent speed and storage capacity have made it possible to achieve the advances in image processing, realtime process control, and a multitude of other important functions that are simply too complex and time consuming to from manual .
- if The modem digital computer is an electronic machine that can perform mathematical and logical calculations and data processing functions in accordance with a predetermined program of instructions.

There are three basic hardware components of a general purpose digital computer.

1. Central processing unit (CPU)
2. Memory
3. Input/output (I/O) section

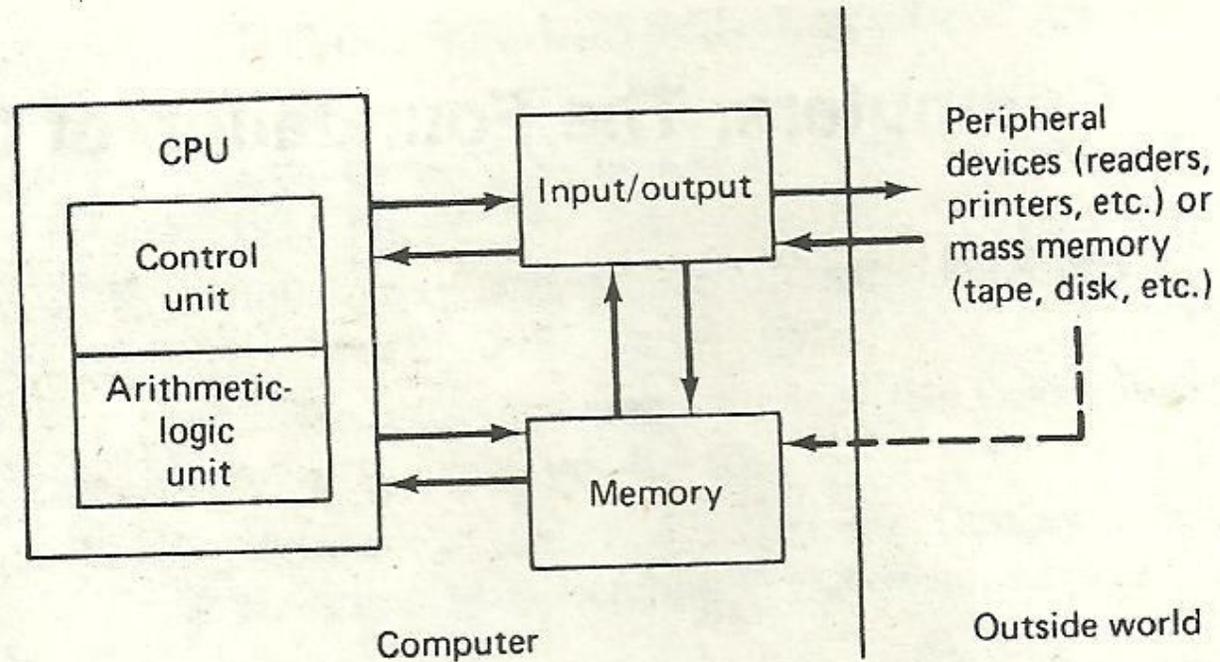


FIGURE 2.1 Basic hardware structure of a digital computer.

The basic hardware structure of a digital computer is illustrated in Figure 2.1. The ce

- CENTRAL PROCESSING UNIT (CPU)
- The central processing unit (CPU) regulates the operation of all system components and performs the arithmetic and logical operations on the data. To accomplish these functions, the CPU consists of two operating units:
  - Control unit
  - Arithmetic-logic unit (ALU)

eration is performed as defined by the function imp

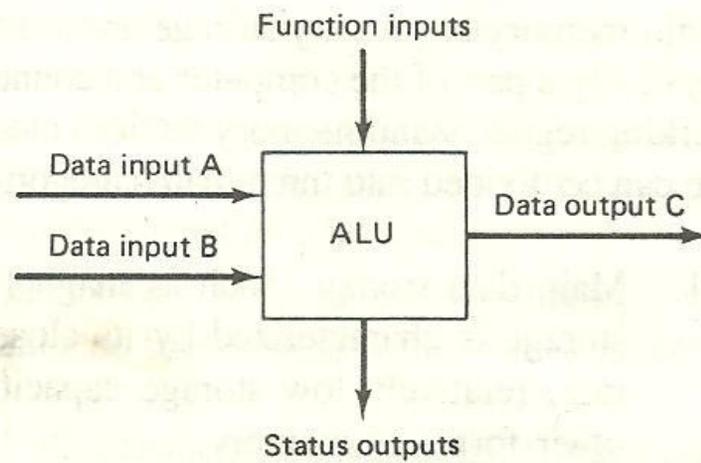


FIGURE 2.4

The control unit coordinates the various operations specified by the program instructions. These operations include receiving data which enter the computer and deciding how and when the data should be processed. The control unit directs the operation of the arithmetic-logic unit.

It sends data to the ALU and tells the ALU what functions to perform on the data and where to store the results. The capability of the control unit to accomplish these operations is provided by a set of instructions called an executive program which is stored in memory.

The arithmetic and logic unit performs operations such as addition, subtractions, and comparisons. These operations are carried out on data in binary form. The logic section can also be used to alter the sequence in which instructions are executed when certain conditions are indicated and to perform other functions, such as editing and masking data for arithmetic operations.

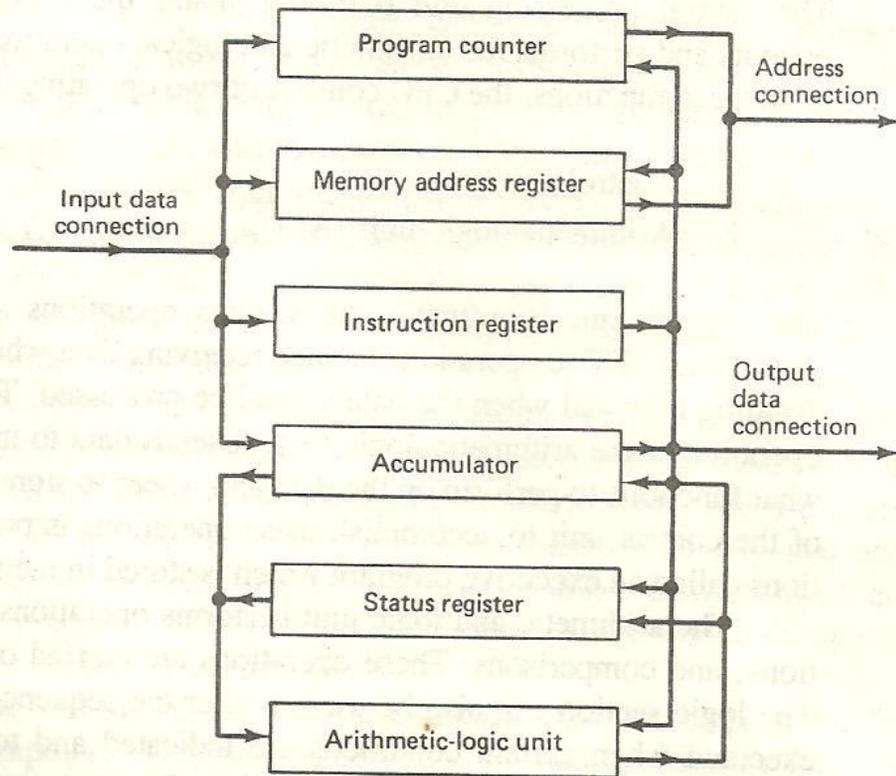


FIGURE 2.3 Typical arrangement of registers in the computer's CPU. (From Lance A. Levanthal, *Introduction to Microprocessors: Software, Hardware, Programming*, ©1978, p. 128. Reprinted by permission of Prentice-Hall, Inc., Englewood Cliffs, N.J.)

- TYPES OF MEMORY
- The memory section consists of binary storage units which are organized into bytes (there are typically 8 bits per byte).
- A byte is a convenient size for the computer to handle. Computer words can typically be 4, 8, 12, 16, 32, or 64 bits long.
- Main memory (primary storage)
- Auxiliary memory (secondary storage)

- Main memory (primary storage):
- Main data storage, such as magnetic core or solid-state memory.
- This storage is characterized by its close proximity to the CPU, fast access rate, relatively low storage capacity, and very high cost compared to other forms of memory.
- Control storage, which commonly contains the microprograms that assist the CPU circuitry in performing its functions
- Local storage, the high-speed working registers used in the arithmetic and logical operations.

- Auxiliary memory (secondary storage):
- *Sequential access storage:*

A sequential access storage unit is distinguished by the fact that to read one particular record in the file, all records preceding it must also be read.

- *Direct access storage:*

With this storage method, individual records can be located and read immediately without reading any other records.

- COMPUTER PROGRAMMING LANGUAGES
- Instructions are communicated to the computer in the form of binary words., executing a program, the computer interprets the configuration of bits as an instruction to perform electronic operations
- The binary-coded instructions that computers can understand are called machine language

- Three levels of computer programming languages:
- 1. Machine language
- 2. Assembly language
- 3. Procedure-oriented (high-level) languages

- Machine languages:
- The language used by the computer is called machine language. It is written in binary, with each instruction containing an operation code and an operand (Memory address)
- The programmer must be familiar with the specific compute system since machine language instructions are different for each computer
- Programming in machine language is tedious, complicated, and time consuming
- Hence, English-like mnemonics for each binary instruction

- Assembly languages:
- These are considered to be low-level languages.
- The programmer must be very knowledgeable about the computer and equipment being programmed
- Low-level languages are the most efficient in terms of fast execution on the computer

- High-level languages:
- Ex. Fortran
- It consist of English-like statements and traditional mathematical symbols. Each high-level statement is equivalent to many instructs.
- A program written on one computer can be run on a different computer without significant modifications to the program.
- The advantage of high-level languages is that it is not necessary for the programmer to be familiar with machine language. The program is written as » English/mathematical symbol like algorithm to solve a problem.
- Like assembly languages, high-level languages must also be converted into machine code. This is accomplished by special program called a compiler

- high-level language used to program automatic machine tools.
- 1.The large mainframe computer
- 2.The minicomputer
- 3.The microcomputer

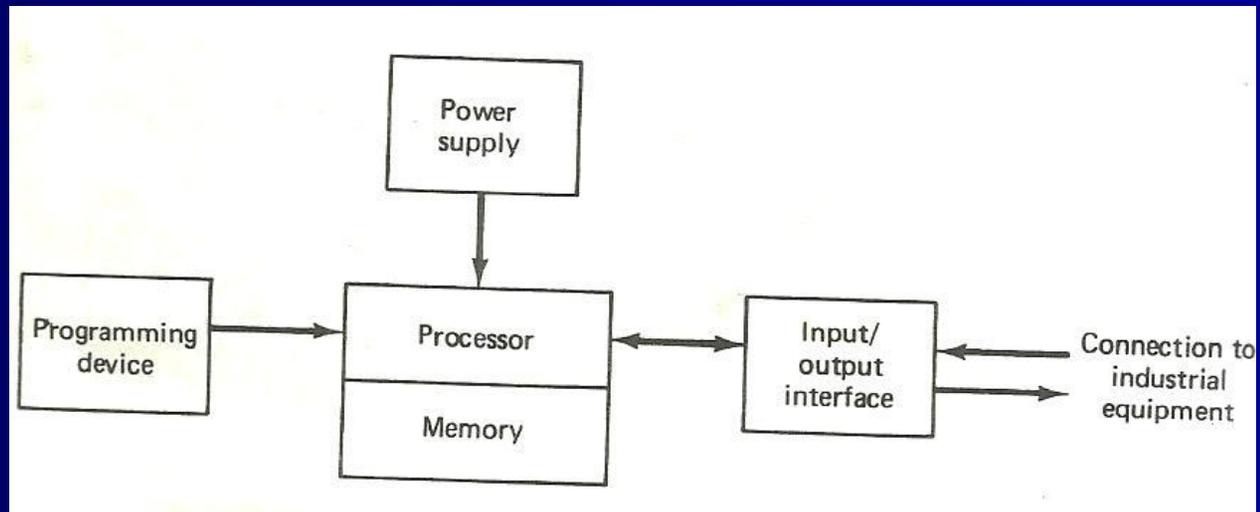
- The large mainframe computer is distinguished by its cost, capacity, and function.
- The price of a new corporate general-purpose computer can run into millions of dollars.
- The main memory capacity is several orders of magnitude larger than the minicomputer, and the speed with which computations can be made is several times the speed of a minicomputer or microcomputer

- Minicomputers:
- are smaller versions of the large mainframe computers. Greater computational power into the same physical size.
- same computational power into a smaller size

- A microcomputer:
- Uses a microprocessor as the basic central processing unit.
- The microprocessor consists of integrated circuits contained on LSI chips.
- The LS chips can be manufactured in large quantities very inexpensively.
- The micropro-cessor is capable of performing virtually all the functions of the conventional CPU.

- The programmable controller (PC) :
- Relay control systems were typically used to regulate the operation of production equipment.
- The problems with electromechanical relays are their physical size and programming inflexibility.
- The programmable controller could perform the same functions as a relay logic system with greater flexibility and lower space requirements.
- Wiring charts called "ladder diagrams"

- The programmable controller (PC) :



- There are several fundamental reasons for implementing a CAD/CAM

*To increase the productivity of the designer:*

This is accomplished by the designer to visualize the product and its component subassemblies and by reducing the time required in synthesizing, analyzing, and document. This productivity improvement translates not only into lower design but also into shorter project completion times.

*To improve the quality of design:*

A CAD system permits a more rough engineering analysis and a larger number of design alternatives can be done. Design errors are also reduced through the greater accuracy provided. These factors lead to a better design.

*To improve communications.*

Use of a CAD system provides better engineering drawings, more standardization in the drawings, better documentation - fewer drawing errors, and greater legibility.

*To create a data base for manufacturing.*

In the process of creating the documentation for the product design (geometries and dimensions of the product components, material specifications for components, bill of materials, etc.) of the required data base to manufacture the product is also created

# THE DESIGN PROCESS:

Recognition of need

Definition of problem

Synthesis

Analysis and optimization

Evaluation

Presentation

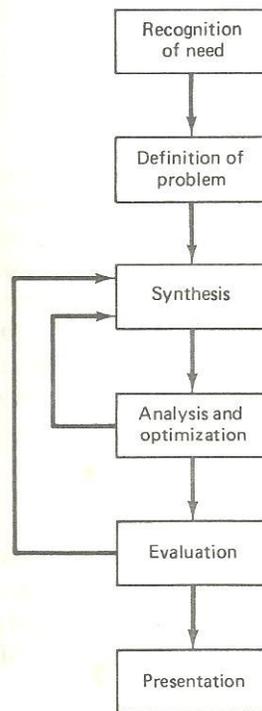


FIGURE 4.2 The general design process as defined by Shigley [13].

- Recognition of need
- This might be the identification of some defect in a current machine design by an engineer.
- the perception of a new product marketing opportunity by a salesperson

# Definition of problem

- Definition of the problem involves through specification of the item to be designed.
- This specification includes physical, functional characteristics, cost, quality, and operating per-formance

# Synthesis

- Synthesis and analysis are closely related and highly iterative in the design process. A certain component or subsystem of the overall system is conceptualized by the designer, subjected to analysis, improved through this analysis procedure, and redesigned .
- The process is repeated until the design has been optimized within the constraints imposed on the designer. The components and subsystems are syn-thesized into the final overall system in a similar iterative manner

# Evaluation

- Evaluation is concerned with measuring the design against the specifications established in the problem definition phase.
- This evaluation often requires the fabrication and testing of a prototype model to assess operating performance, quality, reliability, and other criteria.

# Presentation

- The final phase in the design process is the presentation of the design. This includes documentation of the design by means of drawings, material specifications, assembly lists, and so on.

# The Design Process : Then and Now

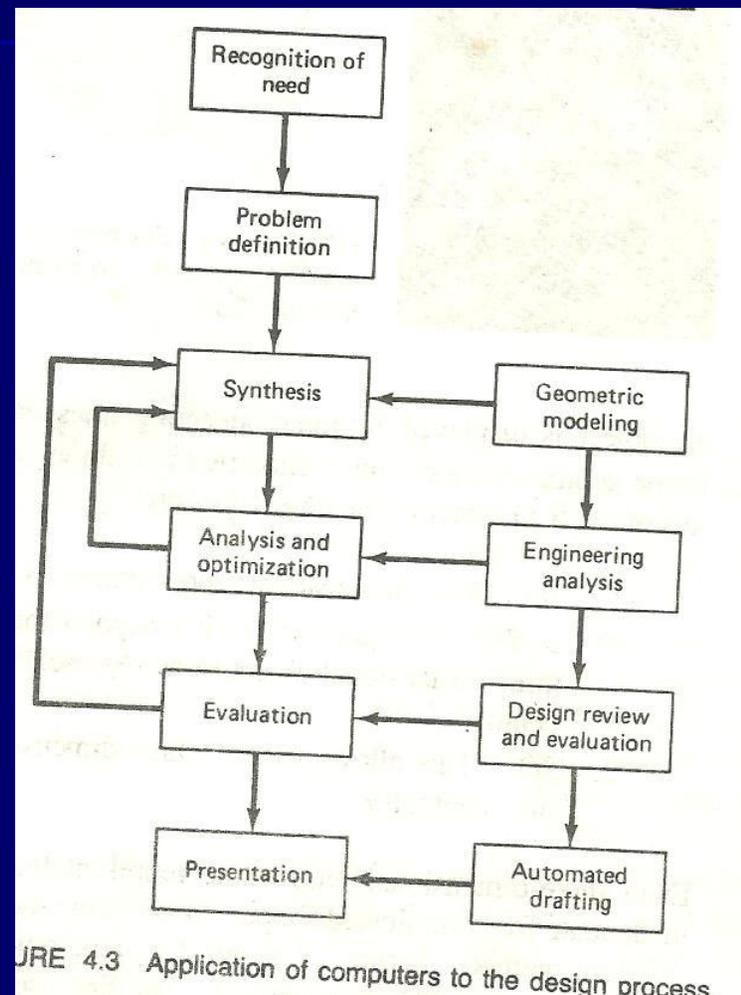
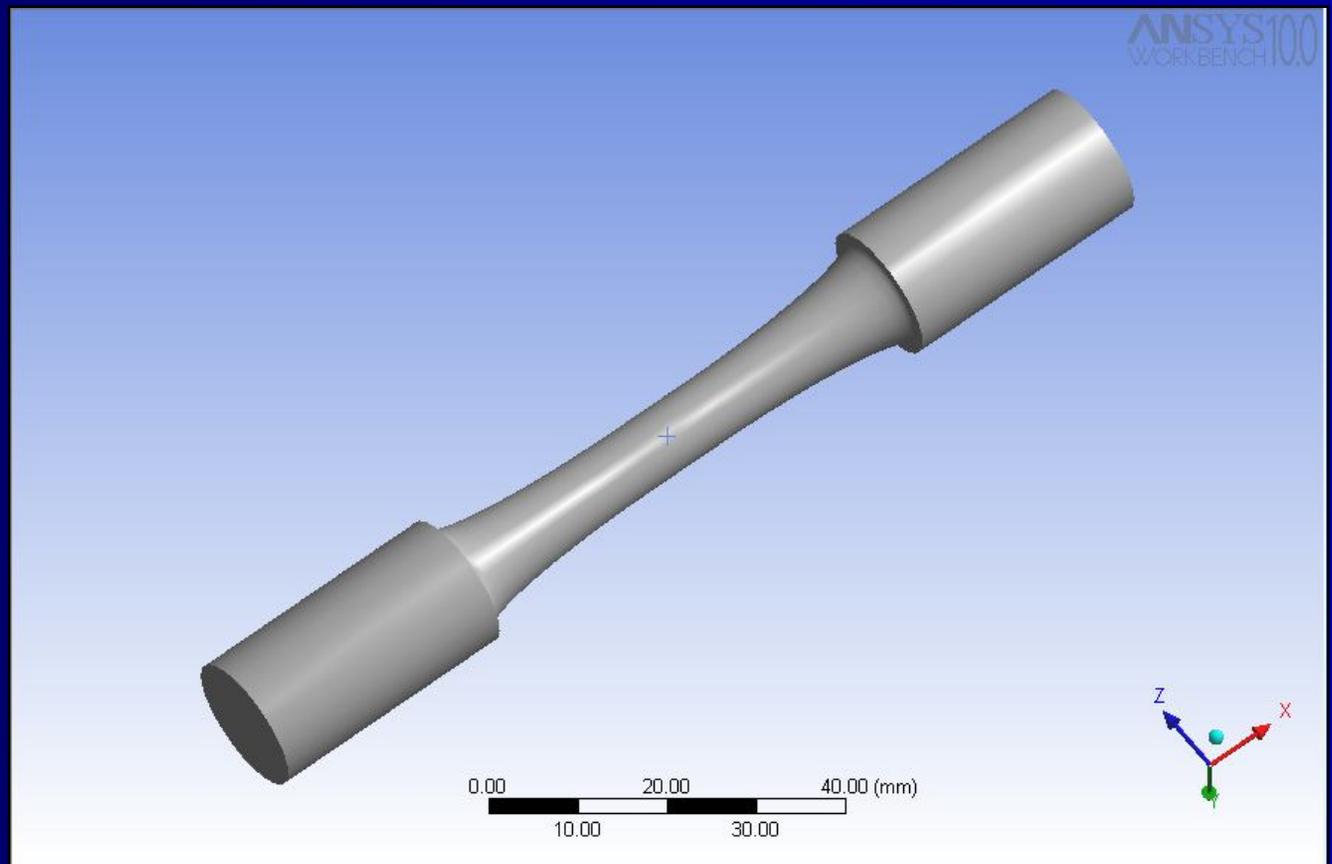
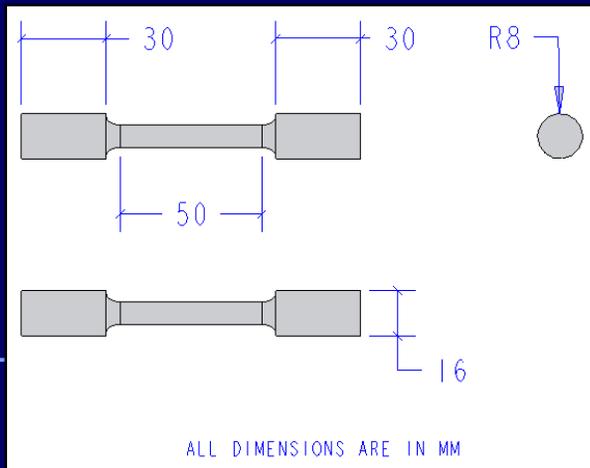


FIGURE 4.3 Application of computers to the design process.

# Geometric Modeling:

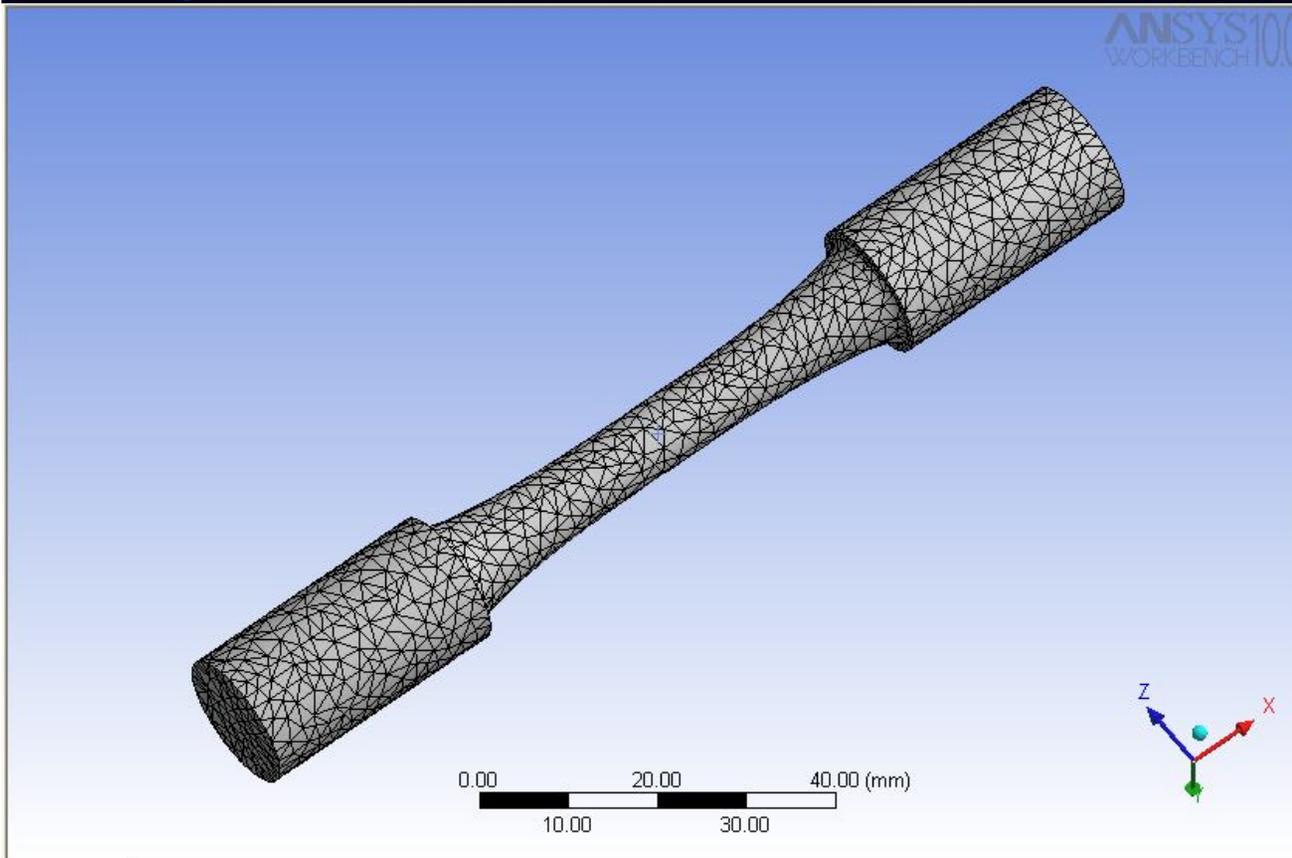
- 1. points, lines, circles etc.,
- Scaling, rotation, transformations, editing
- Finally desired shape arrived
- 2D, 2 1/2 D, 3D modeling



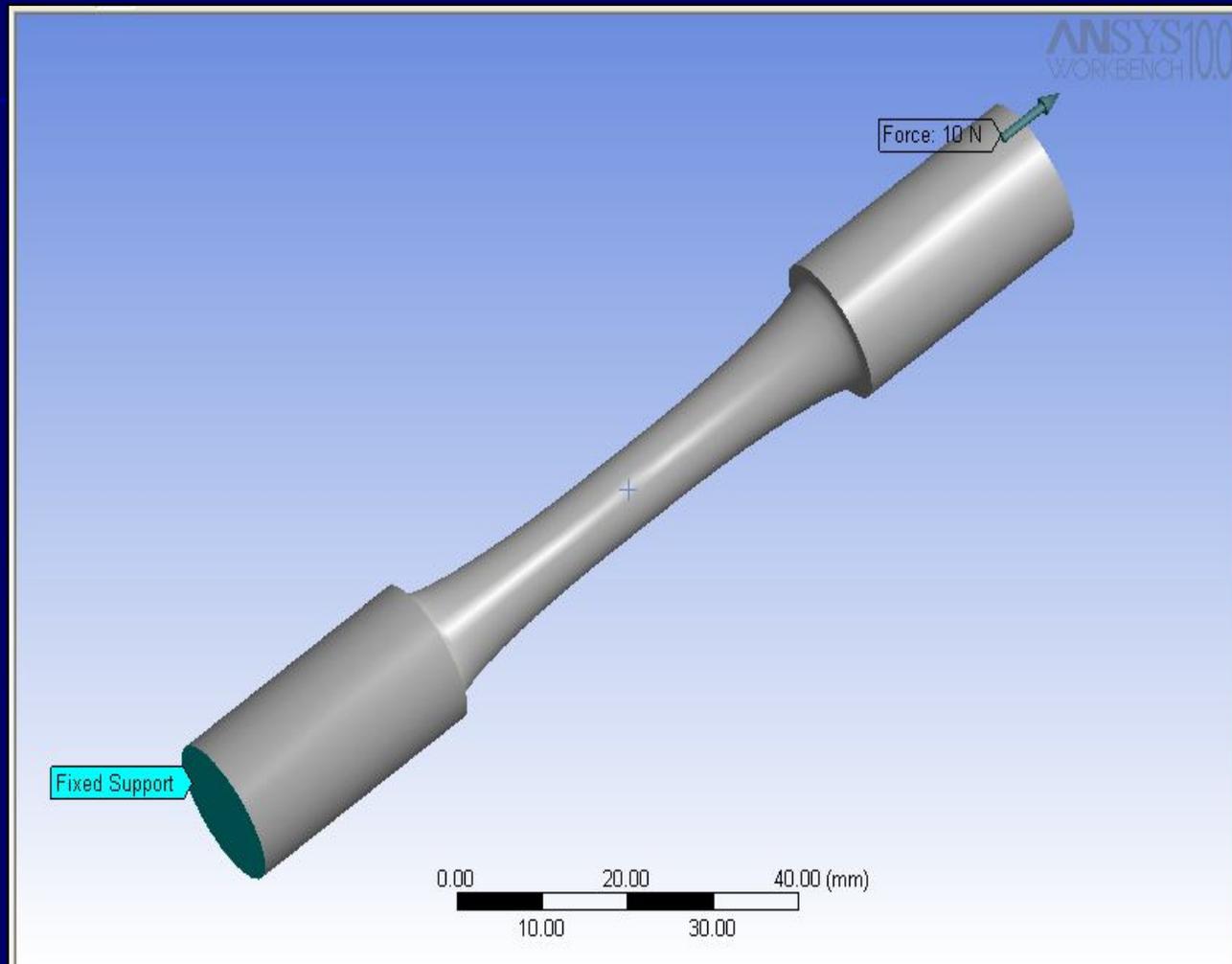
# Engg. Analysis

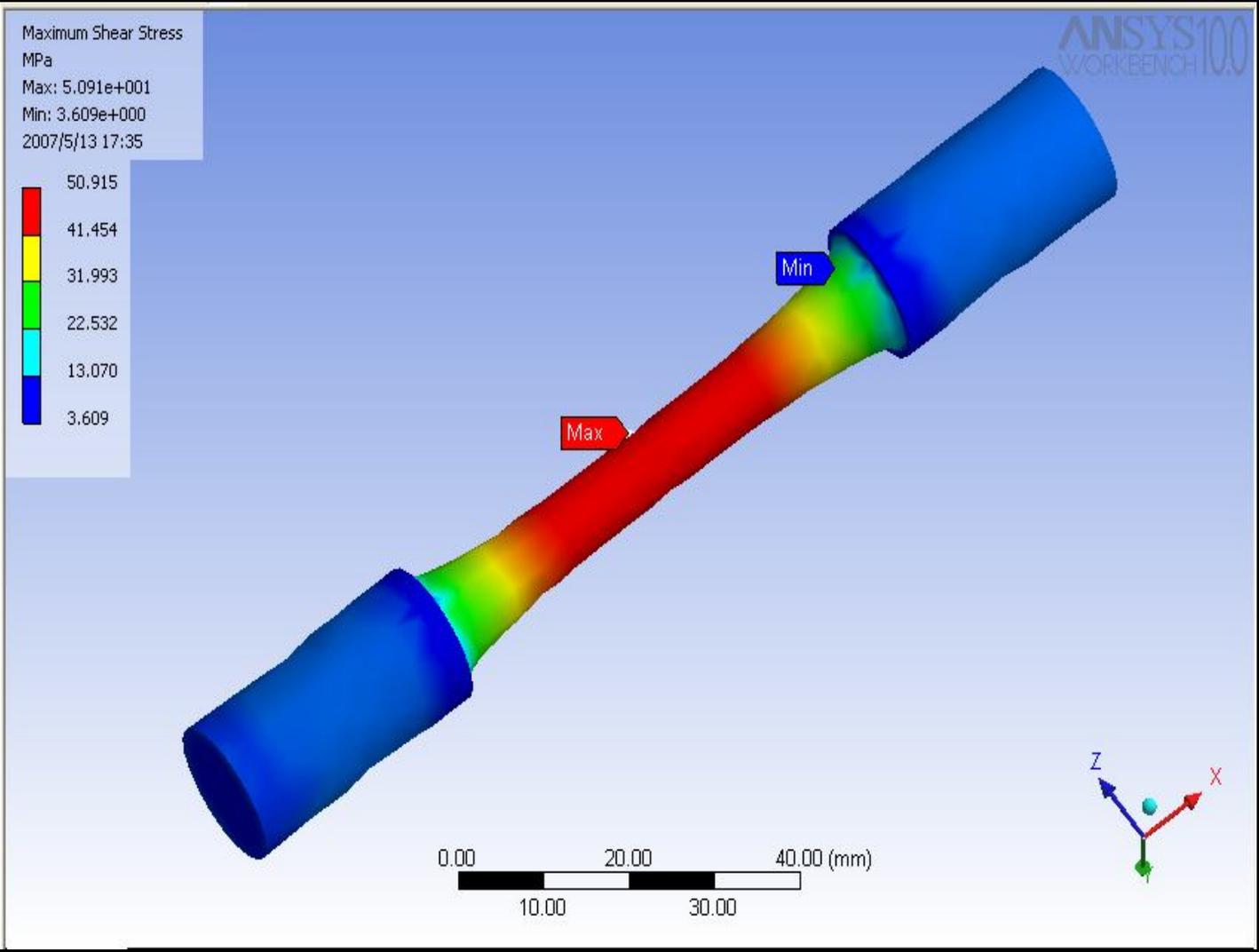
- Stress-Strain analysis
- Heat transfer analysis
- Dynamic Behaviour
- Analysis of Mass properties
- Finite Element Analysis

# 3D Model with Mesh



FE Model Summary	
Description	Quantity
Total Nodes	24987
Total Elements	16370
Total Body Elements	16370





# Design review and evaluation

- The designer can zoom in on part design details and magnify the image on the graphics screen for close scrutiny
- One of the most interesting evaluation features available on some computer-aided design systems is kinematics. The available kinematics packages provide the capability to animate the motion of simple designed mechanisms such as hinged components and linkages.
- This involves the analysis of an assembled structure in which there is a risk that the components of the assembly may occupy the same space.
- This risk occurs in the design of large chemical plants, air-separation cold boxes, and other complicated piping structures

- Automated drafting:
- Automated drafting involves the creation of hard-copy engineering drawings directly from the CAD data base.
- CAD systems can increase productivity in the drafting function by roughly five times over manual drafting

# Automated drafting:

- Dimensioning, generation of crosshatched areas, scaling of the drawing, a capability to develop sectional views and enlarged views of particular part.
- The ability to rotate the part or to perform other transformations of the image oblique, isometric, or perspective views.
- Most CAD systems are capable of generate six views of the part.

# CAD/CAM DATA BASE

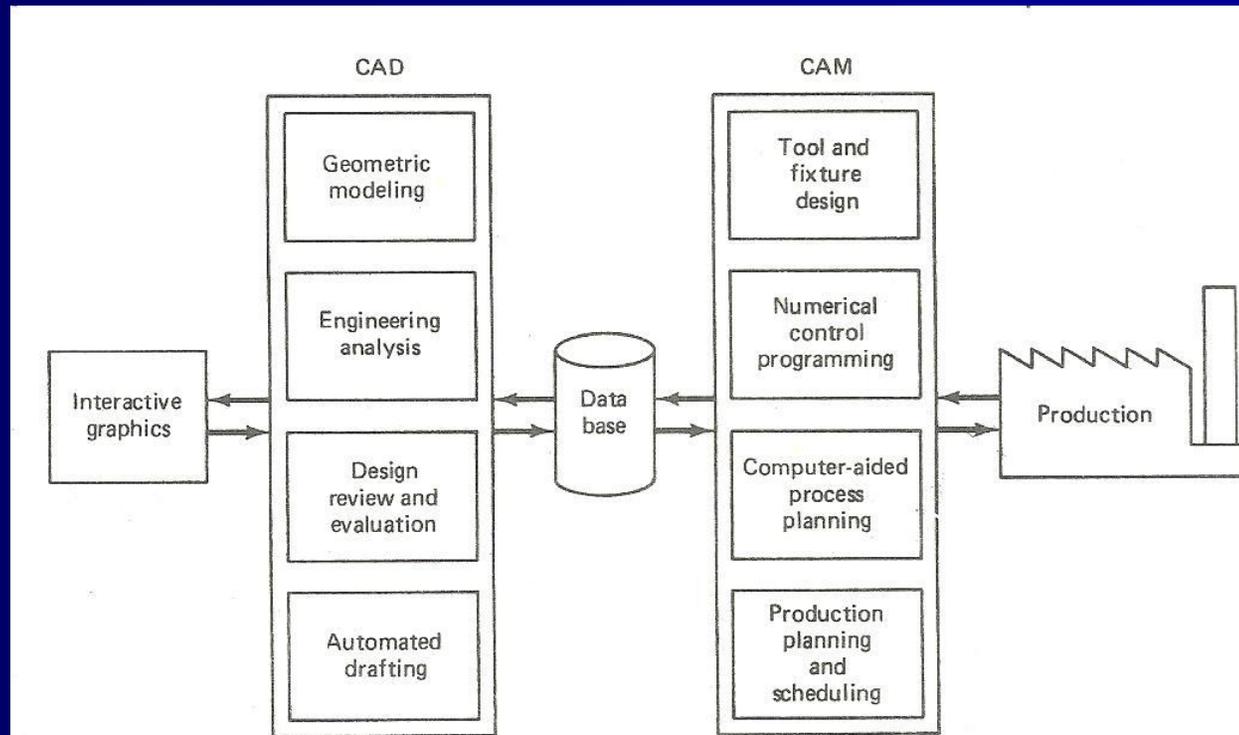


FIGURE 4.10 Desirable relationship of CAD/CAM data base to CAD and CAM.

# Benefits of Computer aided Design:

- Productivity improvement in design
- Shorter lead time
- Design analysis
- Fewer design errors
- Greater accuracy in design calculations
- Standardization of design, drafting and documentation procedures
- Drawings are more understandable
- Improved procedures for engineering changes
- Benefits in manufacturing

# Checklist of Potential Benefits

- Improved engineering productivity
- Shorter lead times
- Reduced engineering personnel requirements
- Customer modifications are easier to make
- Faster response to requests for quotations
- Avoidance of subcontracting to meet schedules
- Minimized transcription errors
- Improved accuracy of design
- In analysis, easier recognition of component interactions
- Provides better functional analysis to reduce prototype testing
- Assistance in preparation of documentation
- Designs have more standardization
- Better designs provided
- Improved productivity in tool design
- Better knowledge of costs provided
- Reduced training time for routine drafting tasks and NC part programming
- Fewer errors in NC part programming
- Provides the potential for using more existing parts and tooling
- Helps ensure designs are appropriate to existing manufacturing techniques
- Saves materials and machining time by optimization algorithms
- Provides operational results on the status of work in progress
- Makes the management of design personnel on projects more effective
- Assistance in inspection of complicated parts
- Better communication interfaces and greater understanding among engineers, designers, drafters, management, and different project groups

# Benefits in manufacturing

- Tool and fixture design for manufacturing
- Numerical control part programming
- Computer-aided process planning
- Assembly lists (generated by CAD) for production
- Computer-aided inspection
- Robotics planning
- Group technology
- Shorter manufacturing lead times through better scheduling

# DESIGN WORKSTATION

- It must interface with the central processing unit.
- It must generate a steady graphic image for the user.
- It must provide digital descriptions of the graphic image.
- It must translate computer commands into operating functions.
- It must facilitate communication between the user and the system.

- Graphics terminal
- Operator Input devices

# Image generation in computer graphics

- Nearly all computer graphics terminals available today use the cathode ray tube (CRT) as the display device. Television sets use a form of the same device as the picture 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

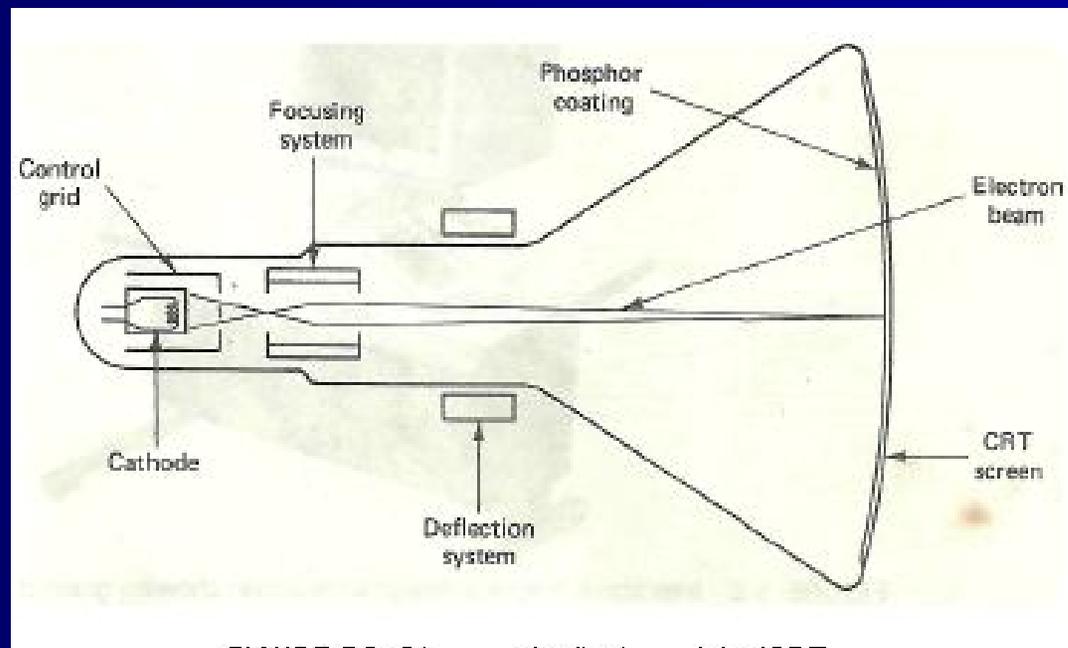
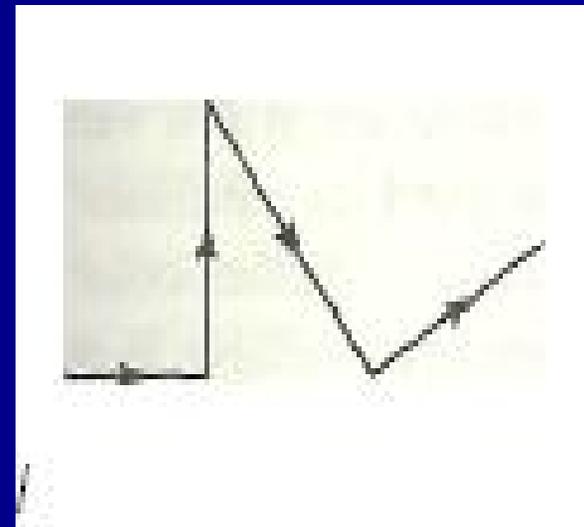
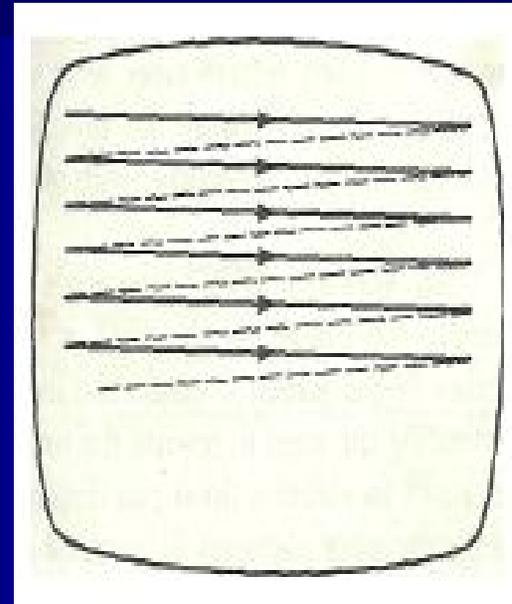


FIGURE 5.9. Schematic of a Cathode ray tube (CRT).

- The stroke-writing system uses an electron beam which operates like a pencil.
- 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.



- In the raster scan approach, the viewing screen is divided into a large number of discrete phosphor picture elements, called pixels.
- Each pixel on the screen can be 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.



# Operator input devices

- 1. Cursor control devices
- 2. Digitizers
- 3. Alphanumeric and other key board terminals

# Cursor control

- Thumb wheels
- Direction keys on a keyboard
- Joy sticks
- Tracker ball
- Light pen
- Electronic tablet/pen

# Digitizers

- The digitizer is an operator input device which consists of a large, smooth board (same as to a mechanical drawing 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.
- The digitizer can be used to digitize line drawings. The user can input data from a rough schematic or large layout drawing and edit the drawing to the desired level of accuracy and detail. The digitizer can also be used to freehand a new design, with subsequent editing to finalize the drawing

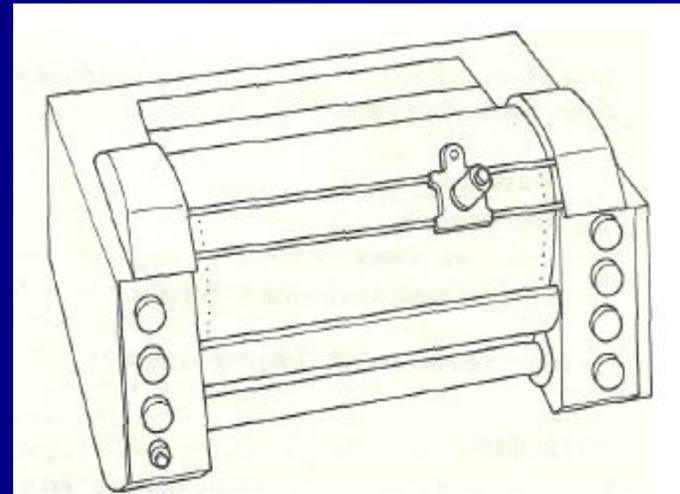
# Keyboard terminals

- The alphanumeric terminal is used to enter commands, functions, and supplemental data to the CAD system. This information is displayed for verification on the CRT or typed on paper. The system also communicates back to the user in a similar manner. Menu listings, program listings, error messages

# Plotters and Output devices

- Pen plotters
- Hard copy units
- Electrostastic plotters
- Computer – output to microfilm (COM) units

- The drum plotter, is generally the least expensive.
- It uses a round drum, usually mounted horizontally, and a slide which can be moved along a track mounted axially with respect to the drum.
- The paper is attached to the drum and the pen is mounted on the slide.
- The relative motion between pen and paper is achieved by coordinating the rotation of the drum with the motion of the slide.
  
- The drum plotter is fast and it can make drawings of virtually unlimited length.
  
- The width, however, is limited by the length of the drum.

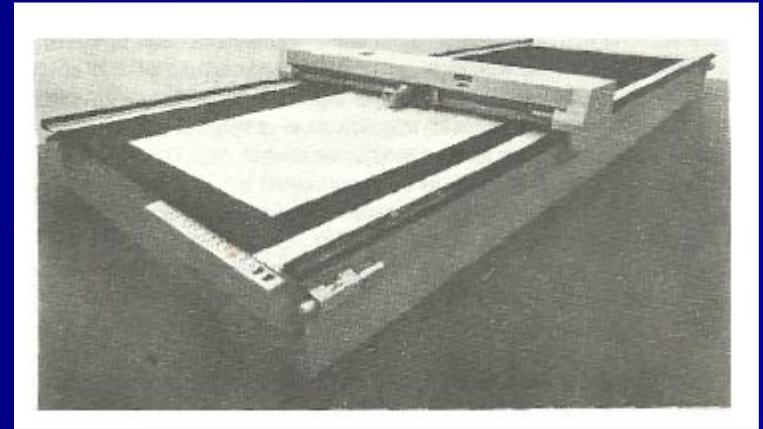


The flat-bed plotter, is more expensive. It uses a flat drawing surface to which the paper is attached.

On some models, the surface is horizontal, while other models use a drawing surface which is mounted in a nearly vertical orientation to conserve floor space.

Parallel tracks are located on two sides of the flat surface. A bridge is driven along these tracks to provide the  $x$ -coordinate motion.

Attached to the bridge is another track, on which rides a writing head.

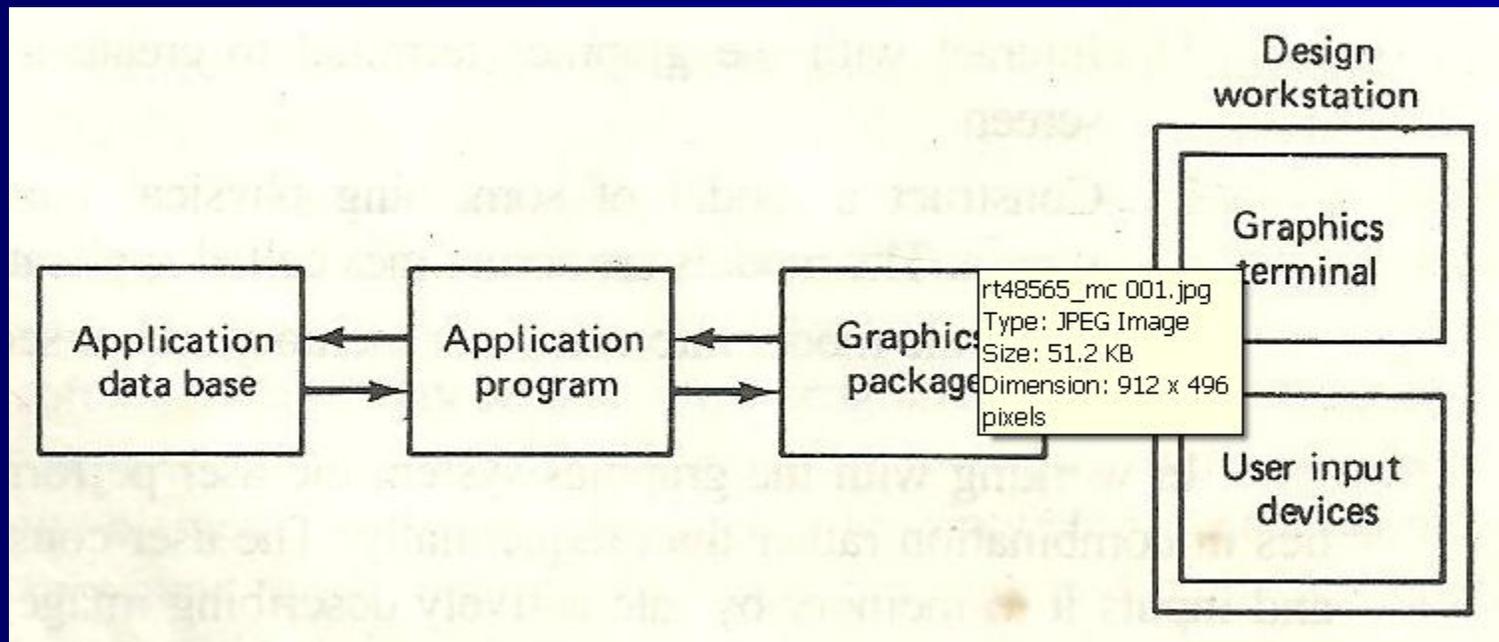


# Computer Graphics Software and Database

Ground rules:

- *Simplicity:* The graphics software should be easy to use.
- *Consistency:* The package should operate in a consistent and predictable way to the user
- *Completeness:* There should be no inconvenient omissions in the set of graphics functions
- *Robustness:* The graphics system should be tolerant of minor instances of misuse by the operator
- *Performance:* Within limitations imposed by the system hardware, the performance should be exploited as much as possible by software. Graphics programs should be efficient and speed of response should be fast and consistent
- *Economy:* Graphics programs should not be so large or expensive as to make their use prohibitive.

# Model of Graphics software configuration



# Functions of GSC

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

- 1. A graphic element in computer graphics is a basic image entity such as a dot (or point), line segment, circle, and so forth. The collection of elements in the system could also include alphanumeric characters and special symbols

- 2. Transformations are used to change the image on the display screen and to reposition the item in the data base. Transformations are applied to the graphic elements in order to aid the user in constructing an application model.

- 3. This function set provides the user with the ability to view the image from the desired angle and at the desired magnification. In effect, it makes use of various transformations to display the application model the way the user wants it shown. This is sometimes referred to as windowing because the graphics screen is like a window being used to observe the graphics model.

- 4. Segmenting functions 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. The segment may define a single element or logical grouping of elements that can be modified as a unit.

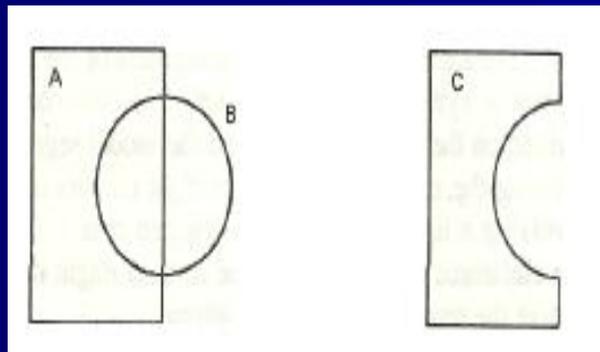
- 5. User input functions constitute a critical set of functions in the graphics package because they permit the operator to enter commands or data to the system. The entry is accomplished by means of operator input devices

# Constructing the Geometry

- 1. First method each new element is being called but before it is added to the model, the user can specify its size, its position, and its orientation. These specifications are necessary to form the model to the proper shape and scale

- 2. The geometric construction process is that graphics elements can be subtracted as well as added.
- 3. During model building is the capability to group several elements together into units which are sometimes called cells. Ex. Bolts

■  $A+B = C$



# Editing the geometry

- A computer-aided design 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.

# TRANSFORMATIONS -2D

- The matrix  $(2, 5)$  would be interpreted to be a point which is 2 units from the origin in the x-direction and 5 units from the origin in the y-direction.
- TRANSLATION- Translation involves moving the element from one location to another.
- $(x', y') = (x, y) + T$

Where,  $x' = x + m$ ,  $y' = y + n$

$x', y'$  = coordinates of the translated point

$x, y$  = coordinates of the original point

$m, n$  = movements x and y direction

# SCALING

- Scaling of an element is used to enlarge it or reduce its size. The scaling need not necessarily be done equally in the  $x$  and  $y$  directions. For example, a circle could be transformed into an ellipse by using unequal  $x$  and  $y$  scaling factors.

# ROTATION

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

# TRANSFORMATIONS -3D

## ■ TRANSLATION

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

## ■ SCALING

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

## ■ Rotation :

$$R_z = \begin{pmatrix} \cos \varnothing & -\sin \varnothing & 0 \\ \sin \varnothing & \cos \varnothing & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$R_y = \begin{pmatrix} \cos \varnothing & 0 & \sin \varnothing \\ 0 & 1 & 0 \\ -\sin \varnothing & 0 & \cos \varnothing \end{pmatrix}$$

$$R_x = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos \varnothing & -\sin \varnothing \\ 0 & \sin \varnothing & \cos \varnothing \end{pmatrix}$$

# Concatenation

- During the editing process when a graphic model is being developed, the use of concatenated transformations is quite common.
- 1. Rotation of the element about an arbitrary point in the element
- 2. Magnifying the element but maintaining the location of one of its points in the same location

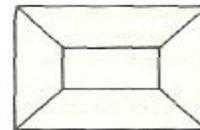
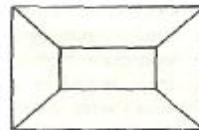
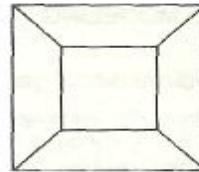
# Concatenation

- In the first case, the sequence of transformations would be: translation to the origin, then rotation about the origin, then translation back to the original location.
- In the second case, the element would be scaled (magnified) followed by a translation to locate the desired point as needed.
- The objective of concatenation is to accomplish a series of image manipulations as a single transformation.

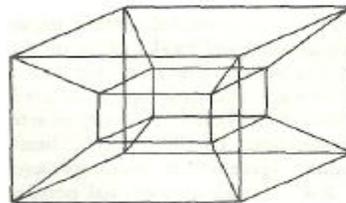
# Wire frame modeling

- For objects in which there are curved surfaces, contour lines can be added, as shown in Figure, to indicate the contour. The image assumes the appearance of a frame constructed out of wire.hence the name "wire-frame" model.

# Wire frame modeling



Orthographic views of three-dimensional object without hidden-line removal.



Perspective view of three-dimensional object of Figure without hidden line removal.

# Solid models

- An improvement over wire-frame models. In this approach, the models are displayed as solid objects to the viewer, with very little risk of misinterpretation. When color is added to the image, the resulting picture becomes strikingly realistic

- 1. Constructive solid geometry (CSG or C-rep), also called the building-block approach
- 2. Boundary representation (B-rep)

# CSG or C Rep

- The user would sketch the various views of the object (front, side, and top, more views if needed), drawing interconnecting lines among the views to establish their relationship. Various transformations and other specialized editing procedures are used to refine the model to the desired shape

# CSG or C Rep

- The C-rep systems usually 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.
- Less storage But more computation reqd.

# B-rep

- Unusual shapes are encountered during design and drawing.
- Ex. Air craft, Turbines, Boilers, Automobile
- Less storage and less computation reqd.
- Easy to convert to B rep and Wire frame model.

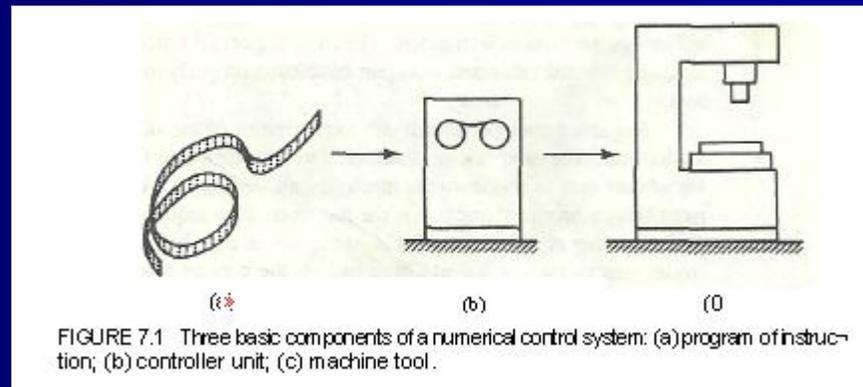
## ■ UNIT - II

# Numerical control defined

- Numerical control can be defined as a form of programmable automation in which the process is controlled by numbers, letters, and symbols. In NC, the numbers form a program of instructions designed for a particular work part or job

## *BASIC COMPONENTS OF AN NC SYSTEM*

1. Program of instructions
2. Controller unit (or) machine control unit (MCU)
3. Machine tool or other controlled process



# Program of instructions

- The program of instructions is the detailed step-by-step set of directions which tell the machine tool what to do.
- It is coded in numerical or symbolic form on some type of input medium that can be interpreted by the controller unit.
- The most common input medium today is 1" wide punched tape

# Controller unit

- The second basic component of the NC system is the controller unit.
- This 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 tape reader, a data buffer, signal output channels to the machine tool, feedback channels from the machine tool.

# Controller unit

- The 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.
- The signal output channels are connected to the servomotors and other controls in the machine tool. Through these channels, the instructions are sent to the machine tool from the controller unit

## Machine tool

- The third basic component of an NC system is the machine tool or other controlled process.
- It is the part of the NC system which performs useful work.
- In the most common example of an NC system, one designed to perform machining operations, the machine tool consists of the worktable and spindle as well as the motors and controls necessary to drive them.
- It also includes the cutting tools, work fixtures, and other auxiliary equipment needed in the machining operation

# Machine tool

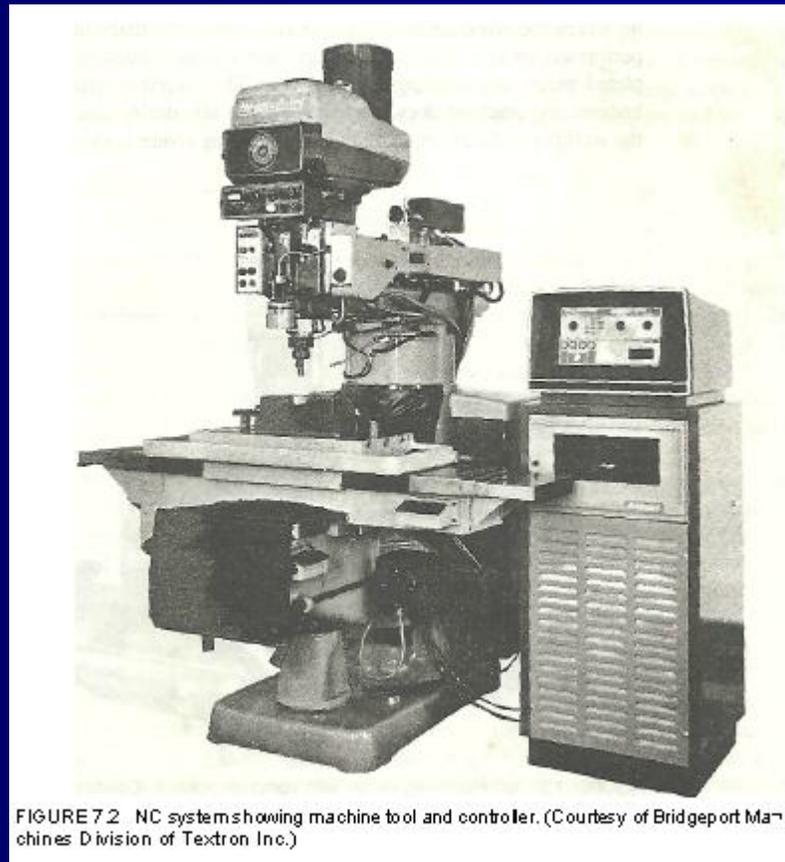


FIGURE 7.2 NC system showing machine tool and controller. (Courtesy of Bridgeport Machines Division of Textron Inc.)

# THE NC PROCEDURE

- 1. *Process planning*

The engineering drawing of the work part must be interpreted in terms of the manufacturing processes to be used. This step is referred to as process planning and 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 work part. It is called a route sheet.

## ***2. Part programming***

- A part programmer plans the process for the portions of the job to be accomplished by NC. Part programmers are knowledgeable about the machining process and they have been trained to program for numerical control. They are responsible for planning the sequence of machining steps to be performed by NC and to document these in a special format.
- Manual part programming
- Computer-assisted part programming
- In manual part programming, the machining instructions are prepared on a form called a part program manuscript. The manuscript is a listing of the relative cutter/work piece positions which must be followed to machine the part.
- In computer-assisted part programming, much of the tedious computational work required in manual part programming is transferred to the computer. This is especially appropriate for complex work piece geometries and jobs with many machining steps. Use of the computer in these situations results in significant savings in part programming time

### **3. *Tape preparation***

- A punched tape is prepared from the part programmer's NC process plan. In manual part programming, the punched tape is prepared directly from the part program manuscript on a type writer like device equipped with tape punching capability.
- In computer-assisted part programming, the computer interprets the list of part programming instructions, performs the necessary calculations to convert this into a detailed set of machine tool motion commands, and 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, a method is usually provided for checking the accuracy of the tape. Sometimes the tape is checked by running it through a computer program which plots the various tool movements (or table movements) on paper.

## 5. *Production*

- This involves ordering the raw work parts, specifying and preparing the tooling and any special fixturing that may be required, and setting up the NC machine tool for the job.
- The machine tool operator's function during production to load the raw work part in the machine and establish the starting position of the cutting tool relative to the work piece.
- The NC system then takes over and machines the part according to the instructions on tape. When the part is completed, the operator removes it from/the machine and loads the next part.

# NC COORDINATE SYSTEMS

- In order for the part programmer to plan the sequence of positions and movements of the cutting tool relative to the work piece, it is necessary to establish a standard axis system by which the relative positions can be specified.
- Two axes,  $x$  and  $y$ , are defined in the plane of the table, as shown in Fig. The  $z$  axis is perpendicular to this plane and movement in the  $z$  direction is controlled by the vertical motion of the spindle. The positive and negative directions of motion of tool relative to table along these axes are as shown in Fig.
- NC drill presses are classified as either two-axis or three-axis machines, depending on whether or not they have the capability to control the  $z$  axis.

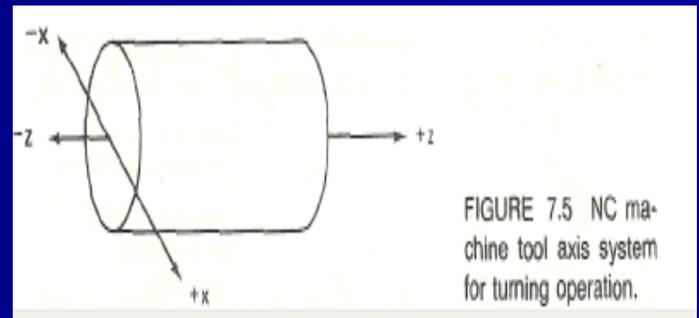
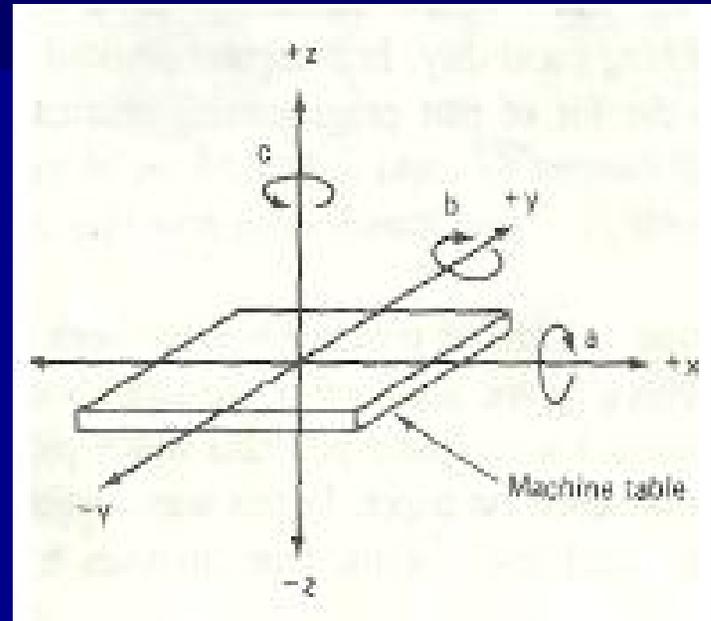


FIGURE 7.5 NC machine tool axis system for turning operation.

# Fixed zero

- The programmer must determine the position of the tool relative to the origin (zero point) of the coordinate system.
- NC machines have either of two methods for specifying the zero point.
- The first possibility is for the machine to have a *fixed zero*. In this case, the origin is always located at the same position on the machine table. Usually, that position is the southwest corner (lower left-hand corner) of the table and all tool locations will be defined by positive  $x$  and  $y$  coordinates.

# Floating zero

- The second and more common feature on modern NC machines allows the machine operator to set the zero point at any position on the machine table. This feature is called *floating zero*. The part programmer is the one who decides where the zero point should be located. The decision is based on part programming convenience

# Absolute positioning and incremental positioning

- *Absolute positioning* means that the tool locations are always defined in relation to the zero point.
- *incremental positioning* means that the next tool location must be defined with reference to the previous tool location.

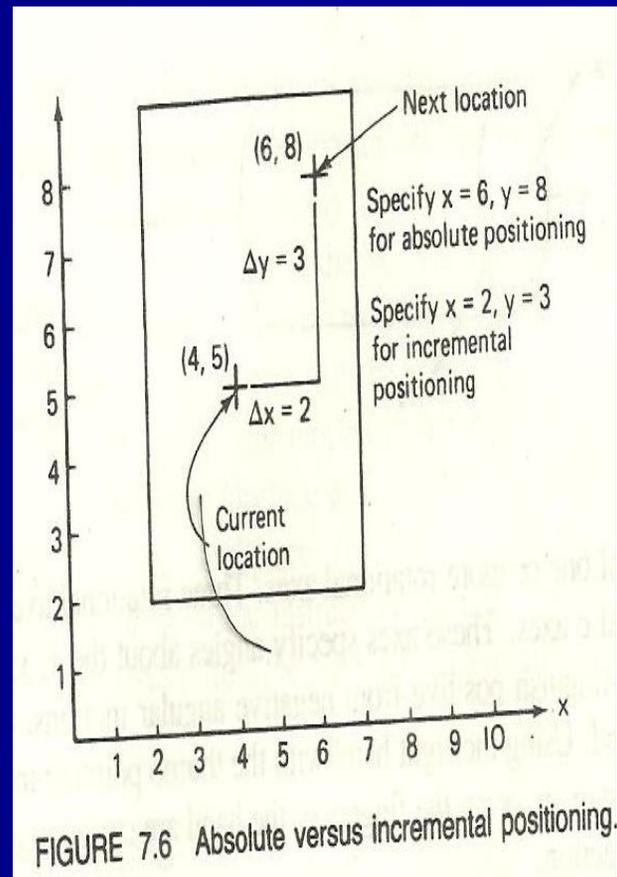


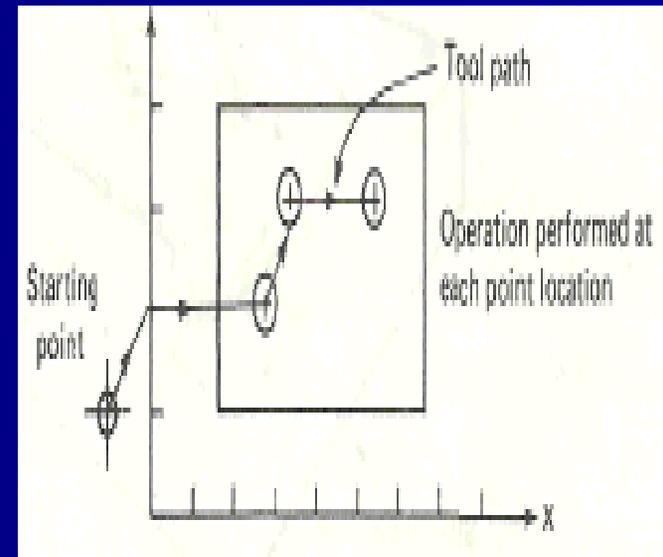
FIGURE 7.6 Absolute versus incremental positioning.

# NC MOTION CONTROL SYSTEMS

- 1. Point-to-point
- 2. Straight cut
- 3. Contouring

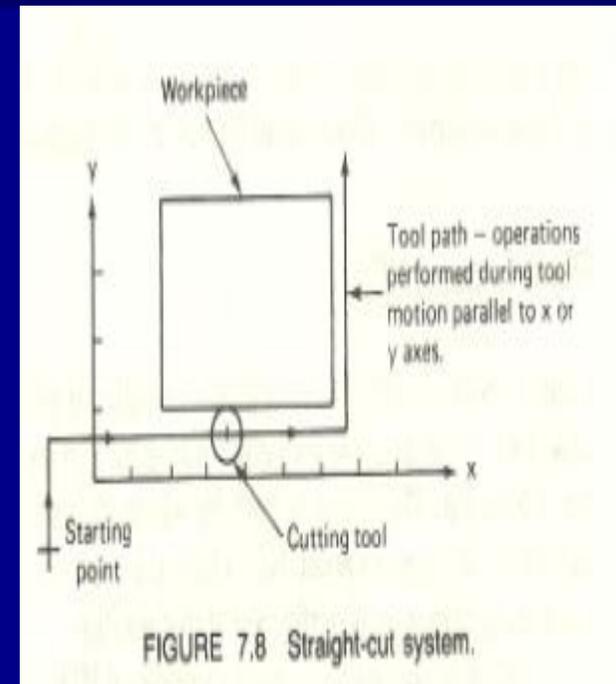
# Point-to-point NC

- Point-to-point (PTP) is also sometimes called a positioning system. In PTP, the objective of the machine tool control system is to move the cutting tool to a predefined location.
- The speed or path by which this movement is accomplished is not important in point-to-point NC.
- Once the tool reaches the desired location, the machining operation is performed at that position.
- Positioning systems are the simplest machine tool control systems and are therefore the least expensive of the three types.
- However, for certain processes, such as drilling operations and spot welding, PTP is perfectly suited to the task.



# Straight-cut NC

- Moving the cutting tool parallel to one of the major axes at a controlled rate suitable for machining.
- It is therefore appropriate for performing milling operations to fabricate work pieces of rectangular configurations.
- With this type of NC system it is not possible to combine movements in more than a single axis direction.
- Therefore, angular cuts on the work piece would not be possible. An example of a straight-cut operation is shown in Figure



# Contouring NC

- Contouring is the most complex, the most flexible, and the most expensive type of machine tool control.
- It is capable of performing both FTP and straight-cut operations.
- In addition, the distinguishing feature of contouring NC systems is their capacity for simultaneous control of more than one axis movement of the machine tool.
- The path of the cutter is continuously controlled to generate the desired geometry of the work piece.
- In order to machine a curved path in a numerical control contouring system, the direction of the feed rate must continuously 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.

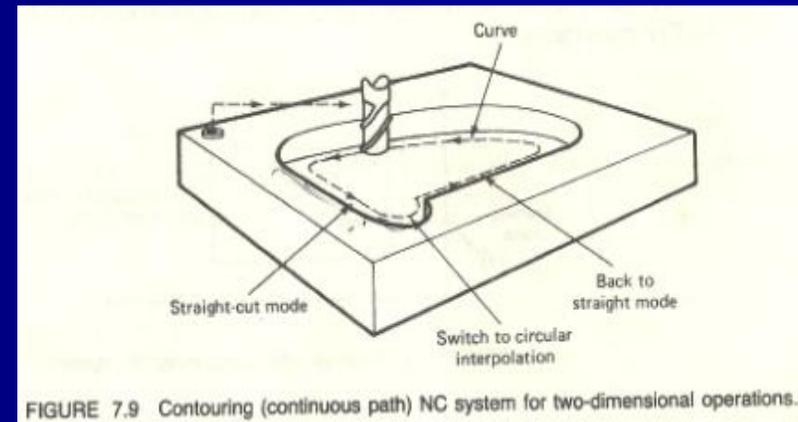


FIGURE 7.9 Contouring (continuous path) NC system for two-dimensional operations.

# APPLICATIONS OF NUMERICAL CONTROL

Milling, Drilling, Boring, Turning, Grinding, Sawing

- Within the machining category, NC machine tools are appropriate for certain jobs like:
  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 work part.
  7. It is an expensive part where mistakes in processing would be costly.
  8. The parts require 100% inspection

# ECONOMICS OF NUMERICAL CONTROL

- Advantages of NC
- 1. *Reduced nonproductive time:* Numerical control has little or no effect on the basic metal cutting (or other manufacturing) process.
- NC can increase the proportion of time the machine is engaged in the actual process. It accomplishes this by means of fewer setups, less time in setting up, reduced work-piece handling time, automatic tool changes on some machines, and so on.
- 2. *Reduced fixturing:* NC requires fixtures which are simpler and less costly to fabricate because the positioning is done by the NC tape rather than the jig or fixture.

- *3. Reduced manufacturing lead time:*
  - Because jobs can be set up more quickly with NC and fewer setups are generally required with NC, the lead time to deliver a job to the customer is reduced.
- *4. Greater manufacturing flexibility:*
  - With numerical control it is less difficult to adapt to engineering design changes, alterations of the production schedule, changeovers in jobs for rush orders.
- *5. Improved quality control:*
  - NC is ideal for complicated work parts where the chances of human mistakes are high. Numerical control produces parts with greater accuracy, reduced scrap, and lower inspection requirements.

- *6. Reduced inventory.* Owing to fewer setups and shorter lead times with numerical control, the amount of inventory carried by the company is reduced.
- *7. Reduced floor space requirements.*  
Since one NC machining center can often accomplish the production of several conventional machines, the amount of floor space required in an NC shop is usually less than in a conventional shop.

# Disadvantages of NC

- 1. *Higher investment cost.* Numerical control machine tools represent a more sophisticated and complex technology. This technology costs more to buy than its non-NC counterpart. The higher cost requires manufacturing managements to use these machines more aggressively than ordinary equipment. High machine utilization is essential in order to get reasonable returns on investment. Machine shops must operate their NC machines two or three shifts per day to achieve this high machine utilization.
- 2. *Higher maintenance cost.* Because NC is a more complex technology and because NC machines are used harder, the maintenance problem becomes more acute. Although the reliability of NC systems has been improved over the years, maintenance costs for NC machines will generally be higher than for conventional machine tools.
- 3. *Finding and/or training NC personnel.* Certain aspects of numerical control shop operations require a higher skill level than conventional operations. Part programmers and NC maintenance personnel are two skill areas where available personnel are in short supply. The problems of finding, hiring, and training these people must be considered a disadvantage to the NC shop.

# Languages:

- ***APT (Automatically Programmed Tools)***. The APT language was the product of the MIT developmental work on NC programming systems.
- Although first intended as a contouring language, modern versions of APT can be used for both positioning and continuous-path programming in up to five axes.
- Versions of APT for particular processes include APTURN (for lathe operations), APTMIL (for milling and drilling operations), and APTPOINT (for point-to-point operations).

- **ADAPT (ADaptation of APT).** Several part programming languages are based directly on the APT program. One of these is ADAPT, which was developed by IBM under Air Force contract. It was intended to provide many of the features of APT but to utilize a smaller computer.

The full APT program requires a computing system that would have been considered large by the standards of the 1960s. This precluded its use by many small and medium-sized firms that did not have access to a large computer.

ADAPT is not as powerful as APT, but it can be used to program for both positioning and contouring jobs.

- **EXAPT (Extended subset of APT).** This was developed in Germany starting around 1964 and is based on the APT language.

There are three, versions: EXAPT I—designed for positioning (drilling and also straight-cut milling), EXAPT II—designed for turning, and EXAPT III—designed for limited contouring operations.

One of the important features of EXAPT is that it attempts to compute optimum feeds and speeds automatically.

- **UNI APT.** The UNIAPT package represents another attempt to adapt the APT language to use on smaller computers. The name derives from the developer, the United Computing Corp. of Carson, California.
- Their efforts have provided a limited version of APT to be implemented on minicomputers, thus allowing many smaller shops to possess computer-assisted programming capacity.
- **SPLIT (Sundstrand Processing Language Internally Translated).** This is a proprietary system intended for Sundstrand's machine tools. It can handle up to five-axis positioning and possesses contouring capability as well.
- One of the unusual features of SPLIT is that the postprocessor is built into the program. Each machine tool uses its own SPLIT package, thus obviating the need for a special postprocessor.

# Apt language:

- APT is not only an NC language; it is also the computer program that performs the calculations to generate cutter positions based on APT statements
- APT is a three-dimensional system that can be used to control up to five axes. We will limit our discussion to the more familiar three axes,  $x$ ,  $y$ , and  $z$ , and exclude rotational coordinates. APT can be used to control a variety of different machining operations. We will cover only drilling and milling applications. There are over 400 words in the APT vocabulary. (There are four types of statements in the APT language:
  1. *Geometry statements.* These define the geometric elements that comprise the work part. They are also sometimes called definition statements.
  2. *Motion statements.* These are used to describe the path taken by the cutting tool.
  3. *Post processor statements.* These apply to the specific machine tool and control system. They are used to specify feeds and speeds and to actuate other features of the machine.
  4. *Auxiliary statements.* These are miscellaneous statements used to identify the part, tool, tolerances, and so on.

## Advantages of NC programming:

- 1. *Savings in geometry definition.* Since the part geometry data have already been created during design using the CAD/CAM graphics system, the part programmer is not required to redefine the geometry of the part. This can be a time-consuming procedure in conventional APT programming.
- 2. *Immediate visual verification.* The graphics terminal provides a display of the tool path for immediate verification by the part programmer. Most programming errors can be detected by the user and corrected at the time the error is made. With conventional APT or other NC language, there is a delay between writing the program and the verification/correction process.
- 3. *Use of automatic programming routines.* For common part programming situations such as profiling and pocketing, the use of automatic MACRO-type routines yields a significant reduction in part programming time.

- 4. *One-of-a-kind jobs*. Because the part programming time is significantly reduced when using a CAD/CAM system, numerical control becomes an economically attractive method for producing one-of-a-kind jobs. Without CAD/CAM, the time required to prepare the part program represents a significant obstacle which often precludes the use of NC for one/off production.
- 5. *Integration with other related functions*. There is the obvious opportunity to integrate the product design function with part programming. Other opportunities for functional integration within manufacturing also exist. These include tool design, process planning, preparation of operator and setup instructions, grouping of parts into families for programming convenience,

# VOICE NC PROGRAMMING

- Voice programming of NC machines (abbreviated VNC) involves vocal communication of the machining procedure to a voice-input NC tape-preparation system.
- VNC allows the programmer to avoid steps such as writing the program by hand, keypunching or typing, and manual verification.
- One of the principal companies specializing in voice-input systems is Threshold Technology, Inc., of Delran, New Jersey.
- To perform the part programming process with VNC, the operator speaks into a headband microphone designed to reduce background acoustical noise.
- Communication of the programming instructions is in shop language with such terms as "turn," "thread," and "mill line," together with numbers to provide dimensional and coordinate data.
- Before the voice-input system can be used, it must be "trained" to recognize and accept the individual programmer's voice pattern.

- This is accomplished by repeating each word of the vocabulary about five times to provide a reference set which can subsequently be compared to voice commands given during actual programming.
- The entire vocabulary for the Threshold system contains about 100 words.
- Most NC programming jobs can be completed by using about 30 of these vocabulary words.
- In talking to the system, the programmer must isolate each word by pausing before and after the word.
- The pause must be only one-tenth of a second or longer. This allows the speech recognition system to identify boundaries for the uttered command so that its wave characteristics can be compared with words in the reference set for that programmer.
- Typical word input rates under this restriction are claimed to be about 70 per minute.

# Problems with NC

- 1. *Part programming mistakes.*

In preparing the punched tape, part programming mistakes are common. The mistakes can be either syntax or numerical errors, and it is not uncommon for three or more passes to be required before the NC tape is correct. Another related problem in part programming is to achieve the best sequence of processing steps. This is mainly a problem in manual part programming. Some of the computer-assisted part programming languages provide aids to achieve the best operation sequences.

- 2. *Non optimal speeds and feeds.*

In conventional numerical control, the control system does not provide the opportunity to make changes in speeds and feeds during the cutting process. As a consequence, the programmer must set the speeds and feeds for worst-case conditions. The result is lower than optimum productivity.

- 3. *Punched tape.*

Another problem related to programming is the tape itself. Paper tape is especially fragile, and its susceptibility to wear and tear causes it to be an 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

# Problems with NC

- 4. *Tape reader.*

The tape reader that interprets the punched tape is generally acknowledged among NC users to be the least reliable hardware component of the machine. When a breakdown is encountered on an NC machine, the maintenance personnel usually begin their search for the problem with the tape reader.

- 5. *Controller.*

The conventional NC controller unit is hard-wired. This means that its control features cannot be easily altered to incorporate improvements into the unit. Use of a computer as the control device would provide the flexibility to make improvements in such features as circular interpolation when better software becomes available.

- 6. *Management information.*

The conventional NC system is not equipped to provide timely information on operational performance to management. Such information might include piece counts, machine breakdowns, and tool changes.

# NC CONTROLLER TECHNOLOGY

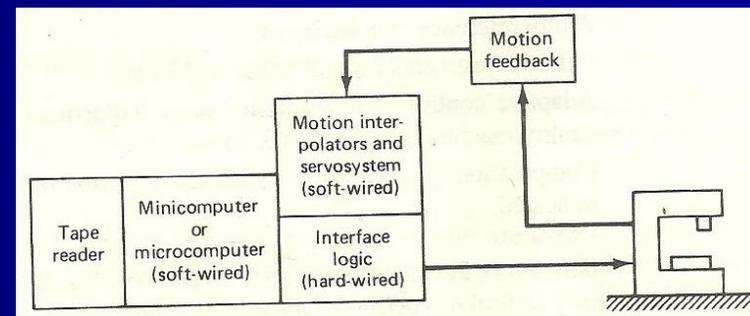
- The hardware technology in NC controls has changed dramatically over the years. At least seven generations of controller hardware can be identified.
  - 1. Vacuum tubes (circa 1952)
  - 2. Electromechanical relays (circa 1955)
  - 3. Discrete semiconductors (circa 1960)
  - 4. Integrated circuits (circa 1965)
  - 5. Direct numerical control (circa 1968)
  - 6. Computer numerical control (circa 1970)
  - 7. Microprocessors and microcomputers (circa 1975)

# Functions of CNC

- There are a number of functions which CNC is designed to perform. Several of these functions would be either impossible or very difficult to accomplish with conventional NC. The principal functions of CNC are:
  - 1. Machine tool control
  - 2. In-process compensation
  - 3. Improved programming and operating features
  - 4. Diagnostics

- (MACHINE TOOL CONTROL. The primary function of the CNC system is control of the machine tool. This involves conversion of the part program instructions into machine tool motions through the computer interface and servo systems
  
- This fact has lead to the development of two alternative controller designs in CNC:
  - 1. Hybrid CNC
  - 2. Straight CNC

- In the hybrid CNC system, the controller consists of the soft-wired computer plus hard-wired logic circuits. The hard-wired components perform those functions which they do best, such as feed rate generation and circular interpolation.
- The computer performs the remaining control functions plus other duties not normally associated with a conventional hard-wired controller.
- There are several reasons for the popularity of the hybrid CNC configuration. As mentioned previously, certain NC functions can be performed more efficiently with the hard-wired circuits.



- 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 machine tool and the operator's console.
- Interpolation, tool position feedback, and all other functions are performed by computer software
- Accordingly, the computer required in a straight CNC system must be more powerful than that needed for a hybrid system.
- The advantage gained in the straight CNC configuration is additional flexibility.
- It is possible to make changes in the interpolation programs, whereas the logic contained in the hard-wired circuits of hybrid CNC cannot be altered.

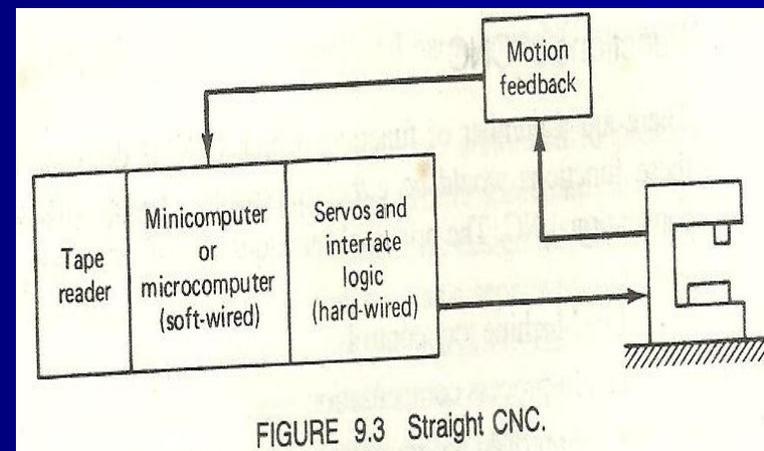


FIGURE 9.3 Straight CNC.

# In-Process Compensation.

- A function closely related to machine tool control is in-process compensation. (This involves the dynamic correction of the machine tool motions for changes or errors which occur during processing)
- Some of the options included within the category of CNC in-process compensation are:
  - Adjustments for errors sensed by in-process inspection probes and gauges.
  - Recomputation of axis positions when an inspection probe is used to locate a datum reference on a work part. 'Offset adjustments for tool radius and length.
  - Adaptive control adjustments to speed and/or feed. Computation of predicted tool life and selection of alternative tooling when indicated.

# Improved programming and operating features

- The flexibility of soft-wired control has permitted the introduction of many convenient programming and operating features.) Included among these features are the following:
  - Editing of part programs at the machine. This permits correction or optimization of the program.
  - graphic display of the tool path to verify the tape.
  - Various types of interpolation: circular, parabolic, and cubic interpolation.
  - Support of both U.S. customary units and metric units (International System). Use of specially written subroutines.
  - Manual data input (MDI).
  - Local storage of more than one part program.

# Diagnostics

- NC machine tools are complex and expensive systems.
- The complexity increases the risk of component failures which lead to system downtime. It also requires that the maintenance personnel be trained to a higher level of proficiency in order to make repairs.
- The higher cost of NC provides a motivation to avoid downtime as much as possible.
- CNC machines are often equipped with a diagnostics capability to assist in maintaining and repairing the system.
- These diagnostics features are still undergoing development and future systems will be much more powerful in their capabilities than current CNC units.
- Ideally, the diagnostics subsystem would accomplish several functions.

- **First**, the subsystem would be able to identify the reason for a downtime occurrence so that the maintenance personnel could make repairs more quickly.
- **Second**, the diagnostics subsystem, would be alert to signs that indicate the imminent failure of a certain component. Hence maintenance personnel could replace the faulty component during a scheduled downtime, thus avoiding an unplanned interruption of production.
- **A third** possible function which goes beyond the normal diagnostics capability is for the CNC system to contain a certain amount of redundancy of components which are considered unreliable.
- When one of these components fails, the diagnostics subsystem would automatically disconnect the faulty component and activate the redundant component. Repairs could thus be accomplished without any breaks in normal operations.

# Advantages of CNC

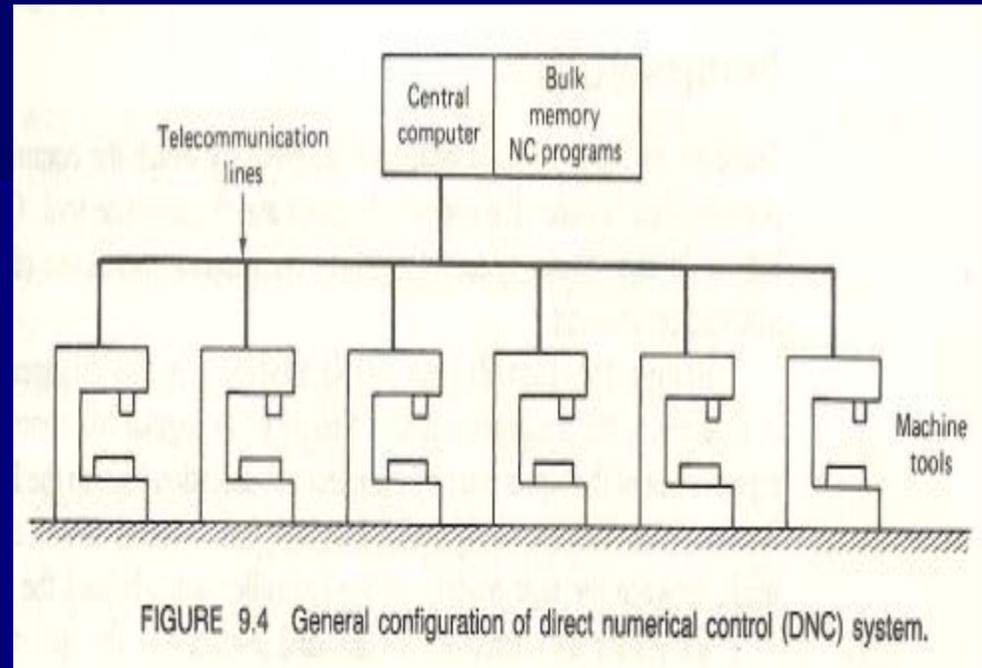
- 1. *The part program tape and tape reader are used only once* to enter the program into computer memory. This results in improved reliability, since the tape reader is commonly considered the least reliable component of a conventional NC system.
- 2. *Tape editing at the machine site.* The NC tape can be corrected and even optimized (e.g., tool path, speeds, and feeds) during tape try out at the site of the machine tool.
- 3. *Metric conversion.* CNC can accommodate conversion of tapes prepared in units of inches into the International System of units.

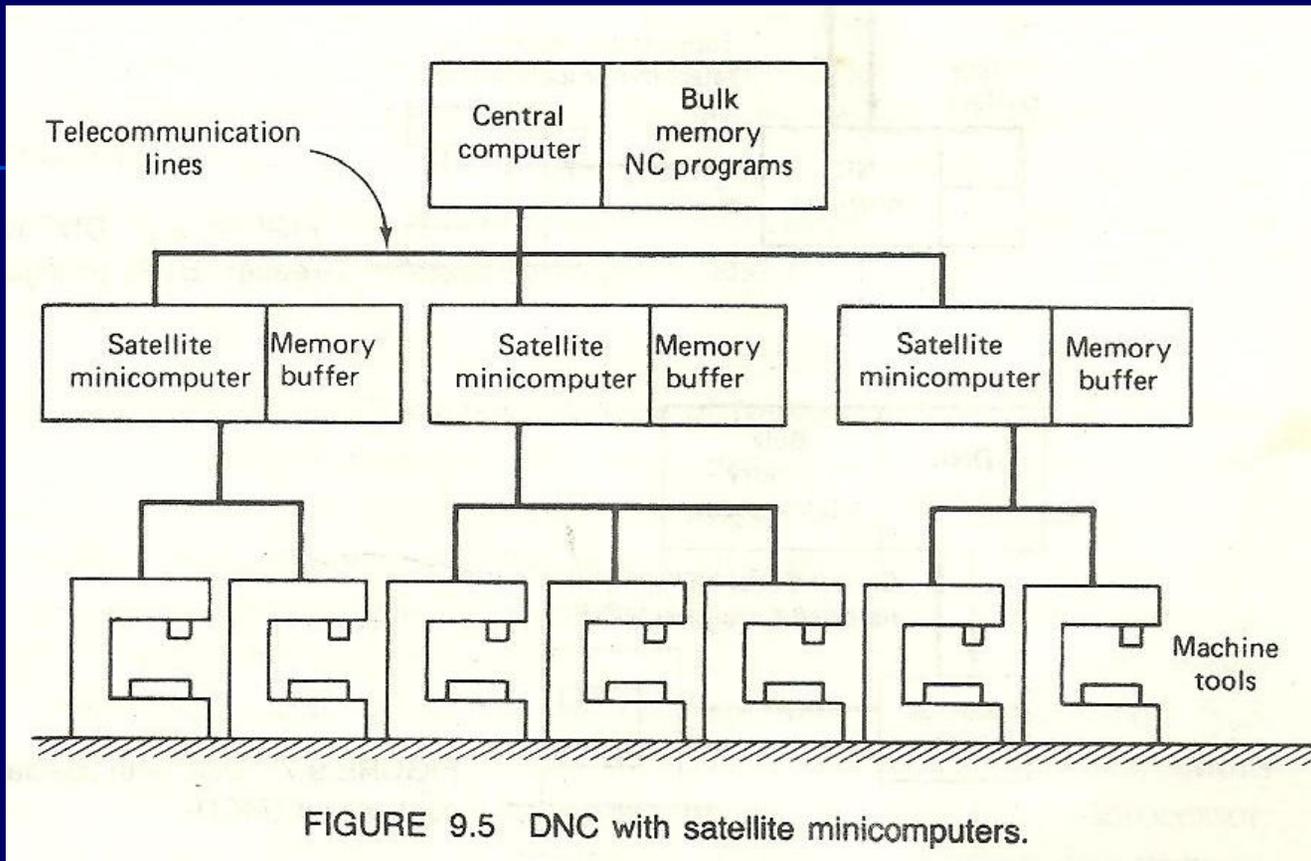
- 4. *Greater flexibility.* One of the more significant advantages of CNC over conventional NC is its flexibility. This flexibility provides the opportunity to introduce new control options (e.g., new interpolation schemes) with relative ease at low cost. The risk of obsolescence of the CNC system is thereby reduced.
- 5. *User-written programs.* One of the possibilities not originally anticipated for CNC was the generation of specialized programs by the user. These programs generally take the form of MACRO subroutines stored in CNC memory which can be called by the part program to execute frequently used cutting sequences.
- 6. *Total manufacturing system.* CNC is more compatible with the use of a computerized factory-wide manufacturing system. One of the stepping stones toward such a system is the concept of direct numerical control.

# DIRECT NUMERICAL CONTROL

- Direct numerical control can be defined as a manufacturing system in which a number of machines are controlled by a computer through direct connection and in real time.
- The tape reader is omitted in DNC, thus relieving the system of its least reliable component. Instead of using the tape reader, the part program is transmitted to the machine tool directly from the computer memory.
- In principle, one large computer can be used to control more than 100 separate machines. The DNC computer is designed to provide instructions to each machine tool on demand. When the machine needs control commands, they are communicated to it immediately. DNC also involves data collection and processing from the machine 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





# Advantages of DNC

- 1. *Elimination of punched tapes and tape readers.*  
Direct numerical control eliminates the least reliable element in the conventional NC system. In some DNC systems, the hard-wired control unit is also eliminated, and replaced by a special machine control unit designed to be more compatible with DNC operation.
- 2. *Greater computational capability and flexibility.*  
The large DNC computer provides the opportunity to perform the computational and data processing functions more effectively than traditional NC. Because these functions are implemented with software rather than with hard-wired devices, there exists the flexibility to alter and improve the method by which these functions are carried out.
- 3. *Convenient storage of NC part programs in computer files.*  
This compares with the more manually oriented storage of punched tapes in conventional NC.

- *4. Programs stored as CLFILE.*

Storage of part programs in DNC is generally in the form of cutter path data rather than post processed programs for specific machine tools. Storing of the programs in this more general format affords the flexibility in production scheduling to process a job on any of several different machine tools.

- *5. Reporting of shop performance.*

One of the important features in DNC involves the collection, processing, and reporting of production performance data from the NC machines.

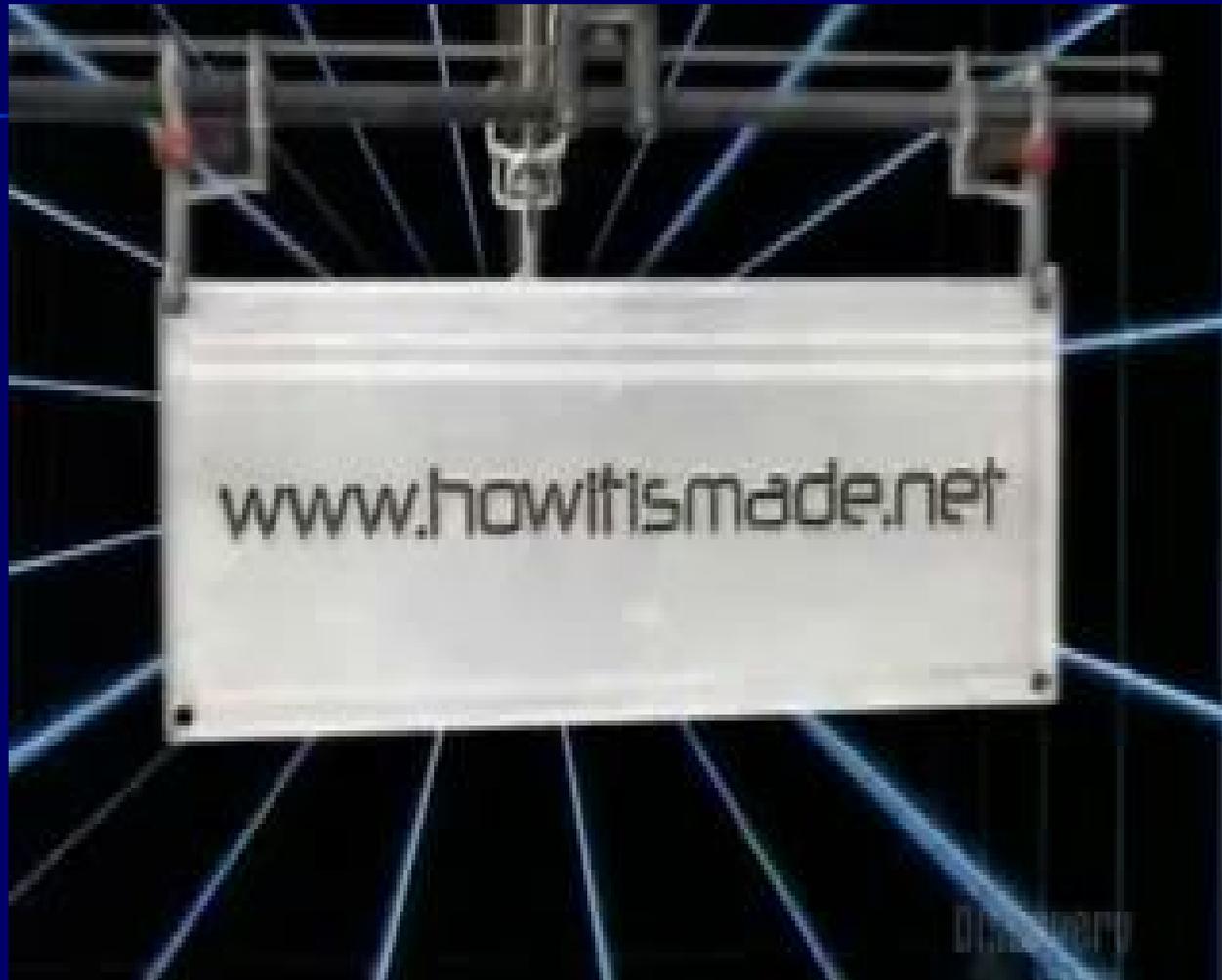
- *6. Establishes the framework for the evolution of the future computer-automated factory.*

The direct numerical control concept represents a first step in the development of production plants which will be managed by computer systems.

# Working of an CNC:



# Automation using CAM



# Computer Aided Manufacturing



## ■ UNIT -III

# Important questions:

1. Explain
  1. Entities,
  2. Cross hatching
  3. Pattern filling
  4. Display
2. Explain
  1. Layers
  2. Edit commands
3. Write commands and their sequence to create 2D wire frame models
  1. A Shaft
  2. A Spur gear.
4. Describe the various graphical input techniques with suitable line Diagrams
5. Explain the various graphical input techniques used for the computer graphics
6. Explain layering
7. Distinguish between rubber banding and dragging
8. Explain cross hatching and pattern filling
9. Edit commands with diagrams
10. What is constructive solid geometry?
11. Explain the drawing utilities
12. Write a short note:
  - (a) Edit commands.
  - (b) Cross hatching.
  - (c) Line types
13. What are the commands and their sequence to create 2D wire frame models j following components?
  - (i) Helical gear.
  - (ii) Shaft
14. Explain the various graphics standards can be used for data exchange

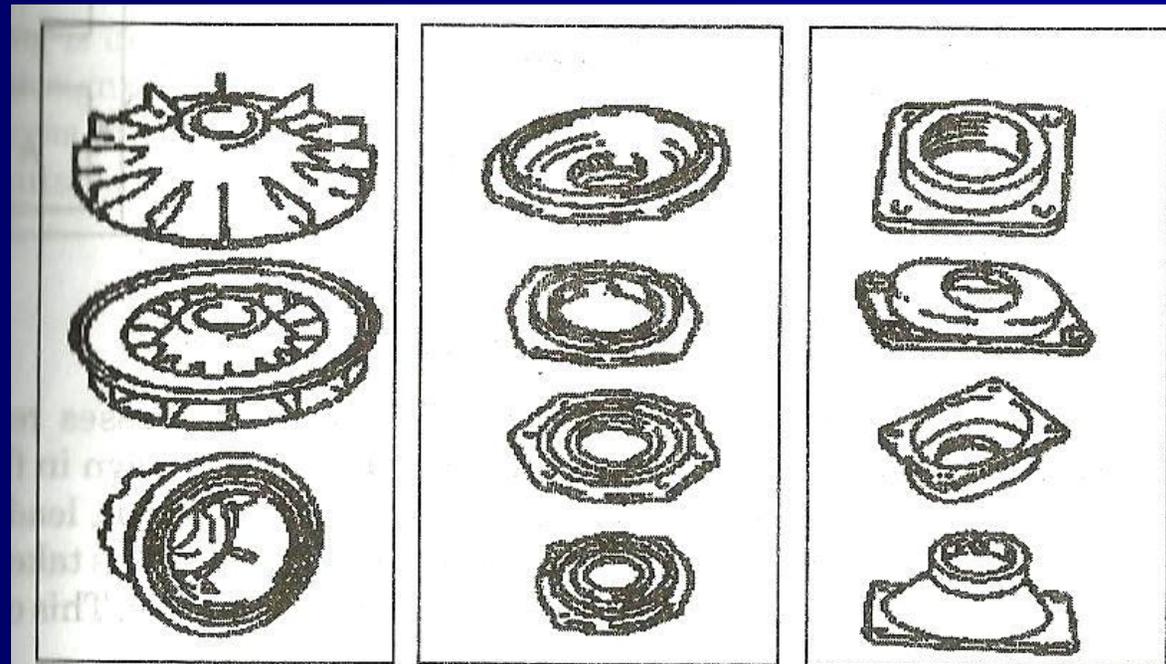
# **UNIT-IV**

## **Group Technology**

# Group Technology

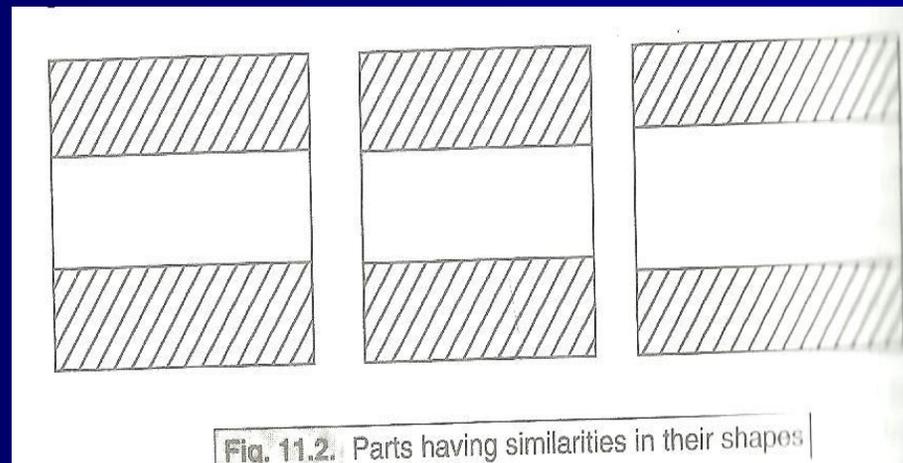
- Group technology concept works on the principle of integration of identical parts components to get economic advantage.
- It is a philosophy which implies that identical or components are grouped together on the basis of design and manufacturing
- This group of parts or components is called part family

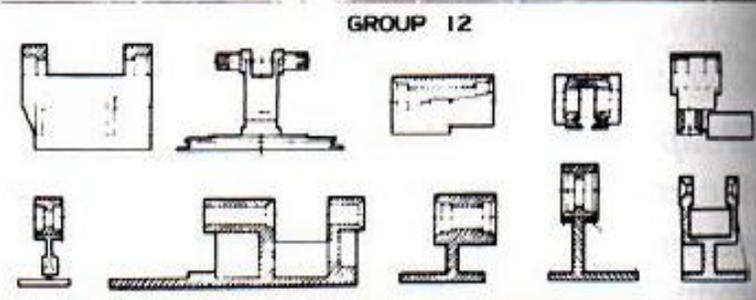
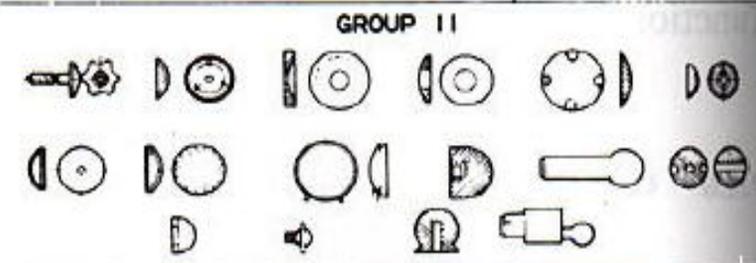
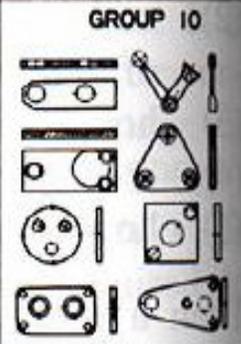
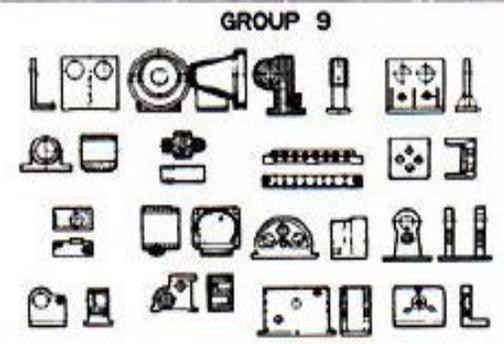
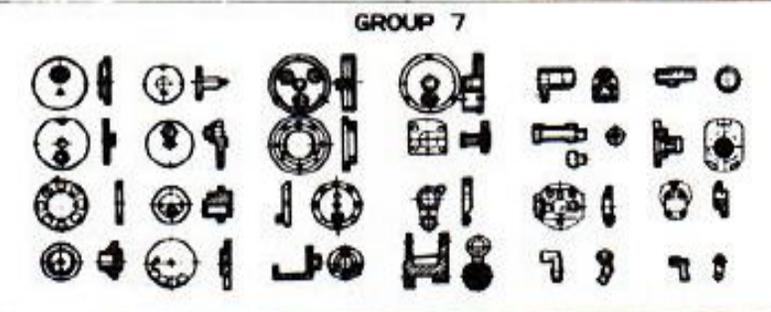
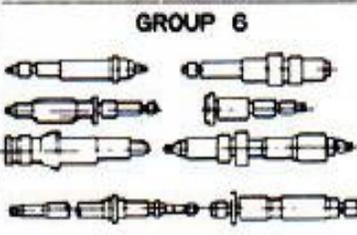
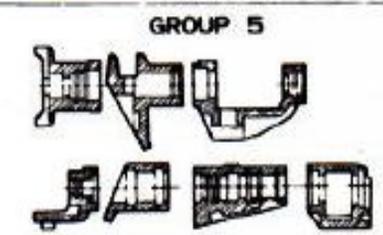
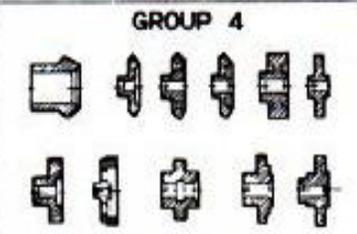
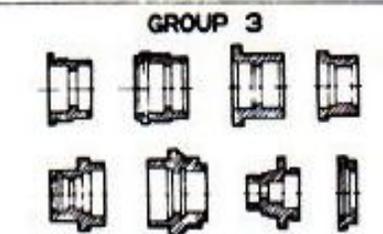
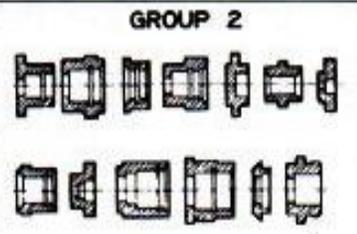
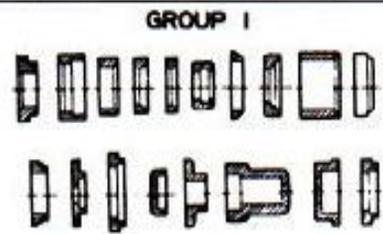
# Group Technology



**Fig. 11.1** Parts having similarities in their manufacturing processes  
(Source: Hyer and Wemmerlov (2002))

# Group Technology





RAGGRUPPAMENTO PEZZI PER SIMILARITA' DI FORMA

# Group Technology

Table 11.1 Design and manufacturing attributes

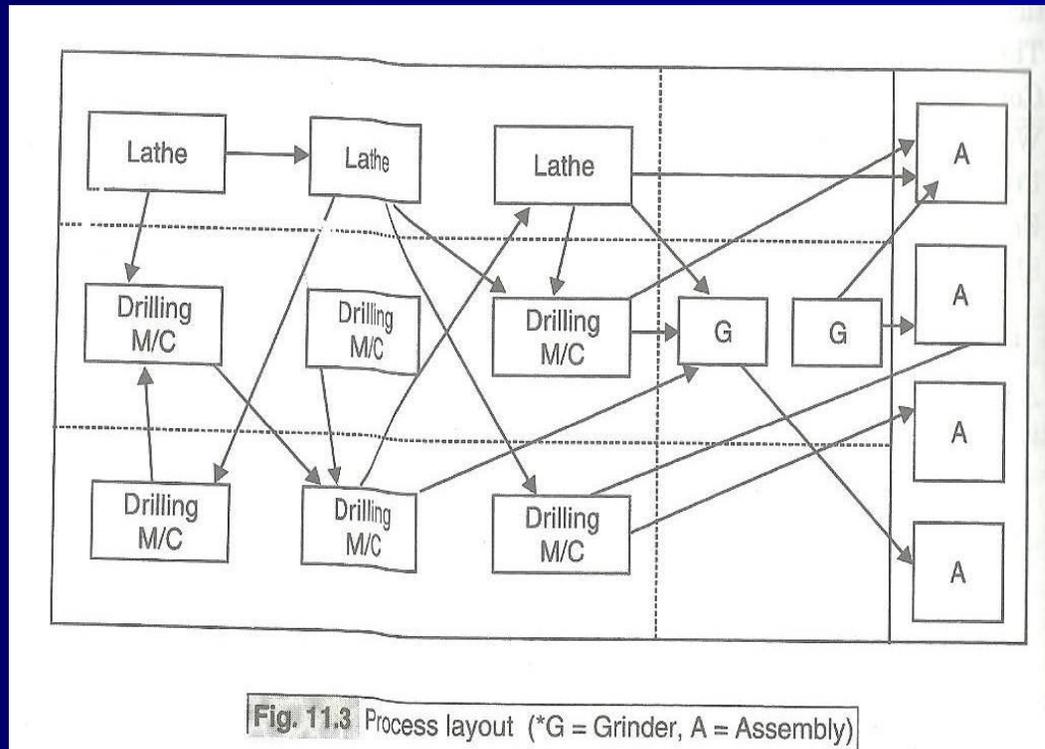
Design Attributes	Manufacturing Attributes
Shape (May be External or Internal)	Manufacturing processes
Rotational, prismatic and sheet metal	Manufacturing equipments
Length/ Diameter ratio	Process sequence
Major/Minor dimensions	Surface treatments
Material	Production time and rate
Tolerances	Cutting tools
Surface Finish	Jigs, Fixtures required

There are three construction methods...

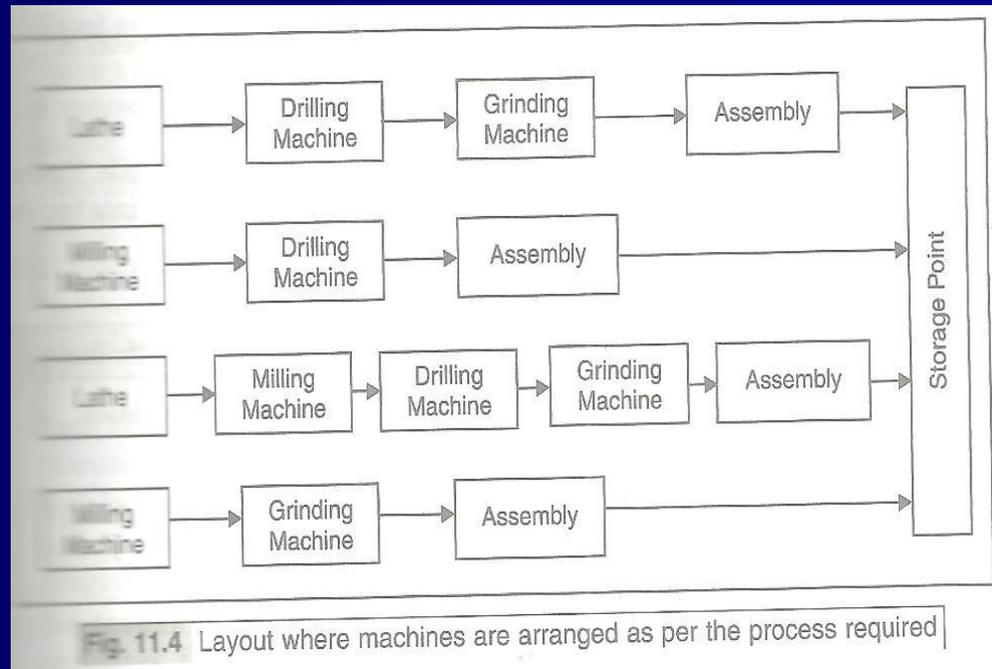
# Group Technology

- Components or parts are classified in families.
- Work loads are balanced between production groups.
- Production groups are clearly identifiable on the shop floor.
- Each group works with a significant degree of autonomy.
- Short cycle flow control to order the parts which are to be made by each group

# Group Technology



# Group Technology



# Group Technology

Organization.

Functional Area	Benefit/Advantage
Design	<ul style="list-style-type: none"> <li>◆ Reduction in number of drawings</li> <li>◆ Reduction in time to identify the drawings</li> <li>◆ Easy modification of designs</li> </ul>
Production, Planning and Control	<ul style="list-style-type: none"> <li>◆ Reduction set up and production time</li> <li>◆ Improved machine loading</li> <li>◆ Reduction in work in process inventory.</li> <li>◆ Simplified production scheduling</li> <li>◆ Easy identification of bottlenecks</li> <li>◆ Reduces complexity and size of parts scheduling problem</li> <li>◆ Reduces manufacturing lead time</li> <li>◆ Leads to automated process planning</li> </ul>
Layout	<ul style="list-style-type: none"> <li>◆ Reduces floor space required for production</li> <li>◆ Less material movements</li> <li>◆ Less material handling efforts</li> <li>◆ More flexibility</li> </ul>
Tooling and Equipment	<ul style="list-style-type: none"> <li>◆ Reduces changes in set up</li> <li>◆ Standardization of tools and equipments</li> <li>◆ Less number of tools, jigs and fixtures required</li> <li>◆ Better utilization of tools and equipments</li> </ul>

# Group Technology

Quality Control	<ul style="list-style-type: none"><li>◆ Less number of defects and rejections</li><li>◆ More precise parts</li><li>◆ Better output quality</li><li>◆ Leads to automated quality control system</li></ul>
Human Resource	<ul style="list-style-type: none"><li>◆ Improved worker's attitude</li><li>◆ Higher level of job satisfaction</li><li>◆ Better delegation and responsibility</li><li>◆ Better management worker relationship</li></ul>
Others	<ul style="list-style-type: none"><li>◆ Accurate and quick cost estimates</li><li>◆ Less number of parts and raw material</li><li>◆ Provides standardized rule for purchasing</li></ul>

# Group Technology

- **First major limitation of group technology system is cost of implementation is high.**
- **Rearranging or reorganizing of machines is very difficult and time consuming process.**
- **There are large numbers of group technology codes.**
- **It may not be suitable when very wide varieties of product.**

# Group Technology: Types

- Visual inspection:
- The visual inspection method is the least sophisticated and least expensive.
- It involves the classification of parts into families by looking at either the physical parts or photographs and arranging them into similar groupings.
- This method is generally considered to be the least accurate of the three.

# Group Technology: Types

- Production flow Analysis (PFA) is a method of identifying part families and associated machine tools groupings by analyzing the route sheets for parts produced in a given shop. It groups together the parts that have similar operation sequences and machine routings.
- The disadvantage of PFA is that it accepts the validity of existing route sheets, with no consideration given to whether these process plans are logical or consistent.

# Group Technology:Types

- Parts classification and coding system
- The third method, parts classification and coding, is the most time consuming and complicated of the three methods. However, it is the most frequently applied method and is generally recognized to be the most powerful of the three.

# Parts classification and Coding:

- This method of grouping parts into families involves an examination of the individual design and/or manufacturing attributes of each part. The attributes of the part are uniquely identified by means of a code number. This classification and coding may be carried out on the entire list of active parts of the firm, or a sampling process may be used to establish the part families. For example, parts produced in the shop during a certain given time period could be examined to identify part family categories

# Parts classification and Coding:

- Many parts classification and coding systems have been developed throughout the world, and there are several commercially available packages being sold to industrial concerns. It should be noted that none of them has been universally adopted. One of the reasons for this is that a classification and coding system should be custom-engineered for a given company or industry. One system may be best for one company while a different system is more suited to another company.

# Coding system structure:

- 1. Hierarchical structure
- 2. Chain-type structure
- 3. Hybrid structure, a combination of hierarchical and chain-type structures

# Coding system structure

- 1. Hierarchical structure
- the interpretation of each succeeding symbol depends on the value of the preceding symbols.
- Other names commonly used for this structure are mono code and tree structure.
- The hierarchical code provides a relatively compact structure which conveys much information about the part in a limited number of digits.

# Coding system structure

- 2.Chain-type structure
- the interpretation of each symbol in the sequence is fixed and does not depend on the value of preceding digits.
- Another name commonly given to this structure is poly code.
- The problem associated with poly codes is that they tend to be relatively long.
- the use of a poly code allows for convenient identification of specific part attributes. This can be helpful in recognizing parts with similar processing requirements

# Coding system structure

- 3. Hybrid structure
  - A combination of hierarchical and chain-type structures
  - Most of the commercial parts coding systems used in industry are a combination of the two pure structures.
  - The hybrid structure is an attempt to achieve the best features of mono codes and poly codes.
  - Hybrid codes are typically constructed as a series of short poly codes. Within each of these shorter chains, the digits are independent.
  - This hybrid coding seems to best serve the needs of both design and production.

# Three parts classification and coding systems:

- 1. Opitz system
- 2. MICLASS system
- 3. CODE system

# Three parts classification and coding systems:

- The Opitz coding system uses the following digit sequence:
  - 12345      6789      ABCD
- The basic code consists of nine digits, which can be extended by adding four more digits.
- The first nine digits are intended to convey both design and manufacturing data.
- The general interpretation of the nine digits is indicated in Fig.
- The first five digits, 12345, are called the "form code" and describe the primary design attributes of the part. The next four digits, 6789, constitute the "supplementary code"
- It indicates some of the attributes that would be of use to manufacturing (dimensions, work material, starting raw work piece shape and accuracy).
- The extra four digits, ABCD, are referred to as the "secondary code" and are intended to identify the production operation type and sequence.

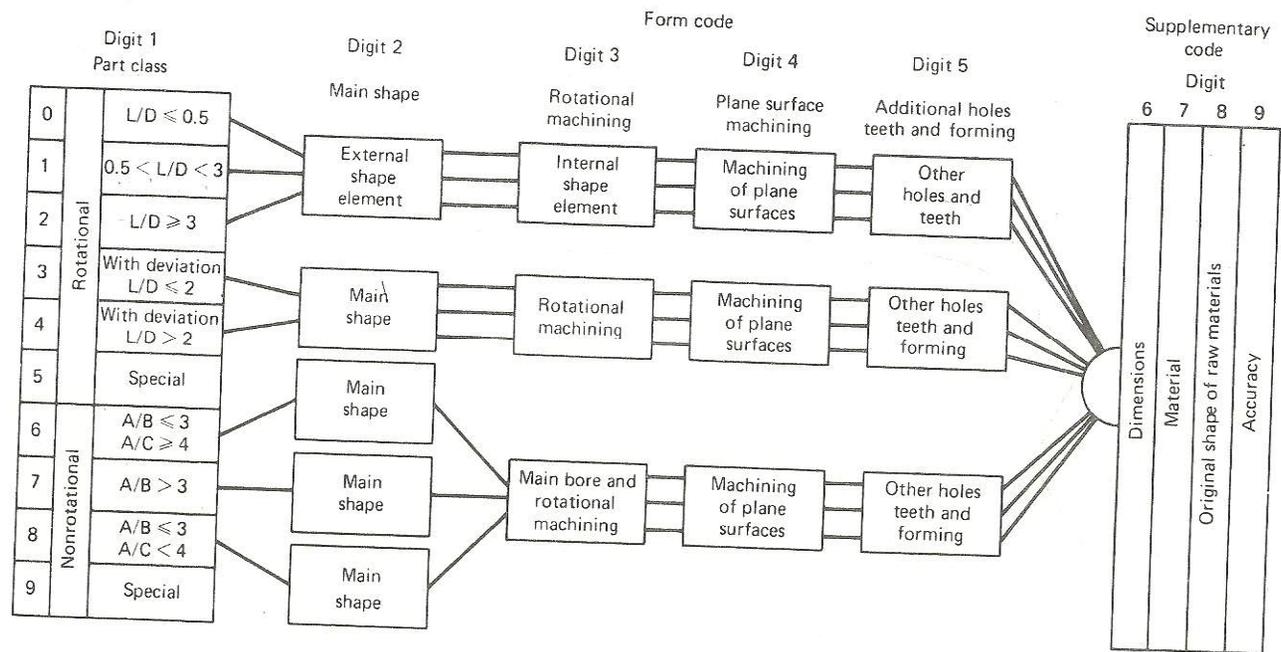


FIGURE 12.5 Basic structure of the Opitz system.

# Three parts classification and coding systems

- 2. MICLASS system(Metal Institute Classification System)
  - The MICLASS system was developed to help automate and standardize a number of design, production, and management functions. These include:
    - Standardization of engineering drawings
    - Retrieval of drawings according to classification number
    - Standardization of process routing
    - Automated process planning
    - Selection of parts for processing on particular groups of machine tools
    - Machine tool investment analysis
  - The MICLASS classification number can range from 12 to 30 digits. The first 12 digits are a universal code that can be applied to any part.
  - Up to 18 additional digits can be used to code data that are specific to the particular company or industry.

## 2. MICLASS system(Metal Institute Classification System)

- The workpart attributes coded in the first 12 digits of the MICLASS number are as follows:
  - 1st digit Main shape
  - 2nd and 3rd digits Shape elements
  - 4th digit Position of shape elements
  - 5th, and 6th digits Main dimensions
  - 7th digit Dimension ratio
  - 8th digit Auxiliary dimension
  - 9th and 10th digits Tolerance codes
  - 11th and 12th digits Material codes
- One of the unique features of the MICLASS system is that parts can be coded using a computer interactively.
- To classify a given part design, the user responds to a series of questions asked by the computer. The number of questions depends on the complexity of the part.

# Three parts classification and coding systems

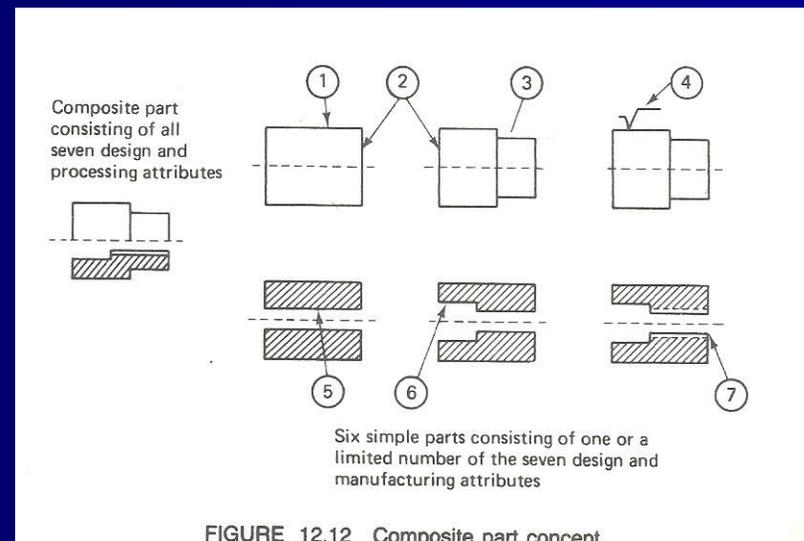
- 3. CODE system
- The CODE system is a parts classification
- Its most universal application is in design engineering for retrieval of part design data, applications in manufacturing process planning, purchasing, tool design, and inventory control.
- The CODE number has eight digits. For each digit there are 16 possible values (zero through 9 and A through F) which are used to describe the part's design and manufacturing characteristics. The initial digit position indicates the 6 basic geometry of the part and is called the Major Division of the CODE system.
- This digit would be used to specify whether the shape was a cylinder, flat piece, block, or other. The interpretation of the remaining seven digits depends on the value of the first digit, but these remaining digits form a chain-type structure. Hence the CODE system possesses a hybrid structure

# Group Technology Machine Cells

- The composite part concept:
- Part families are defined by the fact that their members have similar design and manufacturing attributes. The composite part concept takes this part family definition to its logical conclusion.
- It conceives of a hypothetical part that represents all of the design and corresponding manufacturing attributes possessed by the various individuals in the family.
- A machine cell would be designed to provide all seven machining capabilities. The machine, fixtures, and tools would be set up for efficient flow of work-parts through the cell.
- A part with all seven attributes, such as the composite part of Fig. would go through all seven processing steps

# Group Technology Machine Cells

- The composite part concept:



# Group Technology: Types of Machine Cells

- Single machine cell
- Group machine layout
- Row line design

# Group Technology: Types of Machine Cells

- Single machine cell
- The single machine approach can be used for work parts whose attributes allow them to be made on basically one type of process, such as turning or milling.

# Group Technology: Types of Machine Cells

- Group machine layout
- The group machine layout is a cell design in which several machines are used together, with no provision for conveyORIZED parts movement between the machines. The cell contains the machines needed to produce a certain family of parts, and the machines are organized with the proper fixtures, tools, and operators to efficiently produce the parts family

# Group Technology: Types of Machine Cells

- Row line design
- The flow line cell design is a group of machines connected by a conveyor system. Although this design approaches the efficiency of an automated transfer line.
- The limitation of the flow line layout is that all the parts in the family must be processed through the machines in the same sequence.

# Benefits of Group Technology

- Product design
- Tooling and setups
- Materials handling
- Production and inventory control
- Employee satisfaction
- Process planning procedures

# CAPP: Advantages

- 1. *Process rationalization.*
- Computer-automated preparation of operation routings is more likely to be consistent, logical, and optimal than its manual counterpart.
- The process plans will be consistent because the same computer software is being used by all planners.
- The process plans tend to be more logical and optimal because the company has presumably incorporated the experience and judgment of its best manufacturing people into the process planning computer software.

# CAPP: Advantages

- *2. Increased productivity of process planners.*
- With computer-aided process planning, there is reduced clerical effort, fewer errors are made, and the planners have immediate access to the process planning data base.
- These benefits translate into higher productivity of the process planners.

# CAPP: Advantages

- *3.Reduced turnaround time.*
- with the CAPP system, the process planner is able to prepare a route sheet for a new part in less time compared to manual preparation
- This leads to an overall reduction in manufacturing lead time.

# CAPP: Advantages

- *4. Improved legibility.*
- The computer-prepared document is neater and easier to read than manually written route sheets.
- CAPP systems employ standard text, which facilitates interpretation of the process plan in the factory.

# CAPP: Advantages

- 5. *Incorporation of other application programs.*
- The process planning system can be designed to operate in conjunction with other software packages to automate many of the time-consuming manufacturing support functions.

# Traditional Process planning:

- There are variations in the level of detail found in route sheets among different companies and industries.
- Individual engineers each have their own opinions about what constitutes the best routing.
- Accordingly, there are differences among the operation sequences developed by various planners.

# Traditional Process planning:

- Problem of variability among planners, there are often difficulties in the conventional process planning procedure.
- New machine tools in the factory render old routings less than optimal.
- Machine breakdowns force shop personnel to use temporary routings, and these become the documented routings even after the machine is repaired.
- For these reasons and others, a significant proportion of the total number of process plans used in manufacturing are not optimal

# Automated Process Planning:

- This system offers the potential for reducing the routine clerical work of manufacturing engineers.
- At the same time, it provides the opportunity to generate production routings which are rational, consistent, and perhaps even optimal.
- There are:
  - 1. Retrieval-type CAPP systems (also called variant systems)
  - 2. Generative CAPP systems

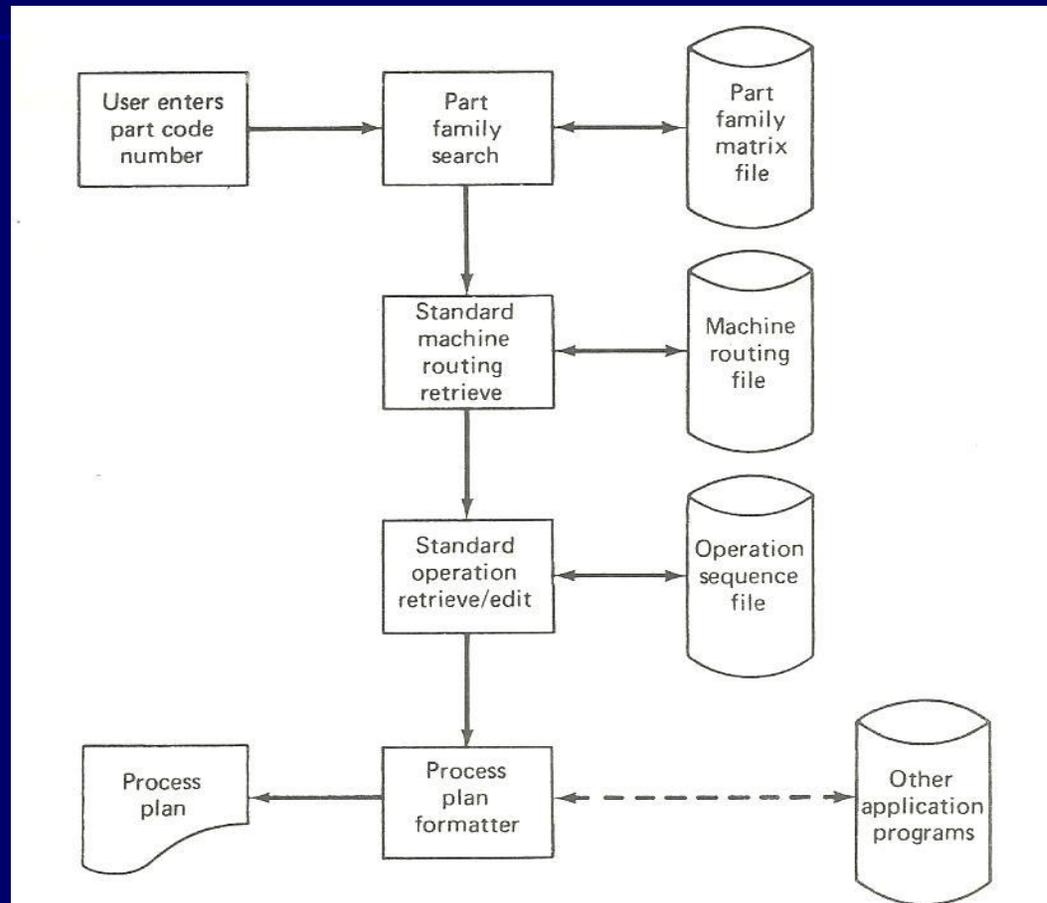
# Automated Process Planning:

- 1.Retrieval-type CAPP systems
- In this approach, the parts produced in the plant are grouped into part families, distinguished according to their manufacturing characteristics; For each part family, a standard process plan is established.

# 1.Retrieval-type CAPP systems

- In this approach, the parts produced in the plant are grouped into part families, distinguished according to their manufacturing characteristics; For each part family, a standard process plan is established. The standard process plan is stored in computer files and then retrieved for new workparts which belong to that family. Some form of parts classification and coding system is required to organize the computer files and to permit efficient retrieval of the appropriate process plan for a new workpart. For some new parts, editing of the existing process plan may be required. This is done when the manufacturing requirements of the new part are slightly different from the standard. The machine routing may be the same for the new part, but the specific operations required at each machine may be different. The complete process plan must document the operations as well as the sequence of machines through which the part must be routed. Because of the alterations that are made in the retrieved process plan, these CAPP systems are sometimes also called by the name "variant system."
- Figure 13.1 will help to explain the procedure used in a retrieval process planning system. The user would initiate the procedure by entering the part code number at a computer terminal.(The CAPP program then searches the part family matrix file to determine if a match exists. If the file contains an identical code number, the standard machine routing and operation sequence are retrieved from the respective computer files for display to the user. The standard process plan is examined by the user to permit any necessary editing of the plan to make it compatible with the new part design. After editing, the process plan formatter prepares the paper document in the proper form.
- If an exact match cannot be found between the code numbers in the computer file and the code number for the new part, the user may search the machine routing file and the operation sequence file for similar parts that could be used to develop the plan for the new part

# 1.Retrieval-type CAPP systems



# Generative Process planning systems:

- In this process planning, the use of the computer to create an individual process plan from scratch automatically and without human assistance.
- The computer would employ a set of algorithms to progress through the various technical and logical decisions towards a final plan for manufacturing.

# Machinability Data Systems:

TABLE 13.1 Characteristics of a Machining Operation

1. Type of Machining Operation
  - a. Process type—turning, facing, drilling, tapping, milling, boring, grinding, etc.
  - b. Roughing operation versus finishing operation.
2. Machine Tool Parameters
  - a. Size and rigidity
  - b. Horsepower
  - c. Spindle speed and feed rate levels
  - d. Conventional or NC
  - e. Accuracy and precision capabilities
  - f. Operating time data
3. Cutting Tool Parameters
  - a. Tool material type (high-speed steel, cemented carbide, ceramic, etc.)
  - b. Tool material chemistry or composition
  - c. Physical and mechanical properties (hardness, wear resistance, etc.)
  - d. Type of tool (single point, drill, milling cutter, etc.)
  - e. Geometry (nose radius, rake angles, relief angles, number of teeth, etc.)
  - f. Tool cost data
4. Workpart Characteristics
  - a. Material—basic type and specific grade
  - b. Hardness and strength of work material
  - c. Geometric size and shape
  - d. Tolerances
  - e. Surface finish
  - f. Initial surface condition of workpiece
5. Operating Parameters Other Than Feed and Speed
  - a. Depth of cut
  - b. Cutting fluid, if any
  - c. Workpiece rigidity
  - d. Fixtures and jigs used

# Computerized machinability data systems:

- Data base systems
- Mathematical model systems

# Computer generated time standards:

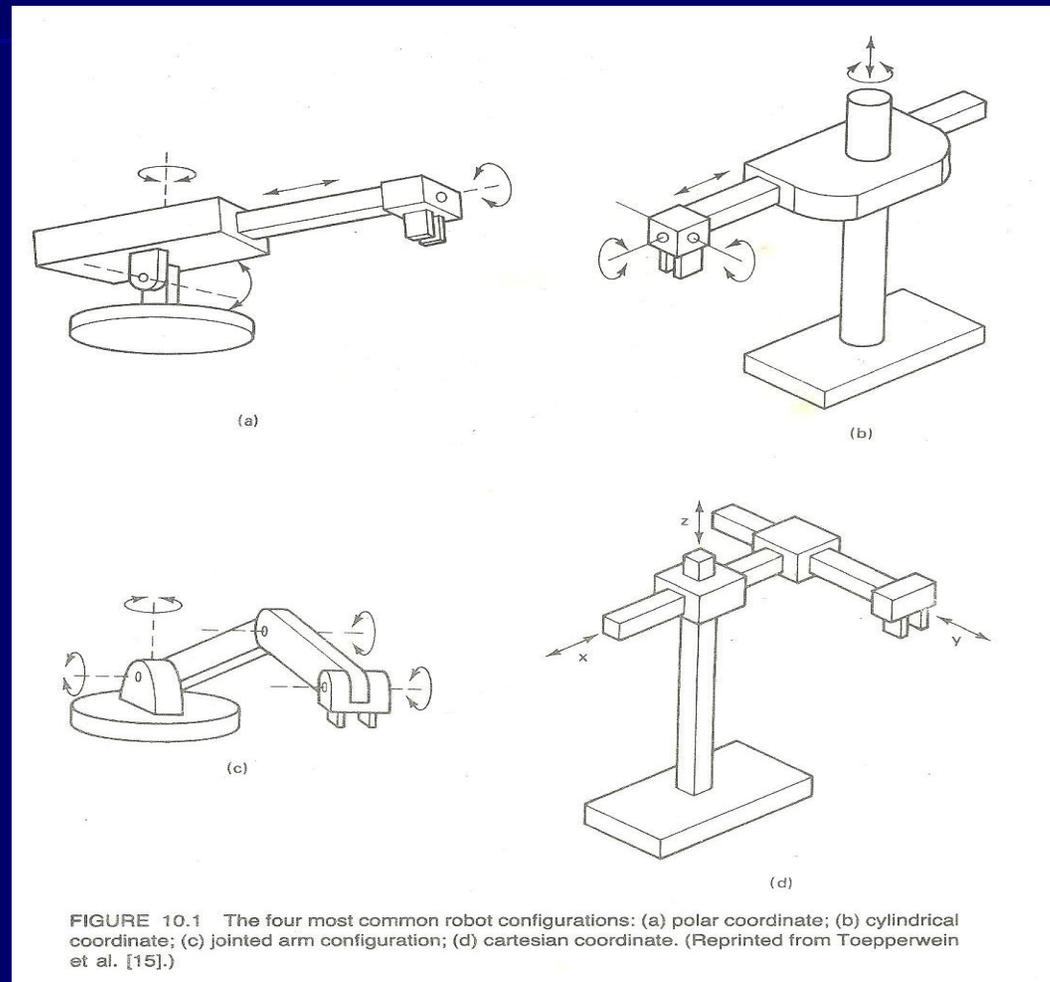
- Wage incentives
- Estimating and job costing
- Production scheduling and capacity planning
- Measurement of worker performance



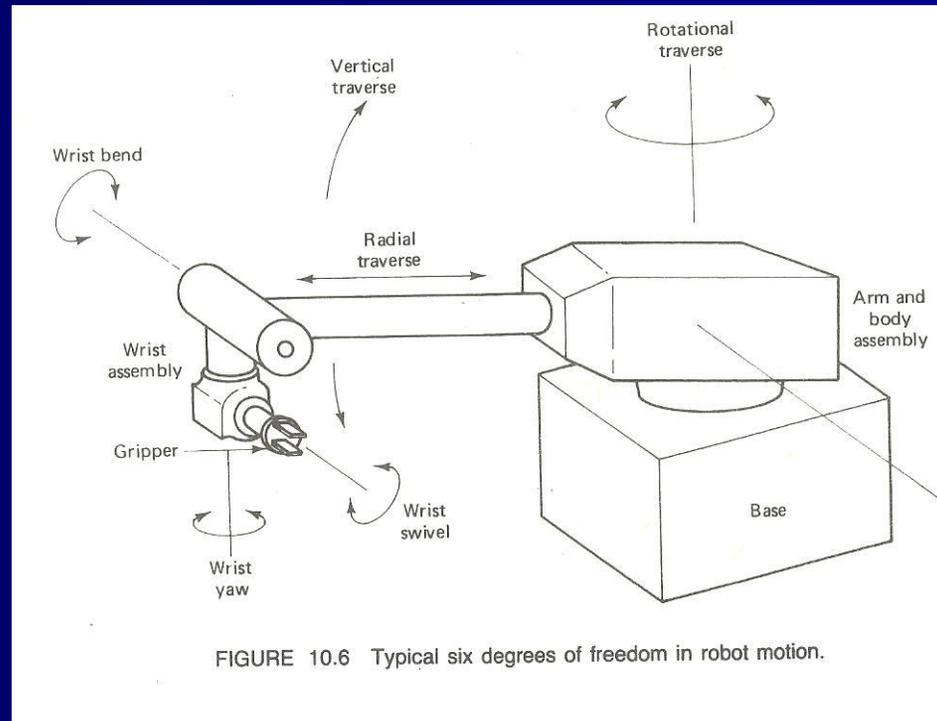
# UNIT-V

- Robotics

# Four types:



# Six degrees of freedom



# Technical features:

- **Work Volume:**  
Phy.confu,size,limits of its arm, joint manipulations
- **Precision movement:**  
Spatial resolution,Accuracy,Repeatability
- **Speed of movement**
- **Weight-carrying capacity**
- **Type of drive system:**  
Hydraulic,Electric motor,Pneumatic

# Programming the Robot:

- **Manual method:**
  - Simpler robots
  - Pick and place operations
  - programming is adequate
- **Walk through method:**
  - Movement recorded in memory
  - Position sequence ?
  - Spray painting
  - Welding robots

- **Lead through method:**

  - Teach the pendent

  - Movement recorded in memory

  - Easy and convenience

- **Off line programming:**

  - Similar to NC part programming

  - higher utilization of Robot

# Robot Programming Languages:

- Based on the production sequences

# End Effectors:

- Grippers
- Tools and effectors

# Grippers

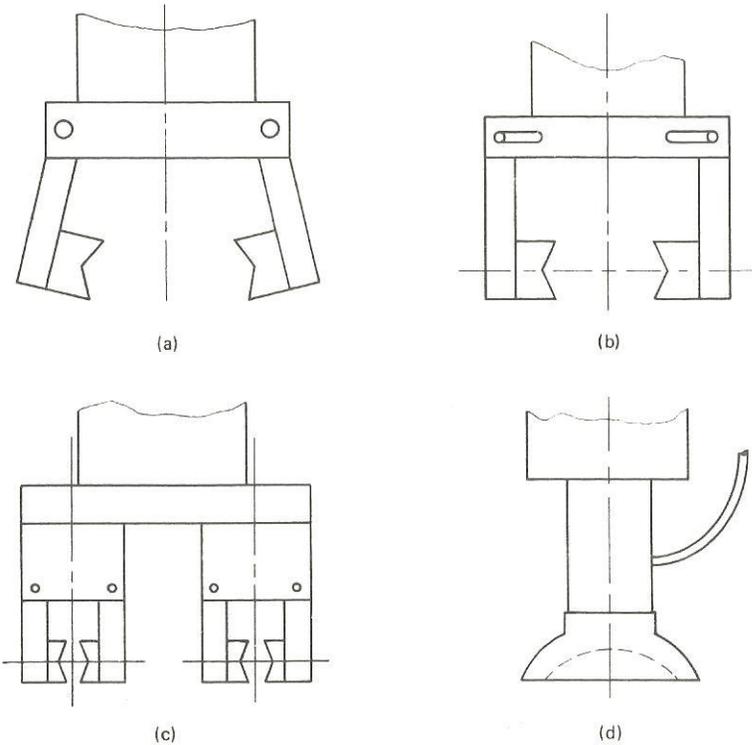


FIGURE 10.11 Sample gripper designs: (a) pivot action gripper; (b) slide action gripper; (c) double gripper—pivot action mechanism; (d) vacuum-operated hand.

## ■ Tools and effectors

Spot welding gun

Arc welding tools

Spray painting gun

Drilling spindle

grinders

# Robotic Sensors:

- Vision Sensors
- Tactile and proximity Sensors
- Voice sensors

# Vision Sensors:

- Robot vision is made possible by means of a video camera, a sufficient light source, and a computer programmed to process image data.
- The camera is mounted either on the robot or in a fixed position above the robot so that its field of vision includes the robot's work volume.
- The computer software enables (In- vision system to sense the presence of an object and its position and orientation.
- Vision capability would enable the robot to carry out the following kinds of operations

Retrieve parts which are randomly oriented on the conveyor

Recognize particular parts which are intermixed with other objects.

Perform visual inspection

# Tactile and proximity Sensors

- Tactile sensors provide the robot with the capability to respond to contact forces between itself and other objects within its work volume. Tactile sensors can be divided into two types:
  1. Touch sensors
  2. Stress sensors (also called force sensors)
- Touch sensors are used simply to indicate whether contact has been made with an object. A simple micro switch can serve the purpose of a touch sensor.
- Stress sensors are used to measure the magnitude of the contact force. Strain gage devices are typically employed in force-measuring sensors.
- Potential uses of robots with tactile sensing capabilities would be in assembly and inspection operations.

# Tactile and proximity Sensors

- In assembly, the robot could perform delicate part alignment and joining operations.
- In inspection, touch sensing would be useful in gauging operations and dimensional-measuring activities.
- Proximity sensors are used to sense when one object is close to another object.
- On a robot, the proximity sensors would be located on or near the end effectors.

# Voice sensors

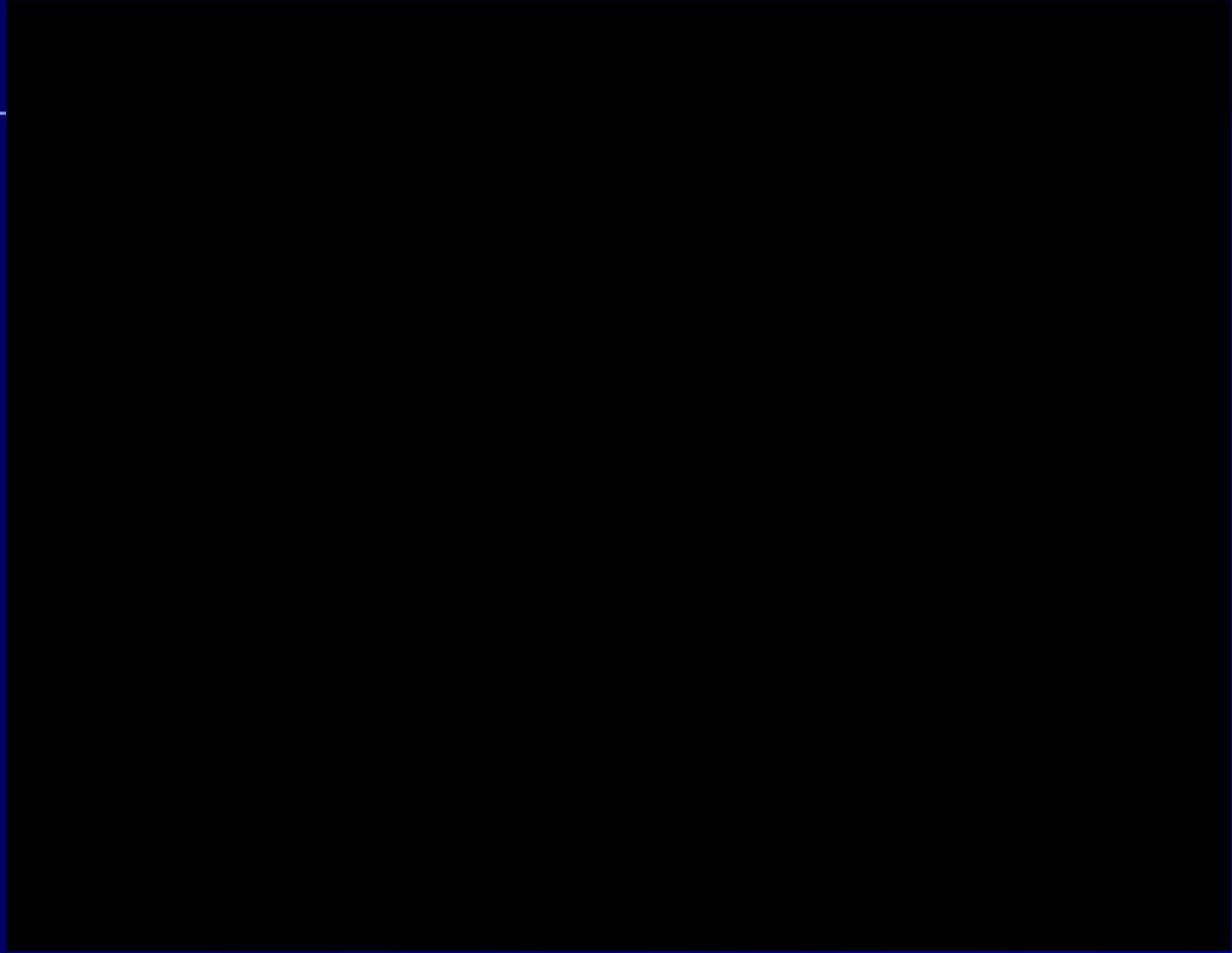
- Another area of robotics research is voice sensing or voice programming.
- Voice programming can be defined as the oral communication of commands to the robot or other machine.
- The robot controller is equipped with a speech recognition system which analyzes the voice input and compares it with a set of stored word patterns.
- When a match is found between the input and the stored vocabulary word, the robot performs some action which corresponds to that word.

# Robot Applications:

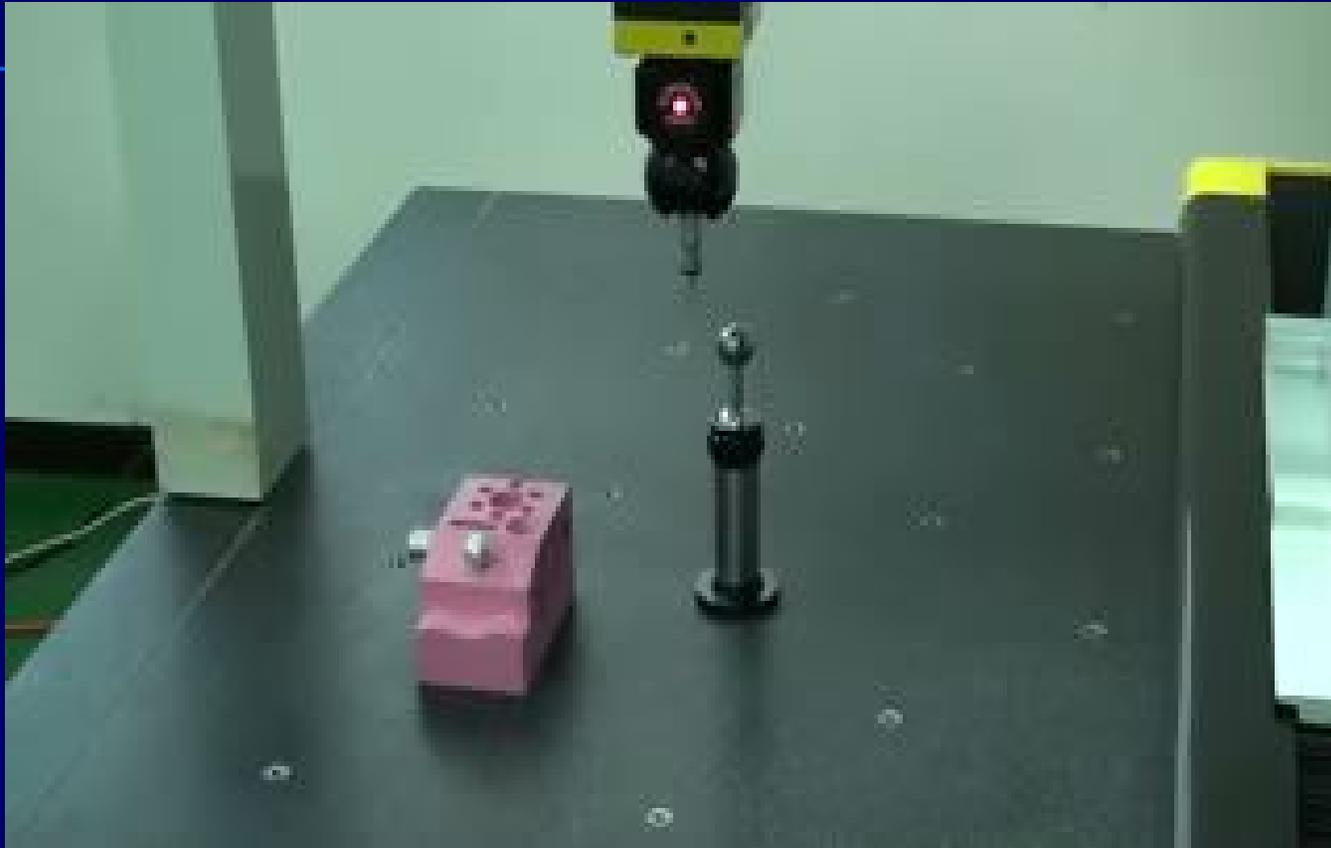
- Welding



# Spray painting



# Inspection



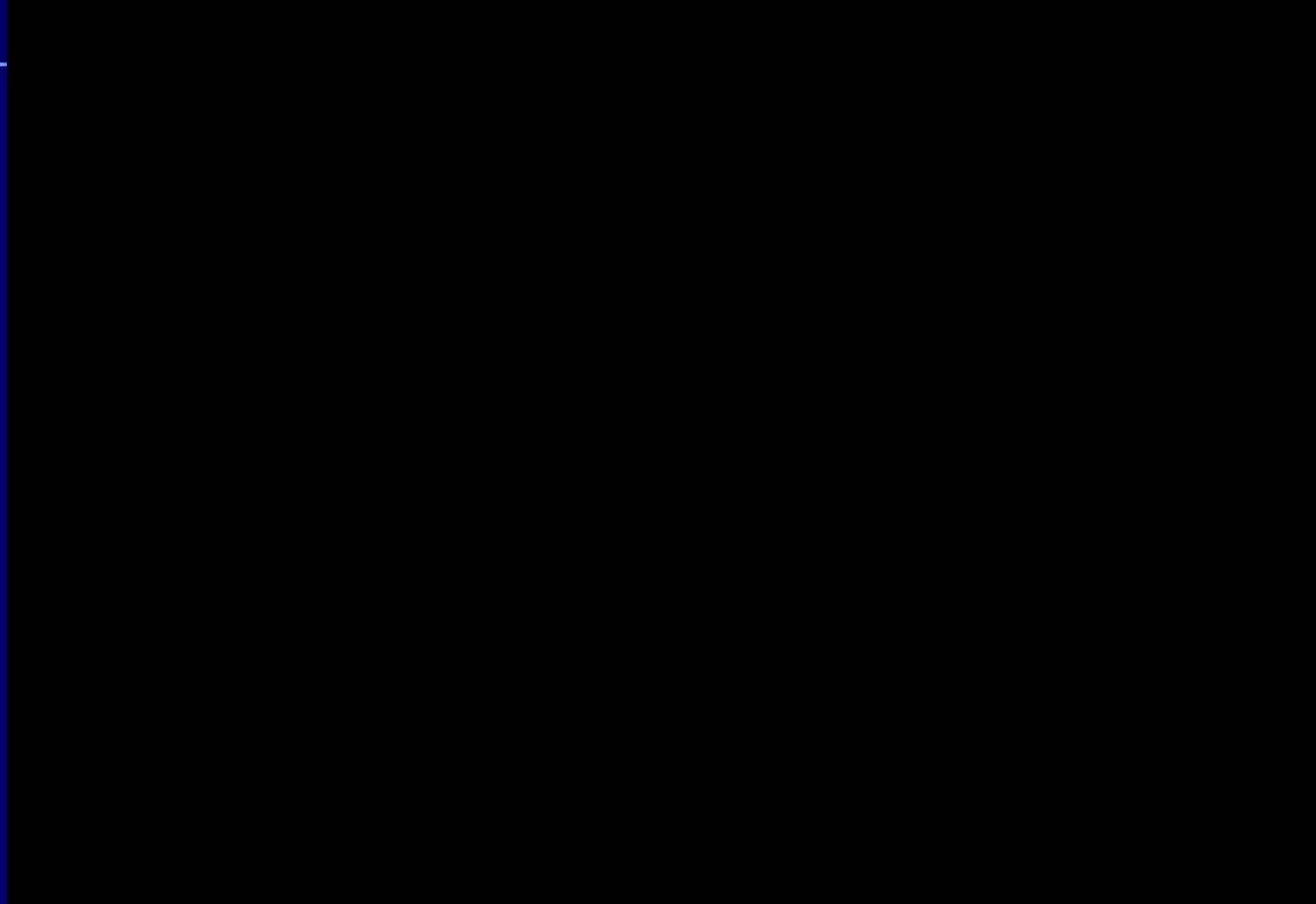
# Inspection

Ford Motor Company

Robotic Plant Laser Inspection  
Technology

B-roll

# Robo - Assembly



# Material handling



# Material handling



“Your attempt may fail,  
But never fail to make an attempt”.