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SCHOOL OF MECHANICAL ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

UNIT – I – INTRODUCTION TO CAD/CAM - SME1205

1. INTRODUCTION TO CAD/CAM

Computer-aided design (CAD) is the use of computer systems to aid in the creation, modification, analysis, or optimization of a design. Computer-aided manufacturing (CAM) is an application technology that uses computer software and machinery to facilitate and automate manufacturing processes. Many CAD vendors market fully integrated CAM systems, aptly called CAD/CAM systems. These CAD/CAM packages deliver many advantages. For starters, they feature a common user interface that allows CAD operators to quickly learn the software. Moreover, users can easily transfer CAD data to the CAM system without worrying about translation errors or other difficulties. And finally, some integrated systems provide full associatively, which means that any modification to the CAD model will prompt the associated tool path to be automatically updated. Computer Aided Design (CAD) has completely changed the drafting business and made the storage and retrieval of projects much easier. However, manual drawing is still very important and provides the basics of learning to draw.

The first system were very expensive, the computer graphics technology was not so advanced at that time and using the system required specialized H/W and S/W which was provided mainly by the CAD vendors. The first CAD systems were mainframe computer supported systems, while today the technology is for networked but stand alone operating workstations (UNIX or WINDOWS based systems). AUTODESK was the first vendor to offer a PC based CAD system the AUTOCAD (beginning of 1980). Today WINDOWS is the main operating system for CAD systems.

The first applications were for 2D-Drafting and the systems were also capable of performing only 2D modeling. Even today 2D-drafting is still the main area of application (in terms of number of workplaces). Later, (mid-1980), following the progress in 3D modeling technology and the growth in the IT H/W, 3D modeling systems are becoming very popular. 3D modeling are at the beginning wire frame based. Aerospace and automotive industries were using surface modeling systems for exact representation of the body of the product. At the same time solid modeling was recognized as the only system, which could provide an unambiguous representation of the product, but it was lacking adequate support for complex part representations. Today we are experiencing a merge of solid and surface modeling technology. Most solid modeling systems are capable of modeling most of industrial products. Systems sold today (especially for mechanical applications, which are the majority of systems sold world-wide) are characterized as NURBS (Non Uniform Rational B-Spline) based systems, employing solid modeling technology, and they are parametric and feature based systems. The use of CAD systems has also been expanded to all industrial sectors, such AEC, Electronics, Textiles, Packaging, Clothing, Leather and Shoe, etc. Today, numerous CAD systems are offered by several vendors, in various countries.

1.1. BENEFITS OF CAD OVER MANUAL DRAWING:

- No need for scaling. All drawing is done full size.
- Both two and three dimensional drawings can be produced.
- The screen drawing area can be set to any size with the click of a button
- Work is copied and stored off the computer for security – you may never lose your work again.
- All of the tools needed are supplied by the program.
- Drawings are stored on disk rather than in a bulky folder.
- Absolute accuracy can be maintained.

- Dimensioning is almost automatic.
- Production details can be extracted directly from the drawing.
- Parts of drawings can be saved and used in other drawings.
- Eliminates the need for full size set outs.
- Everything you learn about manual drawing technique applies to CAD/CAM drawing development.
- The images are displayed on the PC screen and, with the click of a button, can be put on paper using printers or plotters.

1.2. MORPHOLOGY OF DESIGN (OR THE DESIGN PROCESS

The design process mainly consists of six phases as shown in figure.

Recognition of need: When someone realizes that problem exists, for which a product can be designed.

Define the problem: Specify the item to be designed. This includes the cost, operating performance and characteristics functions.

Synthesis: Each subsystem of the designed is thoroughly conceptualized and analyzed, and if some shortcomings are there, improve this with the help of software like CAD.

Analysis and optimization: The product is redesigned and analyzed again and again. This process will go on till the designed is optimized.

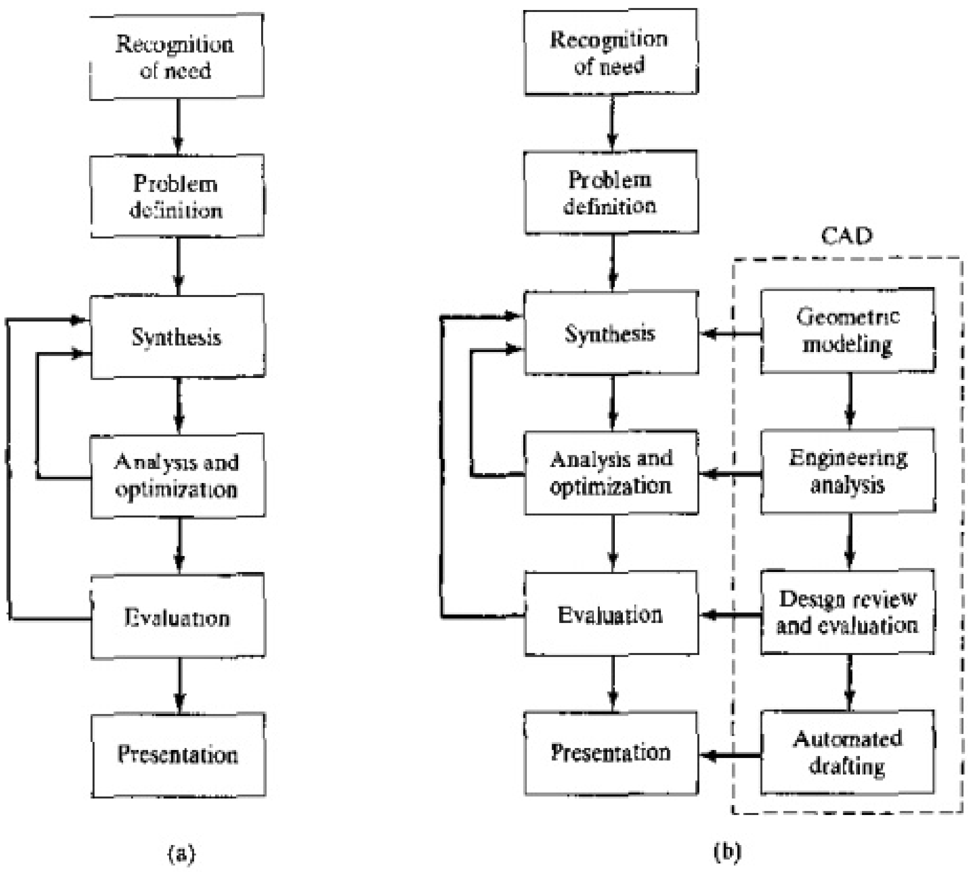

Fig 1.1. Design Process

Evaluation of design: Measure and test the design as specified in the problem definition phase. Tests are to be conducted on prototype model.

Presentation: Make the final drawing of the design by mentioning its material, size and assembly list. It means a database of the design is created for manufacturing.

1.3. APPLICATION OF CAD

1.3.1. Computer-aided design (CAD)

Defined as any design activity that involves the effective use of the computer to create, modify, analyze, or document an engineering design. CAD is most commonly associated with the use of an interactive computer graphics system, referred 10 as a CAD system. The term CAD/CAM system is also used if it supports manufacturing as well as design applications. With reference to the six phases of design defined previously, a CAD system can beneficially be used in four of the design phases, as indicated in Table.

Computer-Aided Design Applied to Four of the Shigley Design Phases

Design Phase	*CAD Function*
1. Synthesis	Geometric modeling
2. Analysis and optimization	Engineering analysis
3. Evaluation	Design review and evaluation
4. Presentation	Automated drafting

Table 1.1. Design phases and CAD functions

1.3.2. *Geometric Modeling*

Geometric modeling involves the use of a CAD system to develop a mathematical description of the geometry of an object. The mathematical description, called a *geometric model,* is contained in computer memory. This is used for the CAD system to display an image of the model on a graphics terminal and toper-form certain operations on the model. These operations include creating new geometric models from basic building blocks available in the system, moving the images around on the screen, zooming in on certain features of the image, and so forth. These capabilities permit the designer to construct a model of a new product (or Its components) or to modify an existing model. One classification distinguishes between two dimensional (2D) and three dimensional (3D) models. Two dimensional models are best utilized for design problems in two dimensions, such as flat objects and layouts of buildings. In the first CAD systems developed in the early 1970s, 2·0systems were used principally as automated drafting systems. They were often used for 3D objects, and it was left to the designer or draftsman to properly construct the various views of the object. Three dimensional CAD systems are capable of modeling an object in three dimensions. The operations and transformations on the model are done by the system in three dimensions according to user instructions. This is helpful in conceptualizing the object since the true *3D*model can be displayed in various views and from different angles. Geometric models in CAD can also be classified as being either wireframe models or solid models. A wireframe model uses inter-connecting lines (straight line segments) to depict the object. Wireframe models of complicated geometries can become somewhat confusing because all of the lines depicting the shape of the object are usually shown, even the lines representing the other side of the object. Techniques are available for removing these so-called hidden lines, but even with this improvement, wireframe representation is still often inadequate. Solid models are a more recent development in geometric modeling. In solid modeling, an object is modeled in solid three dimensions, providing the user with a vision of the object very much like it would be seen in real life. More important for engineering purposes, the geometric model is stored in the CAD system as a 3D solid model. thus providing a more accurate representation of the object. This is useful for calculating mass properties, in assembly to perform interference checking between mating components, and in other engineering calculations. Finally, two other features in CAD system models are color and animation. Some CAD systems have color capability in addition to black-and-white. The value of color is largely to enhance the ability of the user to visualize the object on the graphics screen. For example, the various components of an assembly can be displayed in different colors, thereby permitting the parts to be more readily distinguished. Animation capability permits the operation of mechanisms and other moving objects to be displayed on the graphics monitor.

1.3.3. Engineering Analysis.

After a particular design alternative has been developed, some form of engineering analysis often must be performed as part of the design process. The analysis may take the form of stress-strain calculations, heat transfer analysis, or dynamic simulation. The computation are often complex and time consuming, and before the advent of the digital computer, these analyses were usually greatly simplified or even omitted in the design procedure. The availability of software for engineering analysis on a CAD system greatly increases the designer's ability and willingness. to perform a more thorough analysis of a proposed design. The term *computer-aided engineering* (CAE) is often used for engineering analyses performed by computer. Examples of engineering analysis software in common use on CAD systems include:

- *Mass properties analysis,* which involves the computation of such features of a solid object as its volume, surface area, weight, and center of gravity. It is especially applicable in mechanical design. Prior to CAD, determination of these properties often required painstaking and time consuming calculations by the designer.
- *Interference checking.* This CAD software examines 2D geometric models consisting of multiple components to identify interferences between the components. It is useful in analyzing mechanical assemblies, chemical plants, and similar multi component designs.
- *Tolerance analysis.* Software for analyzing the specified tolerances of a product components is used for the following functions: (1) to assess how the tolerances may affect the product's function and performance, (2) to determine how tolerances may influence the ease or difficulty of assembling the product and (3) to assess how variations in component dimensions may affect the overall size of the assembly.
- *Finite element analysis.* Software for finite element analysis (FEA), also known as *finite element modeling* (FEM). is available for use on CAD systems to aid in stress-strain, heat transfer, fluid flow, and other engineering computations, Finite element analysis is a numerical analysis technique for determining approximate solutions to physical problems described by differential equations that are very difficult or impossible to solve. In FEA. The physical object is modeled by an assemblage of discrete interconnected nodes (finite elements), and the variable of interest (e.g., stress, strain, temperature) in each node can be described by relatively simple mathematic cal equations, By solving the equations for each node. the distribution of values of the variable throughout the physical object is determined.

- *Kinematic and dynamic analysis.* Kinematic analysis involves the study of the operation of mechanical linkages to analyze their motions. A typical kinematic analysis consists of specifying the motion of one or more driving members of the subject linkage, and the resulting motions of the other links are determined by the analysis package. Dynamic analysis extends kinematic analysts by including the effects of the mass of each linkage member and the resulting acceleration forces as well as any externally applied forces.
- *Discrete-event simulation.* This type of simulation is used to model complex operational systems, such as a manufacturing cell or a material handling system, as events occur at discrete moments in time and affect the status and performance of the system. For example, discrete events in the operation of a manufacturing cell include parts arriving for processing or a machine breakdown in the cell. Measures of the status and performance include whether a given machine in the cell is idle or busy and the overall production rate of the cell. Current discrete-event simulation software usually includes an animated graphics capability that enhances visualization of the system's operation.

1.3.4. Design Evaluation and Review

Design evaluation and review procedures can be augmented *by* CAD. Some of the CAD features that are helpful in evaluating: and reviewing a proposed design include:

- A*utomatic dimensioning* routines that determine precise distance measures between surfaces on the geometric model identified hy the user.
- *Error checking.* This term refers 10 CAD algorithms that are used to review the accuracy and consistency of dimensions and tolerances and to assess whether the proper design documentation format has been followed.

1.3.5. Automated Drafting

The fourth area where CAD is useful (step 6 in the design process) is presentation and documentation. CAD systems can be used as automated drafting machines to prepare highly accurate engineering drawings quickly. It is estimated that a CAD system increases productivity in the drafting function by about fivefold over manual preparation of drawings

1.4. PRODUCT CYCLE COMPUTER AIDED DESIGN

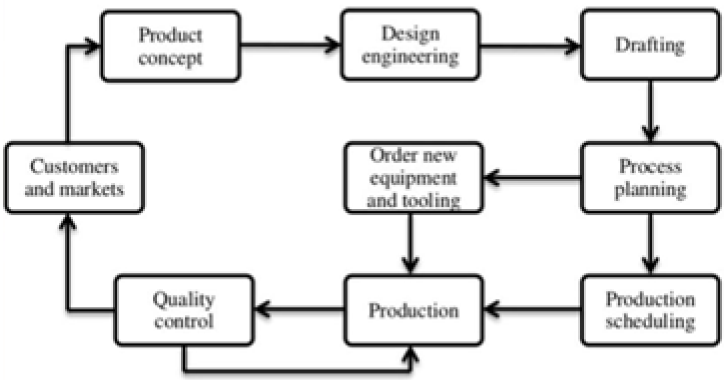

Fig 1.2: Product life cycle

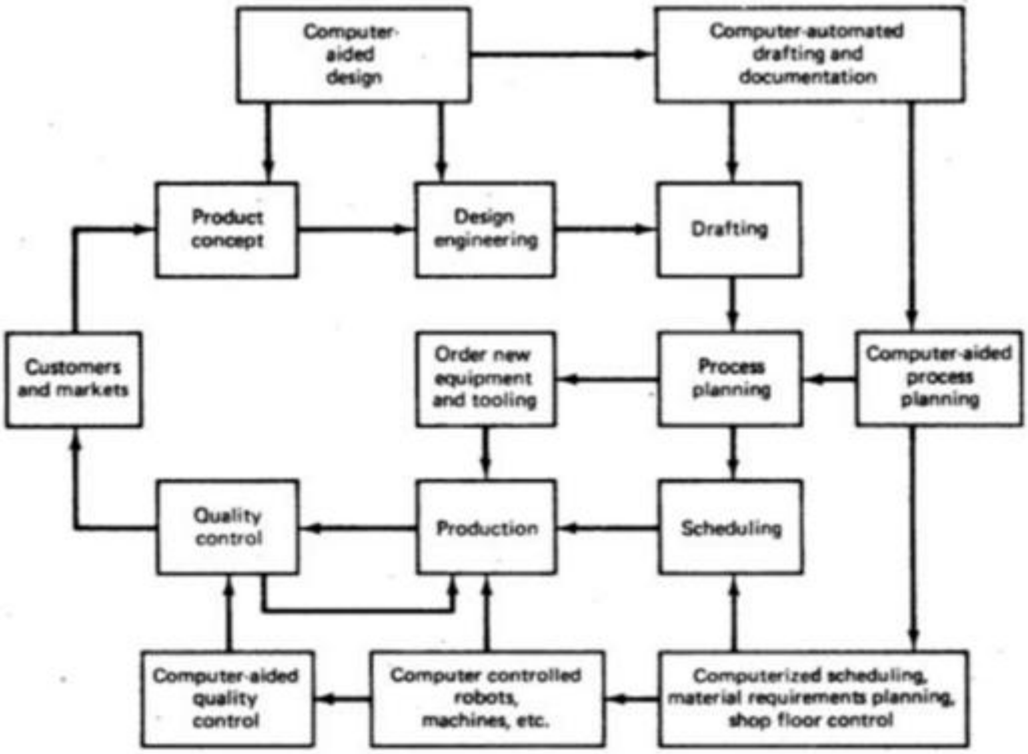

Fig 1.3: Implement of CAD/CAM in Product life cycle

1.5. DATABASE MANAGEMENT

The manufacturing database and its management are major issues in CIM. The issues are complex but they are beginning to be addressed in a number of ways, including schemes for organizing data, standards for product data exchange and standards for communication protocols. The standards for product data exchange are discussed and communication protocols have been discussed elsewhere. This chapter hence is devoted to the organization of data.

A major problem to be solved to implement CIM has always been that of distributing information among different computer based systems. As indicated in earlier chapters CIM is typically integration of islands of computer aided functions running on different computers using different databases.

Joining those islands into an effective CIM enterprise requires proper methods of processing information. Information, if it is to be useful, must be appropriate, machine-interpretable, and available when and where it is needed.

1.5.1. Features of A Database Management System

A database management system consists of a collection of interrelated data and a set of programs to access that data. Database management involves:

- Organize a database.
- Add new data to the database.
- Sort the data in some meaningful order.

- Search the database for types of information.
- Print the data into formatted reports.
- Edit the data.

1.5.2. Database Administrator

The person responsible for managing the database is often referred to as database administrator. His functions include:

- Creating the primary database structure
- Backing up and restoring data in case of crash
- Modifying the structure
- Transfer data to external files
- Allocate and control user access rights
- Monitoring performance

1.5.3. Comparison of Database and Traditional File Systems

File system represents a tight coupling between physical data and user's program. They lack almost all the flexibilities offered by DBMS. Most of the indispensable facilities of DBMS of are, therefore forced to be absorbed by user's program. In other words besides the logic of the application the user has to provide logic for constructing the logical view of data, has to interpret the operations on the logical view and translate them in to the primitive file operations, and has to be responsible for maintaining the files that store the physical data. The tight coupling and interdependence of between a user's application and the physical data would not allow sharing of the same data by other applications that may need to view and manipulate them differently.

This then forces the data to be duplicated among various applications. File systems lack dynamism in the sense that the application programs are designed, coded, debugged, and catalogued ahead of time for the preconceived requests and applications. The following list summarizes the problems of file systems that can be overcome by DBMS.

i. Data dependence

ii. Rigidity

iii. Static nature

iv. Lack of integration

v. Data duplication

vi. Inconsistency

vii. Difficulty in sharing information

viii. Inefficiency

ix. Inability to handle ado requests.

1.6. PRINCIPLES OF COMPUTER GRAPHICS

Traditionally drawings are prepared on plane drawing sheets. This has several limitations. The sketches have to be made only in two dimensions. Though the depth can be represented by pictorial projections like isometric and perspective projections, the projections have to be necessarily reduced to two dimensions. Use of computer graphics has opened up tremendous possibilities for the designer. Some of them are listed below:

Use of computer graphics has opened up tremendous possibilities for the designer. Some of them are listed below:

- The object is represented by its geometric model in three dimensions (X,Y and Z).
- The mathematical representation reduces creation of views like orthographic, isometric, axonometric or perspective projections into simple viewing transformations.
- Though the size of the screen is limited, there is no need to scale the drawings.
- Drawings can be made very accurate.
- The geometric models can be represented in color and can be viewed from any angle. Sections can be automatically created.
- The associatively ensures that any change made in one of the related views will automatically reflect in other views.
- Revision and revision control are easy.
- Drawings (geometric models) can be modified easily.
- More important than all, drawings can be reused conveniently.
- Storage and retrieval of drawings are easy

Modern computer graphics displays are simple in construction. They consist of basically three components.

i. Monitor
ii. Digital Memory or Frame Buffer
iii. Display Controller

Most of the computer graphics displays use raster CRT which is a matrix of discrete cells each of which can be made bright. A graphic entity like line or circle is represented as a series of points or dots‖ on the screen. Therefore, it is called as a point plotting device. The video display screen is divided into very small rectangular elements called a picture element or pixel.

This happens to be the smallest addressable screen element. Graphic images are formed by setting suitable intensity and color to the pixels which compose the image. Depending upon the resolution screens may have varying number of pixels. For example, an SVGA monitor with a resolution of 1024 x 768 will have 1024 pixels in every row (X - direction) and 768 pixels in every column (Y-direction). Monitors of larger size will have resolution of 1024 x 1024 or more.

A raster scan system displays the image on a CRT in a certain fixed sequence. The refresh rate is the number of complete images or frames scanned per second. In the case of interlaced refresh cycle odd numbered raster lines are refreshed during 1/60th of a second. Even numbered raster lines are refreshed during the next 1/60th of a second. In non-interlaced displays, all lines are refreshed in 1/60th of a second. The quality of no interlaced display is hence, superior. These systems, however, require expensive frame buffer memory and display controller.

1.6.1. Graphic primitives

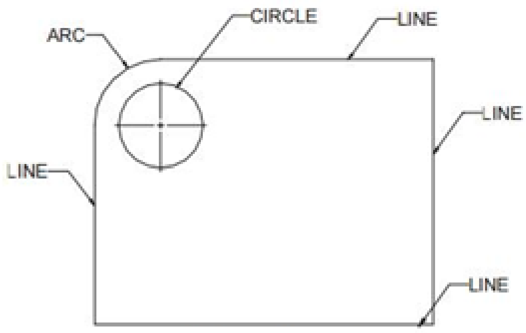

Fig 1.4. Primitives

A drawing is created by an assembly of points, lines, arcs, circles. For example, drawing shown in Fig 1.4. consists of several entities. In computer graphics also drawings are created in a similar manner. Each of these is called an entity. The drawing entities that a user may find in a typical CAD package include : point line construction line, multi-line, polyline circle spline arc ellipse polygon rectangle.

1.6.2. Point plotting

The frame buffer display is an example of a point plotting device. The smallest unit accepted by such displays is a single pixel. To construct a useful picture on a point plotting device, a picture must be built out of several hundreds of pixel.

1.6.3. Drawing of lines

Straight line segments are used a great deal in computer generated pictures. The following criteria have been stipulated for line drawing displays.

- Lines should appear straight
- Lines should terminate accurately
- Lines should have constant density
- Line density should be independent of length and angle
- Line should be drawn rapidly

The process of turning on the pixels for a line segment is called vector generation. If the end points of the line segment are known, there are several schemes for selecting the pixels between the end pixels. One method of generating a line segment is a symmetrical digital differential analyzer (DDA)

1.7 COMPUTER AIDED PROCESS MONITORING

The advances in automation have enabled industries to develop islands of automation. Examples are flexible manufacturing cells, robotized work cells, flexible inspection cells etc.

One of the objectives of CIM is to achieve the consolidation and integration of these islands of automation.

This requires sharing of information among different applications or sections of a factory, accessing incompatible and heterogeneous data and devices. The ultimate objective is to meet the competition by improved customer satisfaction through reduction in cost, improvement in quality and reduction in product development time.

CIM makes full use of the capabilities of the digital computer to improve manufacturing. Two of them are:

i. Variable and Programmable automation
ii. Real time optimization

The computer has the capability to accomplish the above for hardware components of manufacturing (the manufacturing machinery and equipment) and software component of manufacturing (the application software, the information flow, database and so on).

The capabilities of the computer are thus exploited not only for the various bits and pieces of manufacturing activity but also for the entire system of manufacturing. Computers have the tremendous potential needed to integrate the entire manufacturing system and thereby evolve the computer integrated manufacturing system.

1.8 ADAPTIVE CONTROL

Adaptive control is the ability to modify a program in real time, based upon sensory data. Robots can make use of abilities such as orienting parts based on features, following a changed path, or recognizing work pieces. Adaptive control requires sensory input and the ability to respond to that input.

Adaptive control will greatly enhance role of the industrial robots in the computer integrated factory. The robot endowed with ability to adjust to its environment, reduces scrap and rework, and a robot equipped with adaptive control can perform quality - control functions integral with its tasks.

Adaptive control is the control method used by a controller which must adapt to a controlled system with parameters which vary, or are initially uncertain. For example, as an aircraft flies, its mass will slowly decrease as a result of fuel consumption; a control law is needed that adapts itself to such changing conditions. Adaptive control is different from robust control in that it does not need a priori information about the bounds on these uncertain or time-varying parameters; robust control guarantees that if the changes are within given bounds the control law need not be changed, while adaptive control is concerned with control law changing themselves.

1.9 COMPUTER AIDED MANUFACTURING

Computer-aided manufacturing (CAM) is defined as the effective use of computer technology in manufacturing planning and control. CAM is most closely associated with functions in manufacturing engineering, such as process planning and numerical control (NC) part programming. The applications of CAM can be divided into two broad categories:(1) manufacturing planning and (2) manufacturing control.

CAM applications for manufacturing planning are those in which the computer is used indirectly to support the production function, but there is no direct connection between the computer and the process. The computer is used "offline" to provide information for the effective planning and management of production activities. The following list surveys the important applications of CAM in this category:

- *Computer-aided process planning (CAPP).* Process planning is concerned with the preparation of route sheets that list the sequence of operations and work centers required 10 produce the product and its components. CAPP systems are available today to prepare these route sheets.
- *Computer-assisted NC part programming.* or complex part geometries, computer assisted part programming represents a much more efficient method of generating the control Instructions for the machine tool than manual part programming is.
- *Computerized machinability data systems.* One of the problems in operating a metal cutting machine tool is determining the speeds and feeds that should be used to machine a given work part. Computer programs have been written to recommend the appropriate cutting conditions to use for different materials. The calculations are based on data that have been obtained either in the factory or laboratory that relate tool life to cutting conditions.
- *Development of work standards.* The time study department has the responsibility for setting time standards on direct labor jobs performed in the factory. Establishing standards have direct time study can be a tedious and time-consuming task. There are several commercially available computer packages for setting work standards. These computer programs 'use standard time data that have been developed for basic work elements that comprise any manual task. By summing the limes for the individual element, required to perform a new Job, the program calculates the standard lime for the job.
- *Cost estimating,* The task of estimating the cost of a new product has been simplified in most industries by computerizing several of the key steps required to prepare the estimate. The computer is programmed to apply the appropriate labor and overhead rates to the sequence of planned operations for the components of new products. the program then sums the individual component costs from the engineering bill of materials to determine the overall product cost.
- *Production and inventory planning.* The computer has found widespread use in many of the functions in production and inventory planning. These functions include: maintenance of inventory records, automatic reordering of stock items when inventory is depicted. production scheduling, maintaining current priorities for the different production orders, material requirements planning, and capacity planning.
- *Computer-aided line balancing.* Finding the best allocation of work elements among stations on an assembly line is a large and difficult problem if the line is of significant size. Computer programs have been developed to assist in the solution of this problem.

The second category of CAM application is concerned with developing computer systems to implement the manufacturing control function. Manufacturing control is concerned with managing and controlling the physical operations in the factory. These management and control areas include:

- *Process monitoring and control.* Process monitoring and control is concerned with observing and regulating the production equipment and manufacturing processes in the plant. The applications of computer process control arc pervasive today in automated production systems. They include transfer lines, assembly systems. NC, robotics. material handling and flexible manufacturing systems.
- *Quality control: Qua1ity* control includes a variety of approaches to ensure the highest possible quality levels in the manufactured product.
- *Shop floor control.* Shop floor control refers to production management techniques for collecting data from factory operations and using the data to help control production and inventory in the factory.
- *Inventory control.* Inventory control is concerned with maintaining the most appropriate levels of inventory in the face of two opposing objectives: minimizing the investment and storage costs of holding inventory and maximizing service to customers.
- *Just-in-time production systems.* The term just-in-time refers to a production system that is organized to deliver exactly the right number of each component to downstream workstations in the manufacturing sequence just at the lime when that component ts needed. The term applies not only to production operations but 10 supplier delivery operations as well.

1.10 DESIGN FOR MANUFACTURING

Design for Manufacturing (DFM) and design for assembly (DFA) are the integration of product design and process planning into one common activity. The goal is to design a product that is easily and economically manufactured. The importance of designing for manufacturing is underlined by the fact that about 70% of manufacturing costs of a product (cost of materials, processing, and assembly) are determined by design decisions, with production decisions (such as process planning or machine tool selection) responsible for only 20%.

The heart of any design for manufacturing system is a group of design principles or guidelines that are structured to help the designer reduce the cost and difficulty of manufacturing an item. The following is a listing of these rules.

1. *Reduce the total number of parts.* The reduction of the number of parts in a product is probably the best opportunity for reducing manufacturing costs. Less parts implies less purchases, inventory, handling, processing time, development time, equipment, engineering time, assembly difficulty, service inspection, testing, etc. In general, it reduces the level of intensity of all activities related to the product during its entire life. A part that does not need to have relative motion with respect to other parts, does not have to be made of a different material, or that would make the assembly or service of other parts extremely difficult or impossible, is an excellent target for elimination. Some approaches to part-count reduction are based on the use of one-piece structures and selection of manufacturing processes such as injection molding, extrusion, precision castings, and powder metallurgy, among others.

2. *Develop a modular design*. The use of modules in product design simplifies manufacturing activities such as inspection, testing, assembly, purchasing, redesign,

maintenance, service, and so on. One reason is that modules add versatility to product update in the redesign process, help run tests before the final assembly is put together, and allow the use of standard components to minimize product variations. However, the connection can be a limiting factor when applying this rule.

3. *Use of standard components.* Standard components are less expensive than custom-made items. The high availability of these components reduces product lead times. Also, their reliability factors are well ascertained. Furthermore, the use of standard components refers to the production pressure to the supplier, relieving in part the manufacture's concern of meeting production schedules.

4. *Design parts to be multi-functional.* Multi-functional parts reduce the total number of parts in a design, thus, obtaining the benefits given in rule 1. Some examples are a part to act as both an electric conductor and as a structural member, or as a heat dissipating element and as a structural member. Also, there can be elements that besides their principal function have guiding, aligning, or self-fixturing features to facilitate assembly, and/or reflective surfaces to facilitate inspection, etc.

5. *Design parts for multi-use*. In a manufacturing firm, different products can share parts that have been designed for multi-use. These parts can have the same or different functions when used in different products. In order to do this, it is necessary to identify the parts that are suitable for multi-use. For example, all the parts used in the firm (purchased or made) can be sorted into two groups: the first containing all the parts that are used commonly in all products. Then, part families are created by defining categories of similar parts in each group. The goal is to minimize the number of categories, the variations within the categories, and the number of design features within each variation. The result is a set of standard part families from which multi-use parts are created. After organizing all the parts into part families, the manufacturing processes are standardized for each part family. The production of a specific part belonging to a given part family would follow the manufacturing routing that has been setup for its family, skipping the operations that are not required for it. Furthermore, in design changes to existing products and especially in new product designs, the standard multi-use components should be used.

6. *Design for ease of fabrication.* Select the optimum combination between the material and fabrication process to minimize the overall manufacturing cost. In general, final operations such as painting, polishing, finish machining, etc. should be avoided. Excessive tolerance, surface-finish requirement, and so on are commonly found problems that result in higher than necessary production cost.

6. *Avoid separate fasteners*. The use of fasteners increases the cost of manufacturing a part due to the handling and feeding operations that have to be performed. Besides the high cost of the equipment required for them, these operations are not 100% successful, so they contribute to reducing the overall manufacturing efficiency. In general, fasteners should be avoided and replaced, for example, by using tabs or snap fits. If fasteners have to be used, then some guides should be followed for selecting them. Minimize the number, size, and variation used; also, utilize standard components whenever possible. Avoid screws that are too long, or too short, separate washers, tapped holes, and round heads and flatheads (not good for vacuum pickup).

Self-tapping and chamfered screws are preferred because they improve placement success. Screws with vertical side heads should be selected vacuum pickup.

TABLE 25.4 General Principles and Guidelines in DFM/A

Guideline	*Interpretation and Advantages*
Minimize number of components	Reduced assembly costs. Greater reliability in final product. Easier disassembly in maintenance and field service. Automation is often easier with reduced part count. Reduced work-in-process and inventory control problems. Fewer parts to purchase; reduced ordering costs.
Use standard commercially available components	Reduced design effort. Fewer part numbers Better inventory control possible. Avoids design of custom-engineered components. Quantity discounts possible.
Use common parts across product lines	Group technology (Chapter 15) can be applied. Quantity discounts are possible. Permits development of manufacturing cells.
Design for ease of part fabrication	Use net shape and near net shape processes where possible. Simplify part geometry; avoid unnecessary features. Avoid surface roughness that is smoother than necessary since additional processing may be needed.
Design parts with tolerances that are within process capability	Avoid tolerances less than process capability (Section 21.1.2). Specify bilateral tolerances. Otherwise, additional processing or sortation and scrap are required.
Design the product to be foolproof during assembly	Assembly should be unambiguous. Components designed so they can be assembled only one way. Special geometric features must sometimes be added to components.
Minimize flexible components	These include components made of rubber, belts, gaskets, electrical cables, etc. Flexible components are generally more difficult to handle.
Design for ease of assembly.	Include part features such as chamfers and tapers on mating parts. Use base part to which other components are added. Use modular design (see following guideline). Design assembly for addition of components from one direction, usually vertically; if mass production, this rule can be violated because fixed automation can be designed for multiple direction assembly. Avoid threaded fasteners (screws, bolts, nuts) where possible, especially when automated assembly is used; use fast assembly techniques such as snap fits and adhesive bonding. Minimize number of distinct fasteners.
Use modular design	Each subassembly should consists of 5-15 parts. Easier maintenance and field service. Facilitates automated (and manual) assembly. Reduces inventory requirements. Reduces final assembly time.
Shape parts and products for ease of packaging	Compatible with automated packaging equipment. Facilitates shipment to customer. Can use standard packaging cartons.
Eliminate or reduce adjustments	Many assembled products require adjustments and calibrations. During product design, the need for adjustments and calibrations should be minimized because they are often time consuming in assembly.

Table 1.2. General principles of DFMA

7. *Minimize assembly directions*. All parts should be assembled from one direction. If possible, the best way to add parts is from above, in a vertical direction, parallel to the gravitational direction (downward). In this way, the effects of gravity help the assembly process, contrary to having to compensate for its effect when other directions are chosen.

8. *Maximize compliance*. Errors can occur during insertion operations due to variations in part dimensions or on the accuracy of the positioning device used. This faulty behavior can cause damage to the part and/or to the equipment. For this reason, it is necessary to include compliance in the part design and in the assembly process. Examples of part built-in compliance features include tapers or chamfers and moderate radius sizes to facilitate insertion, and nonfunctional external elements to help detect hidden features. For the assembly process, selection of a rigid-base part, tactile sensing capabilities, and vision systems are example of compliance. A simple solution is to use high-quality parts with designed-in-compliance, a rigid-base part, and selective compliance in the assembly tool.

9. *Minimize handling*. Handling consists of positioning, orienting, and fixing a part or component. To facilitate orientation, symmetrical parts should be used when ever possible. If it is not possible, then the asymmetry must be exaggerated to avoid failures. Use external guiding features to help the orientation of a part. The subsequent operations should be designed so that the orientation of the part is maintained. Also, magazines, tube feeders, part strips, and so on, should be used to keep this orientation between operations. Avoid using flexible parts - use slave circuit boards instead. If cables have to be used, then include a dummy connector to plug the cable (robotic assembly) so that it can be located easily. When designing the product, try to minimize the flow of material waste, parts, and so on, in the manufacturing operation; also, take packaging into account, select appropriate and safe packaging for the product.

SCHOOL OF MECHANICAL ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

UNIT – 2 – COMPUTER AIDED DRAFTING AND MODELING - SME1205

2. COMPUTER AIDED DRAFTING AND MODELING

2.1. GRAPHICS SOFTWARE

The most important characteristic of CAD/CAM software is its fully three-dimensional, associative, centralized, and integrated database. Such a database is always rich in information needed for both the design and manufacturing processes. The centralized concept implies that any change in or addition to a geometric model in one of its views is automatically reflected in the existing views or any views. Users of CAD/CAM software can be classified into three groups: software operators, applications programmers, and system programmers. The majority of users including engineers and designers fall into the operator's category. The main concern of this group is to master using the software so that the anticipated productivity increases are achieved.

The needs for graphics standards were obvious and were acknowledged by the CAD'CAM community—both vendors and users. The following are some of these needs:

1. Application program portability. This avoids hardware dependence of the program. For example, if the program is written originally for a DVST display, it can be transported to support a raster display with minimal effort.

2. Picture data portability. Description and storage of pictures should be independent of different graphics devices.

3. Text portability. This ensures that text associated with graphics can be presented in an independent form of hardware.

4. Object database portability. While the above needs concern CAD/CAM vendors, transporting design and manufacturing (product specification) data from one system to another is of interest to CAD/CAM users. In some cases, a company might need to ship a CAD database of a specific design to an outside vendor to manufacture and produce the product.

2.1.1. Standard functioning at various level of the graphics system

1. GKS is an ANSI and ISO standard. It is device independent, host system independent and application-independent. It supports both two-dimensional and three-dimensional data and viewing. It interfaces the application program with the graphics support package.

2. PHIGS (programmer's hierarchical interactive graphics system) is intended to support high function workstations and their related CAD'CAM applications. The significant extensions it offers beyond GKS-3D. are in supporting segmentation used to display graphics and the dynamic ability to modify segment contents and relationships. PHIGS operates at the same level as GKS (interface A).

3. VDM (virtual device metafile) defines the functions needed to describe a picture. Such description can be stored or transmitted from one graphics device to another. It functions at the level just above device drivers. VDM is now called CGM (computer graphics metafile).

4. VDI (virtual device interface) lies between GKS or PHIGS .

5. IGES enables an exchange of model databases on CAD/CAM systems. It functions at object database and application data structures.

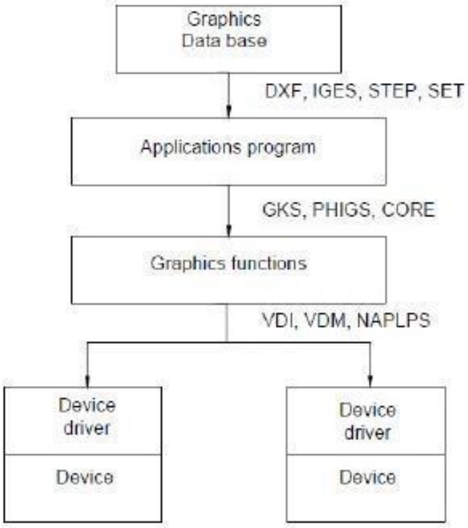

Fig 2.1. Graphics functions

Computer databases are now replacing paper blueprints in defining product geometry and non-geometry for all phases of product design and manufacturing. It becomes increasingly important to find effective procedures for exchanging these databases. Transferring data between dissimilar CAD/CAM systems must embrace the complete product description stored in its database. Four types of modeling data make up this description. These are shape, non-shape, design, and manufacturing data. Shape data consists of both geometrical and topological information as well as part or form features. Features allow high-level concept communication about parts. Examples are hole, flange, web, pocket, chamfer, etc. Non-shape data includes graphics data such as shaded images, and model global data as measuring units of the database and the resolution of storing the database numerical values.

Early attempts to design data formats, e.g., IGES, focused on CAD -to-CAD exchange where primarily shape and non-shape data were to be transferred from one system to another. Soon it became apparent that new data formats need to be designed or the scope of existing ones must be extended to include CAD-to-CAD and CAM-to-CAM exchanges, that is, exchange of complete product descriptions.

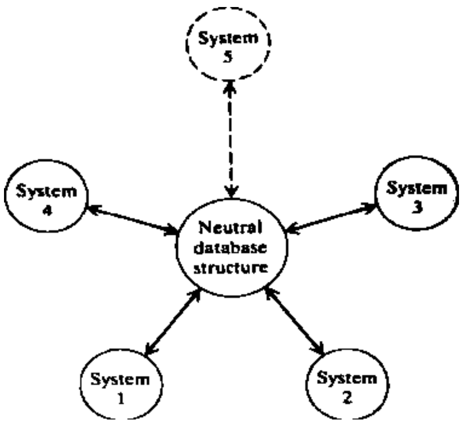

Fig 2.2 Neutral database

2.1.2. Requirements for the Exchange

- *Shape data:* both geometric and topological information, part and form features. Fonts, color, annotation are considered part of the geometric information.

- *Non-shape data:* graphics data such as shaded images, and model global data as measuring units of the database and the resolution of storing the database numerical values.

- *Design data:* information that designers generate from geometric models for analysis purposes. Mass property and finite element mesh data belong to this type of data.
- *Manufacturing data*: information as tooling, NC tool paths, tolerance, process planning, tool design, and bill of materials (BOM).

2.1.3. Standard neutral data formats:

- Initial Graphics Exchange Specification (IGES) - the most popular format of the Neutral file, supported by all CAD/CAE/CAM systems and defined by the international standard organization (ISO).

- Drawing Interchange Format (DXF) - a format originated by Auto Desk and used mainly for the exchange of drawing data.

A number of other neutral data formats for CAD/GAE/CAM s ys t e m s were used in the past. These include PHIGS, NAPLPS and GKS. Currently, CAD systems, which used to support IGES format, are moving toward the use of STEP.

2.2 GRAPHICAL KERNEL SYSTEM

Graphical Kernel System (GKS) provides a set of functions for the purpose of generating 2D pictures on vector graphics and/or raster devices. It also supports operator input and interaction by supplying basic functions for graphical input, picture segmentation and subsequent storage, retrieval and dynamic modification of graphical information.

GKS provides a functional interface between an application program and a configuration of graphical input and output devices. The functional interface contains all basic functions for interactive and non-interactive graphics on a wide variety of graphical equipment.

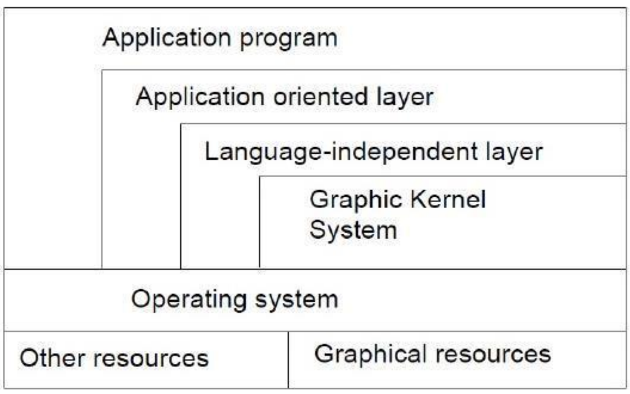

Fig 2.3. Layers of GKS

The geometric information (coordinates) contained in the output primitives, attributes and logical input values can be subjected to transformations. These transformations perform mapping between three coordinate systems, namely:

(a) World Coordinates (WC) used by the application programmer to describe graphical information to GKS.

(b) Normalized Device Coordinates (NDC) used to define a uniform coordinate system for all workstations.

(c) Device Coordinates (DC), one coordinate system per workstation, representing its display surface coordinates. Input containing coordinates are expressed to GKS by the device using DC values.

Output primitives and attributes are mapped from WC to NDC by normalization transformation, from NDC to NDC by segment transformation (as indicated by a transformation matrix defining rotation, scaling and shift factors) and from NDC to DC by workstation transformation. Input from the display surface (expressed in DC) is mapped by an inverse workstation transformation from DC to NDC and by one of the inverse normalization transformation from NDC to WC.

Output primitives and primitive attributes may be grouped together in a segment. Segments are units for manipulation and change. Manipulation includes creation, deletion, and renaming while change includes transforming a segment, changing its visibility and also highlighting segments, i.e., causing segments to "flash". Segments also form the basis for workstation independent storage of pictures at run time. Via this storage, a special workstation called Workstation Independent Segment Storage (WISS), segments can be inserted into other existing ones or transferred to other workstations.

2.3. INITIAL GRAPHICS EXCHANGE SPECIFICATION (IGES)

First developed by National Institute of Standards and Technology (NIST) in 1980. Then adopted by the American National Standards Institute (ANSI) in the same year. Exchanges primarily shape (both geometric and topological) and non-shape data, which is referred as CAD-to-CAD exchange.

File is composed of 80-character ASCII records, a record length derived from the punched card era. Text strings are represented in "Hollerith" format, the number of characters in the string, followed by the letter "H", followed by the text string, e.g., "4HSLOT" (this is the text string format used in early versions of the Fortran language). Early IGES translators had problems with IBM mainframe computers because the mainframes used EBCDIC encoding for text, and some EBCDIC-ASCII translators would either substitute the wrong character, or improperly set the parity bit, causing a misread.

The file is divided into 5 sections: Start, Global, Directory Entry, Parameter Data, and Terminate indicated by the characters S, G, D, P, or T in column 73. The characteristics and geometric information for an entity is split between two sections; one in a two record, fixed-length format (the Directory Entry, or DE Section), the other in a multiple record, comma delimited format (the Parameter Data, or PD Section), as can be seen in a more human-readable representation of the file.

```
                                                                        S      1
1H,,1H;,4HSLOT,37H$1$DUA2:[IGESLIB.BDRAFT.B2I]SLOT.IGS;,                G      1
17HBravo3 BravoDRAFT,31HBravo3->IGES V3.002 (02-Oct-87),32,38,6,38,15,  G      2
4HSLOT,1.,1,4HINCH,8,0.08,13H871006.192927,1.E-06,6.,                   G      3
31HD. A. Harrod, Tel. 313/995-6333,24HAPPLICON - Ann Arbor, MI,4,0;     G      4
     116       1       0       1       0       0       0       0       1D      1
     116       1       5       1       0                               0D      2
     116       2       0       1       0       0       0       0       1D      3
     116       1       5       1       0                               0D      4
     100       3       0       1       0       0       0       0       1D      5
     100       1       2       1       0                               0D      6
     100       4       0       1       0       0       0       0       1D      7
     100       1       2       1       0                               0D      8
     110       5       0       1       0       0       0       0       1D      9
     110       1       3       1       0                               0D     10
     110       6       0       1       0       0       0       0       1D     11
     110       1       3       1       0                               0D     12
116,0.,0.,0.,0,0,0;                                                    1P      1
116,5.,0.,0.,0,0,0;                                                    3P      2
100,0.,0.,0.,0.,1.,0.,-1.,0,0;                                         5P      3
100,0.,5.,0.,5.,-1.,5.,1.,0,0;                                         7P      4
110,0.,-1.,0.,5.,-1.,0.,0,0;                                           9P      5
110,0.,1.,0.,5.,1.,0.,0,0;                                            11P      6
S      1G      4D      12P      6                                       T      1
```

Fig 2.4 An example of IGES File

2.4. GEOMENTRIC MODELLING

Geometric modeling deals with the mathematical representation of curves, surfaces, and solids necessary in the definition of complex physical or engineering objects. The associated field of computational geometry is concerned with the development, analysis, and computer implementation of algorithms encountered in geometric modeling. The objects we are concerned with in engineering range from the simple mechanical parts (machine elements) to complex sculptured objects such as ships, automobiles, airplanes, turbine and propeller blades, etc.

Geometric modeling attempts to provide a complete, flexible, and unambiguous representation of the object, so that the shape of the object can be:

- Easily visualized (rendered)
- Easily modified (manipulated)
- Increased in complexity
- Converted to a model that can be analyzed computationally
- Manufactured and tested

2.4.1 Wireframe modeling

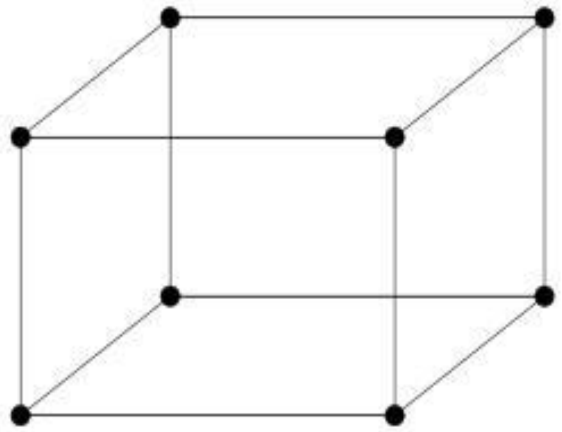

Fig 2.5. Wireframe model

Wireframe modeling, developed in the early 1960's, is one of the earliest geometric modeling techniques. It represents objects by edge curves and vertices on the surface of the object, including the geometric equations of these entities. It is created by intersecting the hull surface with three sets of orthogonal planes. Usually the hull surface is taken as the molded hull surface which is the inner side of the hull plating. Intersections of the hull surface with vertical planes (from bow to stern) are called buttock lines. Intersections of the hull surface with horizontal planes (parallel to keel) are the waterlines, while intersections with transverse vertical planes are called sections. Wireframes are rather incomplete and possibly ambiguous representations that were superseded by surface models.

2.4.2 Surface modeling

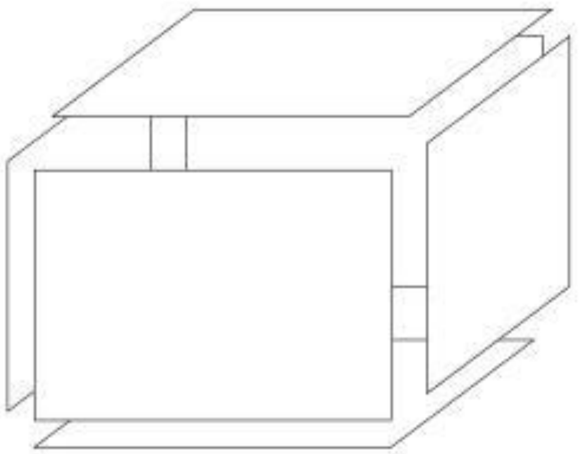

Fig 2.6. Surface model

Surface modeling techniques, developed in the late 1960's, go one step further than wireframe representations by also providing mathematical descriptions of the shape of the surfaces of objects. Surface modeling techniques allow graphic display and numerical control machining of carefully constructed models, but usually offer few integrity checking features (e.g. closed volumes). The surfaces are not necessarily properly connected and there is no explicit connectivity information stored. These techniques are still used in areas where only the visual display is required, e.g. flight simulators.

2.4.3. Solid modeling

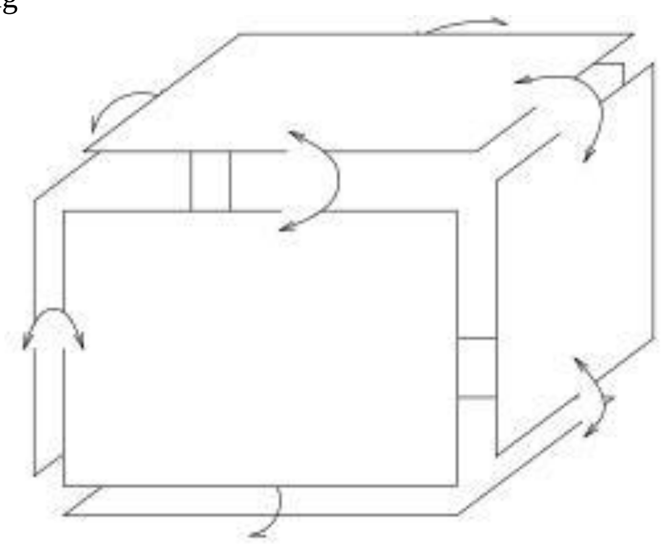

Fig 2.7. Solid model

Solid modeling, first introduced in the early 1970's, explicitly or implicitly contains information about the closure and connectivity of the volumes of solid shapes. Solid modeling offers a number of advantages over previous wireframe and surface modeling techniques. In principle, it guarantees closed and bounded objects and provides a fairly complete description of an object modeled as a rigid solid in 3D space illustrates that for a boundary based solid model of a single homogeneous object, every surface boundary is always directly adjacent to one other surface boundary, guaranteeing a closed volume. Solid models, unlike surface models, enable a modeling system to distinguish the outside of a volume from the inside. This capability, in turn, allows integral property analysis for the determination of volume, center of volume or gravity, moments of inertia, etc

2.5. SOLID MODELING TECHNIQUES

Solid modeling techniques are based on informational complete, valid and unambiguous representations of objects. Simply stated, a complete geometric data representation of an object is one that enables points in space to be classified relative to the object, if it is inside, outside, or on the object. This classification is sometimes called spatial addressability. Both wireframe and surface models are incapable of handling spatial addressability as well as verifying that the model is well formed. The latter meanings that these models cannot verify whether two objects occupy the same space.

User input required to create solid models on existing CAD/CAM systems depends on both the internal representation scheme used by each system as well as the user interface. It is crucial to distinguish between the user interface and the internal data representation of a given CAD/CAM system. The two are quite separate aspects of the systems and can be linked together by software that is transparent to the user. For example, a system that has a B-rep (boundary representation) internal data representation may use a CSG (constructive solid geometry)-oriented user interface; that is, input a solid model by its primitives. Most systems use the building-block approach (CSG oriented) and sweep operations as the basis for user interface.

Solid modelers store more information (geometry and topology) than wireframe or surface modelers (geometry only). Geometry (sometimes called metric information) is the actual dimensions that define the entities of the object. The geometry that defines the object shown in Figure1 is the lengths of lines *L*1, *L*2 and *L*3, the angles between the lines, and the radius R *and* the center P1 of the half-circle. Topology (sometimes called combinatorial structure), on the other hand, is the connectivity and associatively of the object entities. It has to do with the notion of neighborhood; that is, it determines the relational information between object entities.

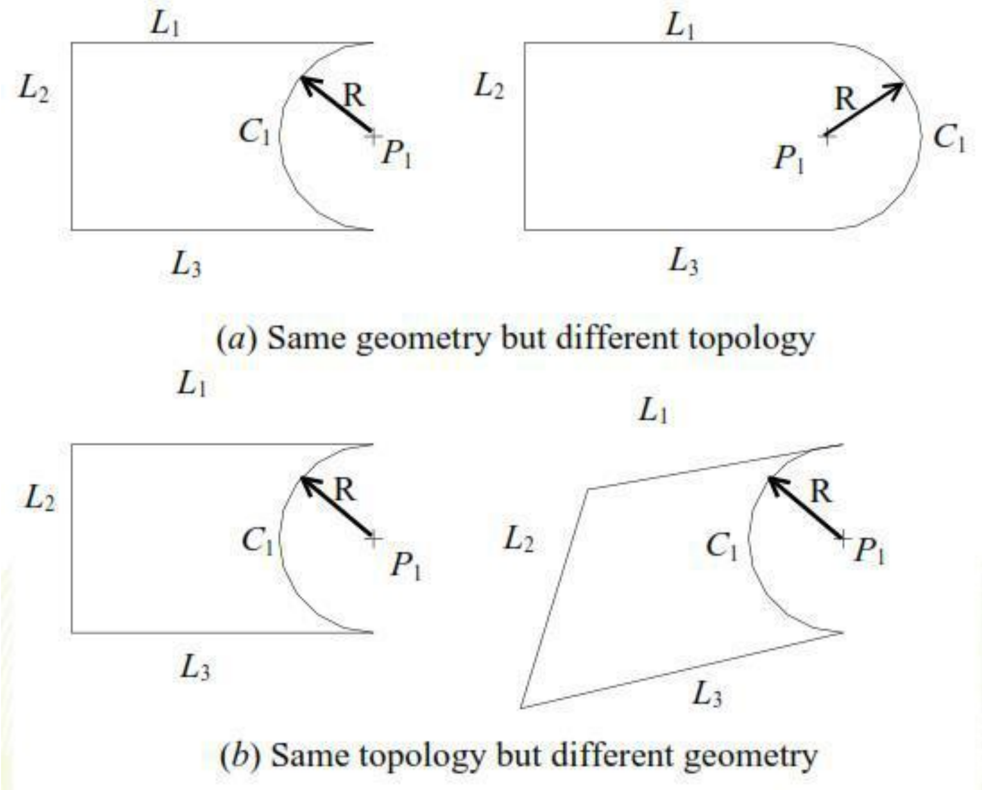

Fig. 2.8. Geometry and topology

Based on these definitions, neither geometry nor topology alone can completely model objects. Wireframe and surface models deal only with geometrical information of objects, and are therefore considered incomplete and ambiguous. From a user point of view, geometry is visible, and topology is considered to be no graphical relational information that is stored in solid model databases and is not visible to users.

2.6. BOUNDARY REPRESENTATION (B-REP)

Boundary representation is one of the two most popular and widely used schemes to create solid models of physical objects. A B-rep model or boundary model is based on the topological notion that a physical object is bounded by a set of faces. These faces are regions or subsets of closed and orient able surfaces. A closed surface is one that is continuous without breaks. An orient able surface is one in which it is possible to distinguish two sides by using the direction of the surface normal to point to the inside or outside of the solid model under construction. Each face is bounded by edges and each edge is bounded by vertices. Thus, topologically, a boundary model of an object is comprised of faces, edges, and vertices of the object linked together in such a way as to ensure the topological consistency of the model. The database of boundary model contains both its topology and geometry. Topology is created by performing Euler operations and geometry is created by operators; ensure the integrity (closeness, no dangling faces or edges, etc.) of boundary models. They offer a mechanism to check the validity of these models. Geometry includes coordinates of vertices, rigid motion and transformation (translation, rotation, etc.), and metric information such as distances, angles, areas, volumes, and inertia tensors. It should be noted that topology and geometry are interrelated and cannot be separated entirely. Both must be compatible otherwise nonsense objects may result. Figure3 shows a square which, after dividing its top edges by introducing a new vertex, is still valid. Topologically but produces a nonsense object depending on the geometry of the new vertex.

2.6.1 Primitives of B-rep

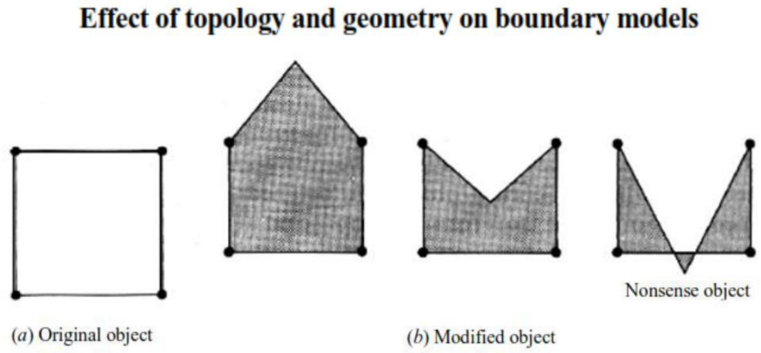

Fig. 2.9. Topology models

If a solid modeling system is to be designed, the domain of its representation scheme (objects that can be modeled) must be defined, the basic elements (primitives) needed to cover such modeling domain must be identified, the proper operators that enable the system users to build complex objects by combining the primitives must be developed, and finally a suitable data structure must be designed to store all relevant data and information of the solid model. Objects that are often encountered in engineering applications can be classified as either polyhedral or curved objects. A polyhedral object (plane-faced polyhedron) consists of planar faces (or sides) connected at straight (linear) edges which, in turn, are connected at vertices. A cube or a tetrahedron is an obvious example. A curved objects (curved polyhedron) is similar to a polyhedral object but with curved faces and edges instead.

2.6.2 Advantages and disadvantages of B-rep

The B-rep scheme is very popular and has a strong history in computer graphics because it is closely related to traditional drafting. Its main advantage is that it is very appropriate to construct solid models of unusual shapes that are difficult to build using primitives.

Another major advantage is that it is relatively simple to convert a B-rep model into a wireframe model because the model's boundary definition is similar to the wireframe definition. One of the major disadvantages of the boundary model is that it requires large amounts of storage because it stores the explicit definition of the model boundaries. It is also a verbose scheme more verbose than CSG. The model is defined by its faces, edges, and vertices which tend to grow fairly fast for complex models. If B-rep systems do not have a CSG-compatible user interface, then it becomes slow and inconvenient to use Euler operators in a design and production environment.

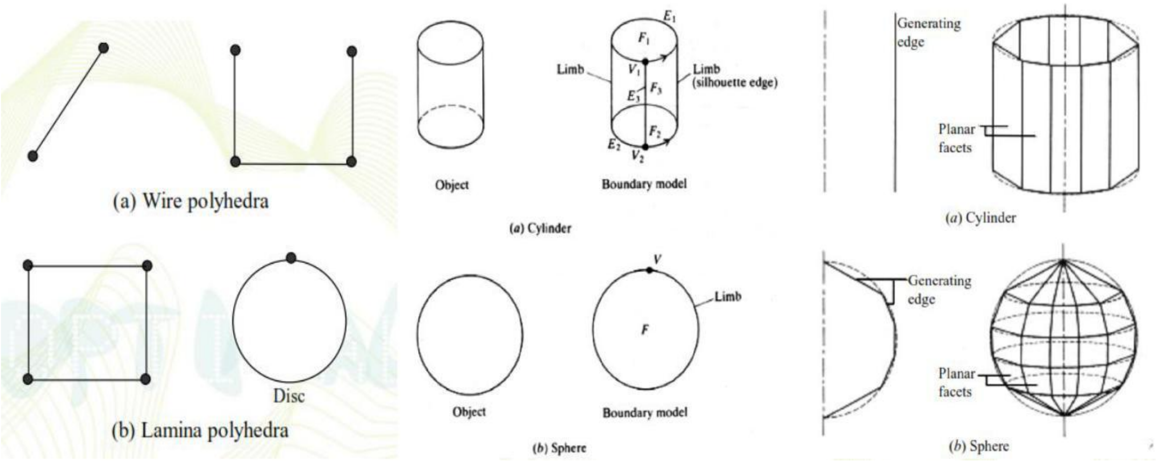

Fig 2.10. B-Rep models

2.7 CONSTRUCTIVE SOLID GEOMETRY (CSG)

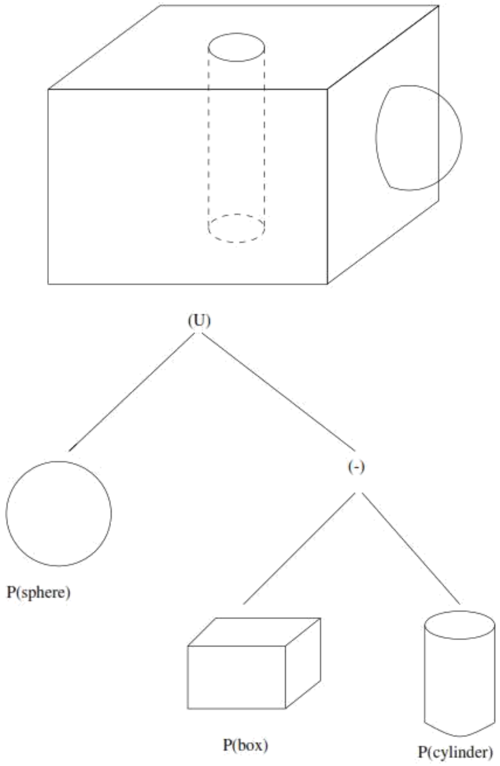

Fig 2.11. CSG Model

Constructive Solid Geometry (CSG) is the Boolean combination of primitive volumes that include the surface and the interior. For example, primitives including rectangular box, sphere, cylinder, cone and torus can be combined using intersection, union and difference operators to form complex solids. Positioning operators (position, orientation) and size operators are applied to the primitives before the Boolean operators are invoked. Terminal nodes on the binary tree are primitive volumes; other nodes are Boolean operators. This representation has a direct manufacturing analogue, where difference indicates drilling or machining and union indicates for example welding. Another example of a related representation is sweeps, where more general primitives are obtained by sweeping a solid along a space curve or sweeping a planar curve through a revolution about an axis in its plane. Sweeps are useful in the representation of blends, volumes swept by machine tools, and in robotics. In a survey of machine elements, 90 to 95% of parts could be represented accurately using the CSG method with the above simple primitive solids.

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DEPARTMENT OF MECHANICAL ENGINEERING

UNIT – 3 – CURVES, SURFACES & TRANSFORMATIONS - SME1205

3. CURVES & SURFACES AND 2D & 3D TRANSFORMATIONS

3.1. 2D TRANSFORMATIONS

Transformation means changing some graphics into something else by applying rules. We can have various types of transformations such as translation, scaling up or down, rotation, shearing, etc. When a transformation takes place on a 2D plane, it is called 2D transformation.

3.1.1. 2D Translation:

Translation moves an object to a different position on the screen. You can translate a point in 2D by adding translation coordinate (tx, ty) to the original coordinate X, Y to get the new coordinate X ′ , Y ′.

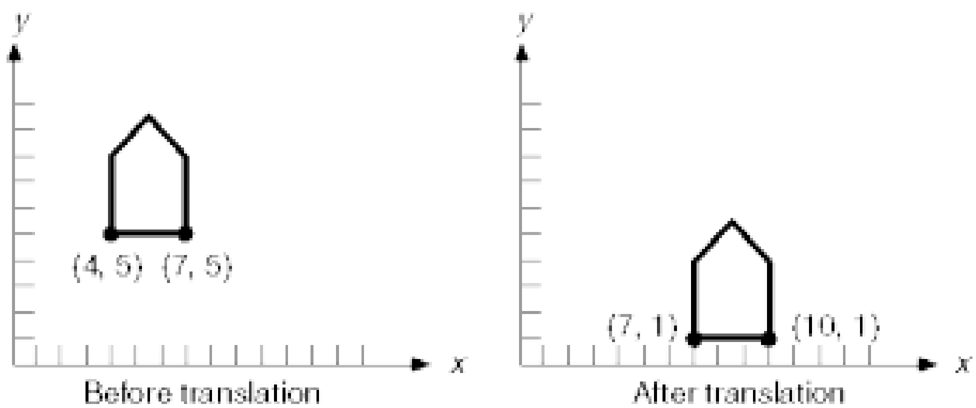
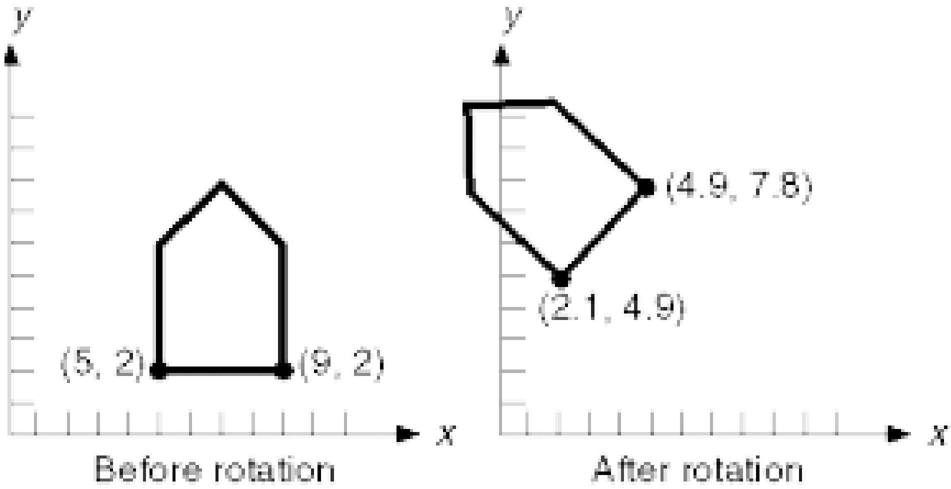


Fig 3.1. 2D Translation

$$x' = x + d_x \qquad \begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} d_x \\ d_y \end{bmatrix}$$
$$y' = y + d_y$$

3.1.2. 2D Rotation

In rotation, we rotate the object at particular angle θ theta from its origin. From the following figure, we can see that the point PX, Y is located at angle φ from the horizontal X coordinate with distance r from the origin. Let us suppose you want to rotate it at the angle θ. After rotating it to a new location, you will get a new point P’ X′ , Y ′ .



$$P' = R \times P$$

Fig 3.2. 2D Rotation

$$x' = x\cos(\alpha) - y\sin(\alpha)$$

$$y' = x\sin(\alpha) + y\cos(\alpha)$$

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos(\alpha) & -\sin(\alpha) \\ \sin(\alpha) & \cos(\alpha) \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

3.1.3. 2D SCALING

To change the size of an object, scaling transformation is used. In the scaling process, you either expand or compress the dimensions of the object. Scaling can be achieved by multiplying the original coordinates of the object with the scaling factor to get the desired result. Let us assume that the original coordinates are X, Y, the scaling factors are (SX, SY), and the produced coordinates are X ′ , Y ′ . This can be mathematically represented as shown below − X' = X . SX and Y' = Y . SY The scaling factor SX, SY scales the object in X and Y direction respectively.

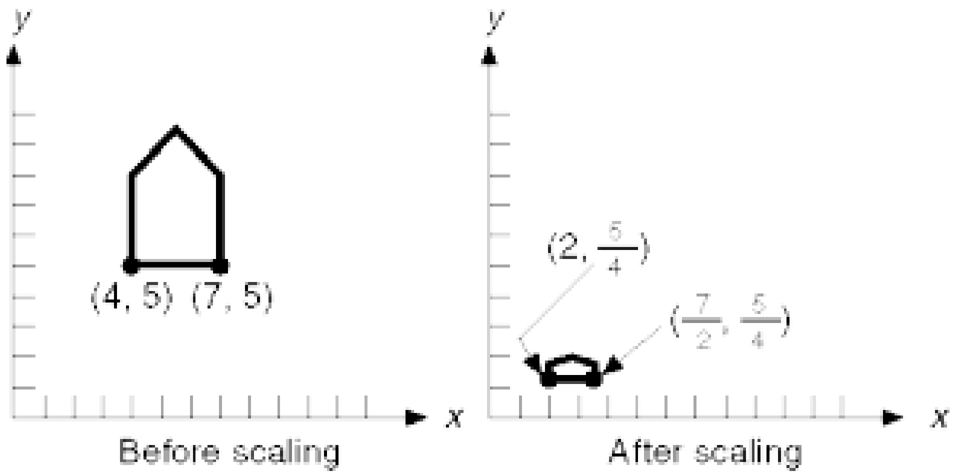
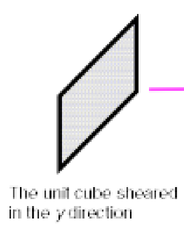


Fig.3.3. 2D Scaling

$$x' = s_x \times x$$
$$y' = s_y \times y$$
$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} s_x & 0 \\ 0 & s_y \end{bmatrix} \times \begin{bmatrix} x \\ y \end{bmatrix}$$

3.1.4. 2D SHEARING

A transformation that slants the shape of an object is called the shear transformation. There are two shear transformations X-Shear and Y-Shear. One shifts X coordinates values and other shifts Y coordinate values. However; in both the cases only one coordinate changes its coordinates and other preserves its values. Shearing is also termed as Skewing.



$$P' = SH_y \times P$$
$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ b & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

$$P' = SH_x \times P$$
$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & a \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

Fig. 3.4. 2D Shearing

3.1.4.1. X-Shear

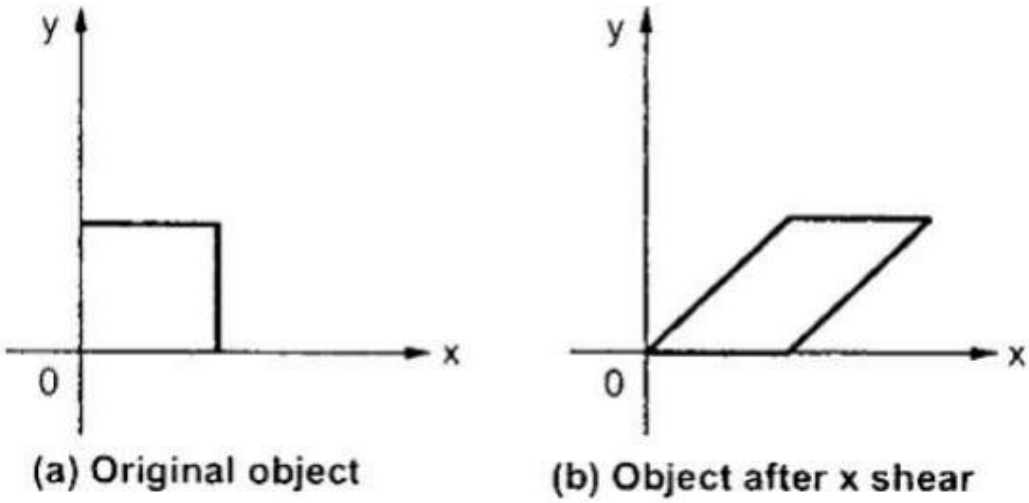


Fig. 3.5. X-Shear

The X-Shear preserves the Y coordinate and changes are made to X coordinates, which causes the vertical lines to tilt right or left as shown in below figure.

3.1.4.2. Y-Shear

The Y-Shear preserves the X coordinates and changes the Y coordinates which causes the horizontal lines to transform into lines which slopes up or down as shown in the following figure.

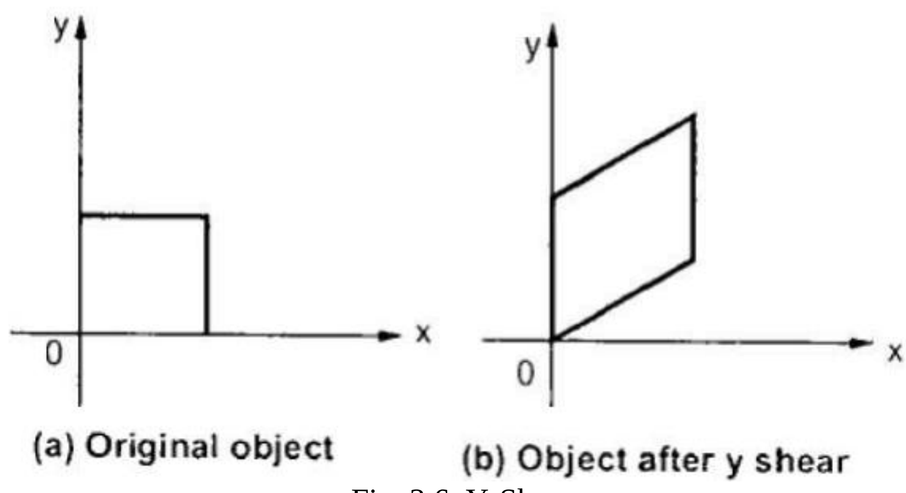


Fig. 3.6. Y-Shear

3.1.5. 2D REFLECTION

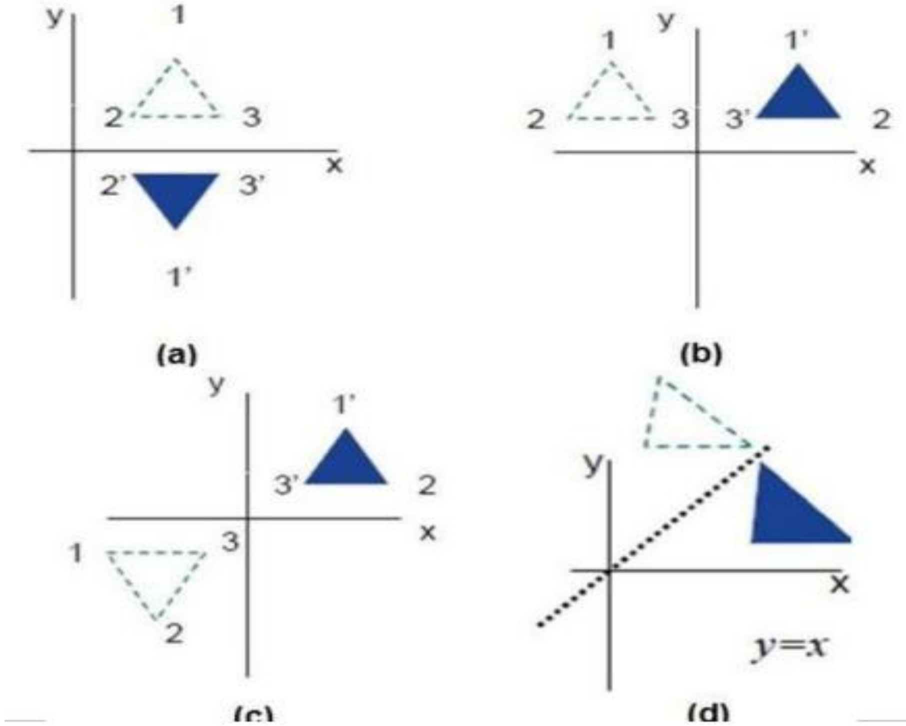


Fig. 3.6. Y-Shear

Reflection is the mirror image of original object. In other words, we can say that it is a rotation operation with 180°. In reflection transformation, the size of the object does not change. The following figures show reflections with respect to X and Y axes, and about the origin respectively.

3.2. 3D TRANSFORMATIONS

In homogeneous coordinates, 3D transformations are represented by 4x4 matrices. A point transformation is performed.

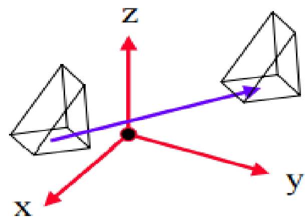
$$\begin{bmatrix} a & b & c & t_x \\ d & e & f & t_y \\ g & h & i & t_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} a & b & c & t_x \\ d & e & f & t_y \\ g & h & i & t_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

- P in translated to P' by:

$$\begin{bmatrix} 1 & 0 & 0 & t_x \\ 0 & 1 & 0 & t_y \\ 0 & 0 & 1 & t_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} x+t_x \\ y+t_y \\ z+t_z \\ 1 \end{bmatrix}$$

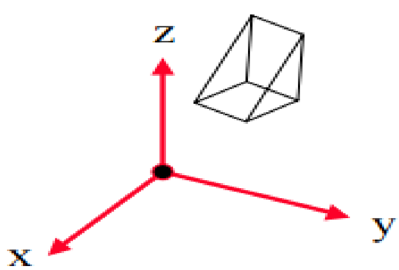
Or $T\,P = P'$

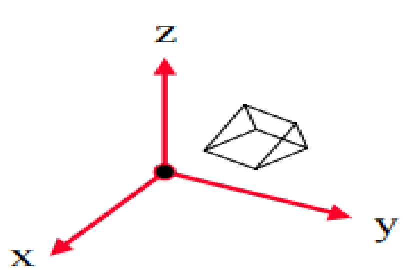


- Inverse translation: $T^{-1}P' = P$

$$\begin{bmatrix} a & 0 & 0 & 0 \\ 0 & b & 0 & 0 \\ 0 & 0 & c & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} ax \\ by \\ cz \\ 1 \end{bmatrix}$$

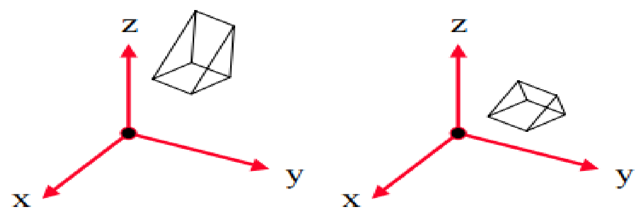
Or $S\,P = P'$



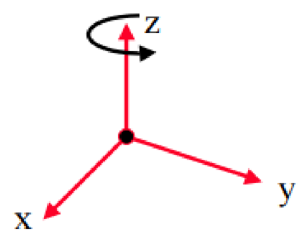


$$\begin{bmatrix} a & 0 & 0 & 0 \\ 0 & b & 0 & 0 \\ 0 & 0 & c & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} ax \\ by \\ cz \\ 1 \end{bmatrix}$$

Or $\quad SP = P'$



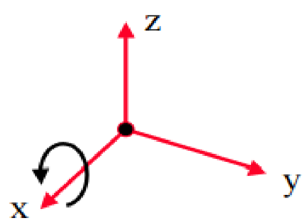
z-axis



$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

$$p' = R_z(\theta)p$$

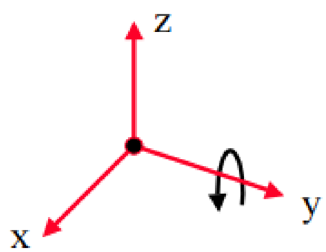
x-axis



$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta & 0 \\ 0 & \sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

$$p' = R_x(\theta)p$$

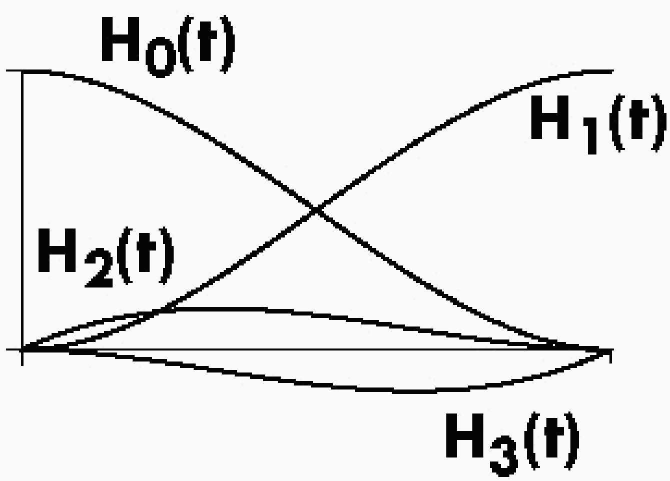
y-axis



$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & 0 & \sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta & 0 & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

$$p' = R_y(\theta)p$$

3.3. HERMITE CURVE



$$H_0(t) = 2t^3 - 3t^2 + 1$$
$$H_1(t) = -2t^3 + 3t^2$$
$$H_2(t) = t^3 - 2t^2 + t$$
$$H_3(t) = t^3 - t^2$$

$$\mathbf{M}_H = \begin{bmatrix} 2 & -3 & 0 & 1 \\ -2 & 3 & 0 & 0 \\ 1 & -2 & 1 & 0 \\ 1 & -1 & 0 & 0 \end{bmatrix}$$

Fig 3.7. Blending functions of Hermite cubic curve

3.3.1. Bezier curve

A quadratic Bezier curve is a Bezier curve of degree 2 and is defined through 3 points (P0, P1 and P2) is show in the fig (A). A cubic Bezier curve is a Bezier curve of degree 3 and is defined by 4 points (P0, P1, P2 and P3). The curve starts at P0 and stops at P3. The line P0P1 is the tangent of the curve in point P0. And so it is the line P2P3 in point P3. In general, the curve will not pass through P1 or P2; the only function of these points is providing directional information. The distance between P0 and P1 determines "how long" the curve moves into direction P1 before turning towards P3 is shows in the fig (B).

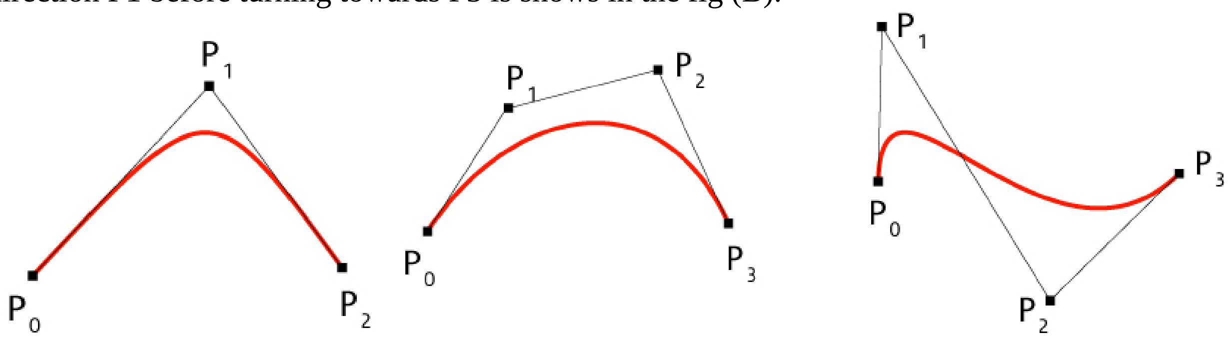


Fig 3.8. Bazier curves

3.3.2. B-Spline curve

The B-Spline curve Tool draws smooth curves when you create open or closed shapes. B-spline, also known as Basis spline, uses a mathematical formula. It is this calculation that produces really nice elegant curves. When you use the B-Spline Tool, control points are connected together as you draw and a polygon is constructed. The polygon controls the position and direction and calculates the smoothest possible curve between two points on the page.

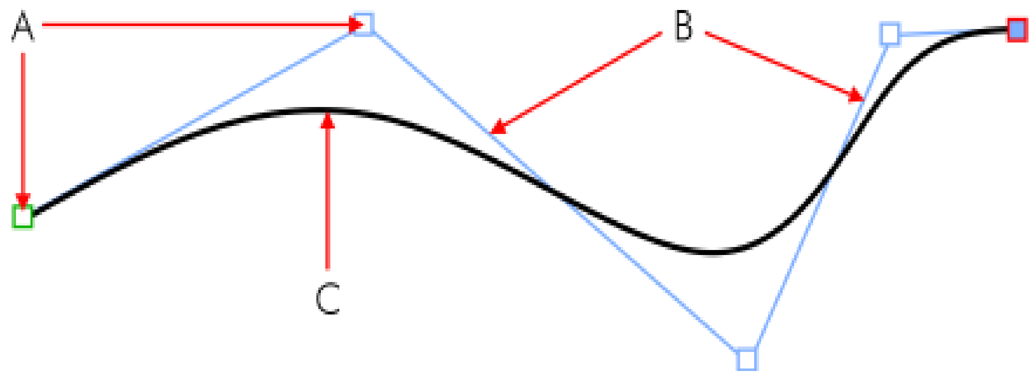


Fig 3.9. B-spline curve

3.3.3. Rational Curve

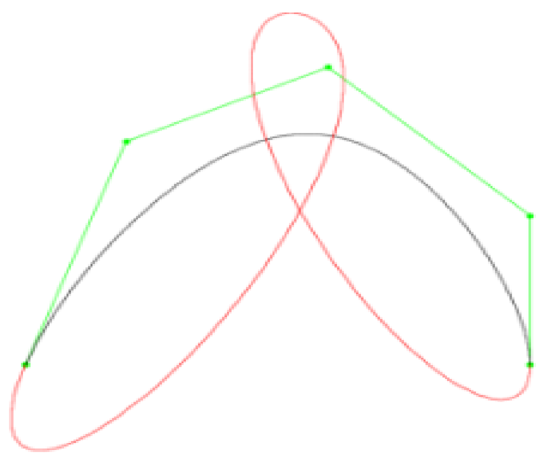


Fig 3.10: Rational normal curve

The rational normal curve is a smooth, rational curve C of degree n in projective n-space Pn. It is a simple example of a projective variety; formally, it is the Veronese variety when the domain is the projective line. For n = 2 it is the flat conic Z0Z2 = Z2 1, and for n = 3 it is the twisted cubic. The term "normal" refers to projective normality, not normal schemes. The intersection of the rational normal curve with an affine space is called the moment curve.

3.4. TECHNIQUES FOR SURFACE MODELING

3.4.1. Surface Patch

The patch is the fundamental building block for surfaces. The two variables *u* and *v* vary across the patch; the patch may be termed *biparametric.* The parametric variables often lie in the range 0 to 1. Fixing the value of one of the parametric variables results in a curve on the patch in terms of the other variable (*Isoperimetric curve*). Figure shows a surface with curves at intervals of *u* and *v* of 0 to 1.

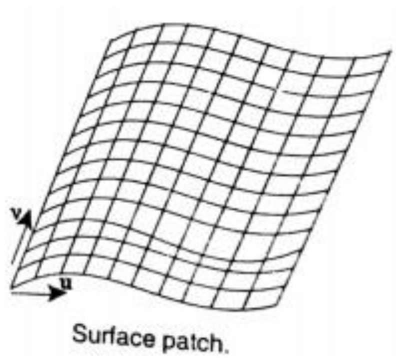


Fig 3.11: Surface patch

3.4.2. Coons Patch

The sculptured surface often involve interpolation across an intersecting mesh of curves that in effect comprise a rectangular grid of patches, each bounded by four boundary curves. The linearly blended coons patch is the simplest for interpolating between such boundary curves. This patch definition technique blends for four boundary curves C$i(u)$ and D$j(v)$ and the corner points pij of the patch with the linear blending functions,

$$f(t) = 1 - t$$
$$g(t) = t$$

using the expression

$$\vec{p}(u, v) = \vec{C}_0(u)\, f(v) + \vec{C}_1(u)\, g(v) + \vec{D}_0(v)\, f(u) + \vec{D}_1(v)\, g(u) - \vec{p}_{00}\, f(u)\, f(v) - \vec{p}_{01}\, f(u)\, g(u) - \vec{p}_{10}\, g(u)\, f(v) - \vec{p}_{11}\, g(u)\, g(v)$$

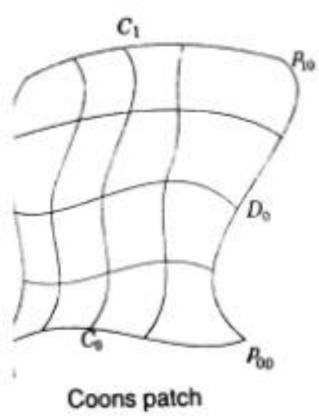


Fig 3.12: Coon's patch

3.4.3. Bicubic Patch

The bi-cubic patch is used for surface descriptions defined in terms of point and tangent vector information. The general form of the expressions for a bi-cubic patch is given by:

$$\overrightarrow{p}(u, v) = \sum_{i=0}^{3} \sum_{j=0}^{3} \overrightarrow{k_{ij}} u^i v^j$$

This is a vector equation with 16 unknown parameters *kij* which can be found by Lagrange interpolation through 4 x 4 grid.

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DEPARTMENT OF MECHANICAL ENGINEERING

UNIT – 4 – COMPUTER AIDED MANUFACTURING - SME1205

4. COMPUTER AIDED MANUFACTURING

4.1. PROCESS DATA

The data collected by the computer in computer process monitoring can generally be classified into three categories:

- *Process data.* These are measured values of input parameters and output variable, that indicate process performance, When the values are found to indicate a problem, the human operator takes corrective action.

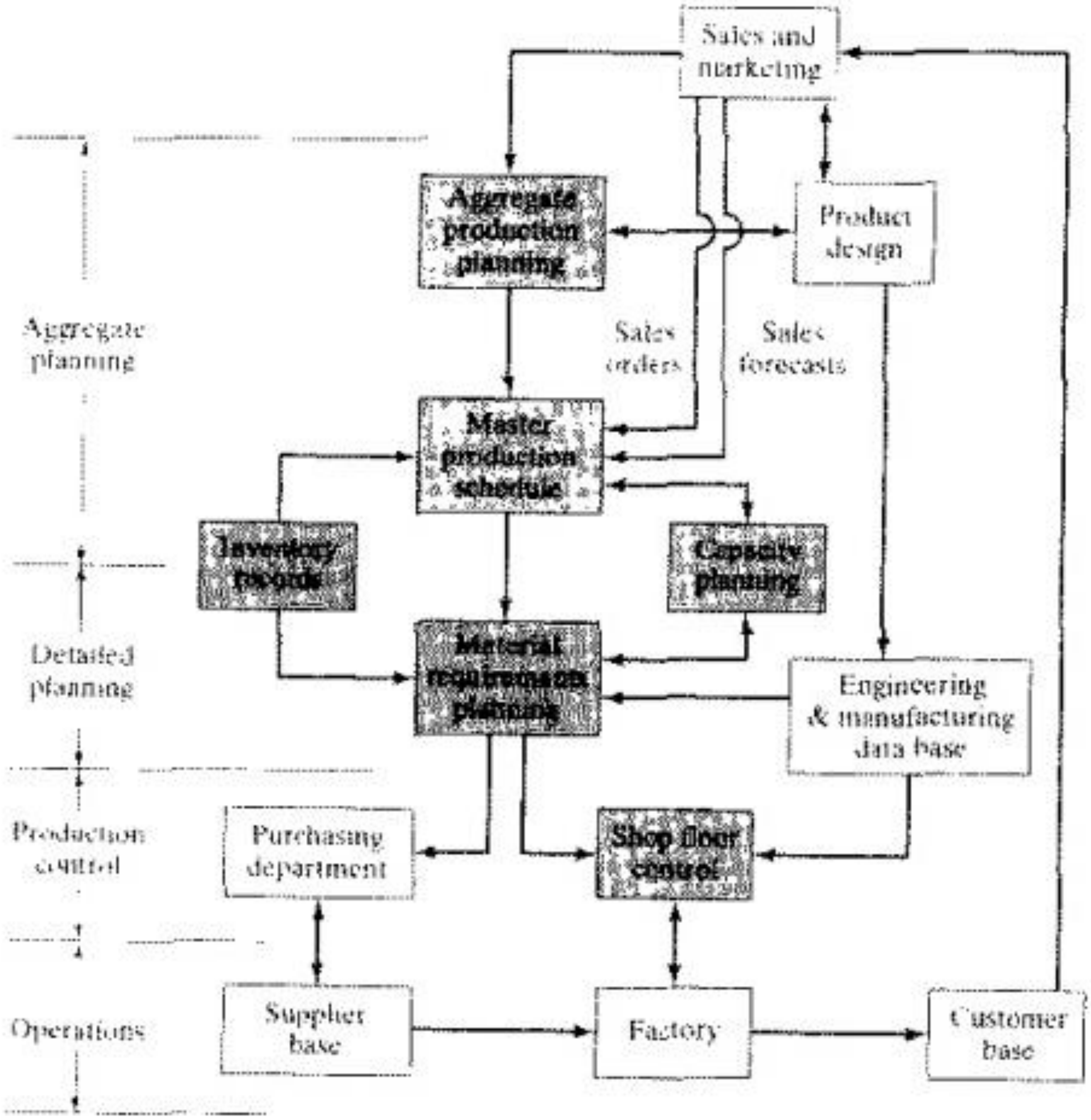
- *Equipment data Process date.* These are measured values of input parameters and output variable, that indicate process performance, When the values are found to indicate a problem, the human operator takes corrective action.

- *Equipment data.* These data indicate the status of the equipment in the work cell. Functions served by the data include monitoring machine utilization, scheduling tool changes, avoiding machine breakdowns. diagnosing equipment malfunctions, and planning preventive maintenance

- *Product data.* Government regulations require certain manufacturing industries to collect and preserve production oeta on their products, The pharmaceutical and medical supply industries are prime examples. Computer monitoring is the most convert, means of satisfying these regulations. A firm may also want 10 collect product data for its own use.

4.2. MANUFACTURING PLANNING & CONTROL

Production planning and control (PPC) is concerned with the logistics problems that are encountered in manufacturing, that is, managing the details of what and how many products to produce and when, and obtaining the raw materials, parts, and resources to product those products. PPC: solves these logistics problems by managing information. The computer is essential for processing the tremendous amounts of data involved to define the products and the manufacturing resources to produce them and to reconcile these technical details with the desired production schedule. Let us nevertheless try to explain what is involved in each of the two function" production planning and production control.



Activities in a PPC system (highlighted in the diagram) and their relationships with other functions in the firm and outside.

Fig. 4.1. PPC System

4.2. PRODUCTION PLANNING

It is concerned with: (1) deciding which products to make, how many of each, and when they should he completed: (2) scheduling the delivery *and/or* production of the pans and products: and (3) planning the manpower and equipment resources needed to accomplish the production plan. Activities within the scope of production planning include:

- *Aggregate production planning.* This involves planning the production output elects for major product lines produced by the firm. These plans must be coordinated among various functions in the firm, including product design, production, marketing and sales
- *Master production planning.* The aggregate production plan must be converted into a master production schedule (\1PS) which is a specific plan of the quantities to be produced of individual models within each product line.

- *Material requirements planning* (MRP) is a planning technique, usually implemented by computer that translates the MPS of end products into a detailed schedule for the raw materials and parts used in those end products
- *Capacity planning* is concerned with determining the labor and equipment resources needed to achieve the master schedule.

4.3. PRODUCTION CONTROL

It is concerned with determining whether the necessary resources 10 implement the production plan haven provided, and if not. it attempts to take corrective action to address the deficiencies. A, its name suggests, production control includes various systems and techniques for controlling production and inventory in the factory. The major topic, covered in this chapter are:

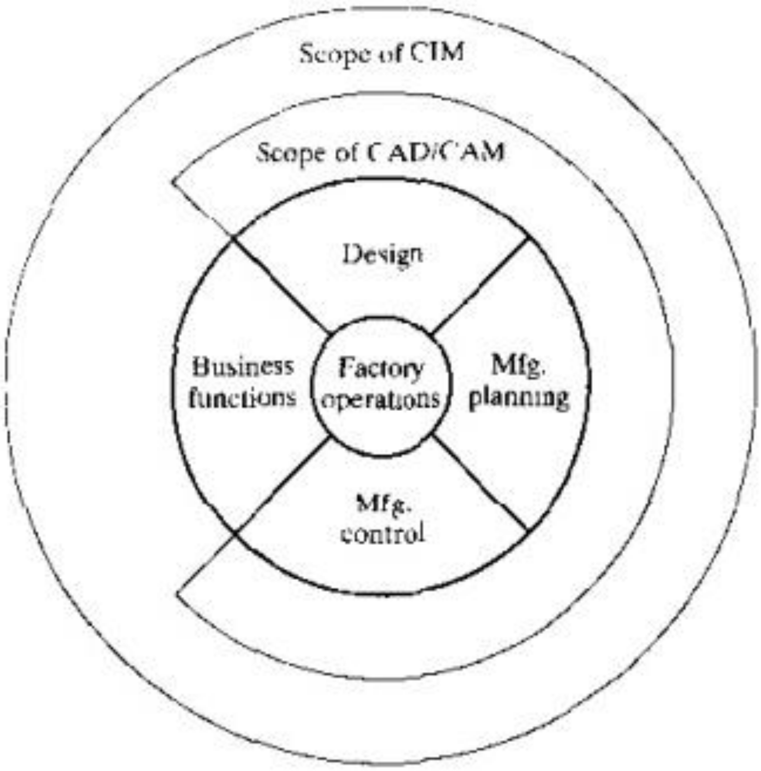
- *Shop floor control.* Shop floor control systems compare the progress and status of production orders in the factory to the production plans (MPS and parts explosion accomplished by MRP)
- *Inventory control.* Inventory control includes it variety of techniques for managing the inventory of a firm. One of the important tools in inventory control is the economic order quantity formula
- *Manufacturing resource planning.* Also known as MRP II. manufacturing resource planning combines MRP and capacity planning as well as shop floor control and other functions related to PPC
- *Just In time production systems.* The term "just in time" refers 10 a scheduling discipline in which materials and parts are delivered to the next work cell or production line station just prior to their heing used. This type of discipline tends to reduce inventory and other kinds of waste in manufacturing.

4.4. CAD/CAM INTEGRATION

CAD/CAM denotes an integration of design and manufacturing activities by means of computer systems. The method of manufacturing a product is a direct function of its design. With conventional procedures practiced for so many years in industry, engineering drawings were prepared by design draftsmen and later used by manufacturing engineers to develop the process plan. The activities involved in designing the product were separated from the activities associated with process planning. Essentially a two-step procedure was employed. This was time-consuming and involved duplication of effort by design and manufacturing personnel. Using CAD/CAM technology, it is possible to establish a direct link between product design and manufacturing engineering. It is the goal of CAD/CAM not only to automate certain phases of design. and certain phases of manufacturing, but also to automate the transition from design to manufacturing. In the ideal CAD/CAM system, it is possible to take the design specification of the product as it resides in the CAD data base and convert it into a process plan for making the product, this conversion. being done automatically by the CAD/CAM system. A large portion of the processing might be accomplished on a numerically controlled machine tool As part of the process plan, the NC part program is generated automatically by CAD/CAM, The CAD/CAM system downloads the NC program directly to the machine tool by means of a telecommunications network. Hence, under this arrangement, product design, NC programming, and physical production are all implemented by computer.

4.5. PRINCIPLES OF COMPUTER INTEGRATED MANUFACTURING

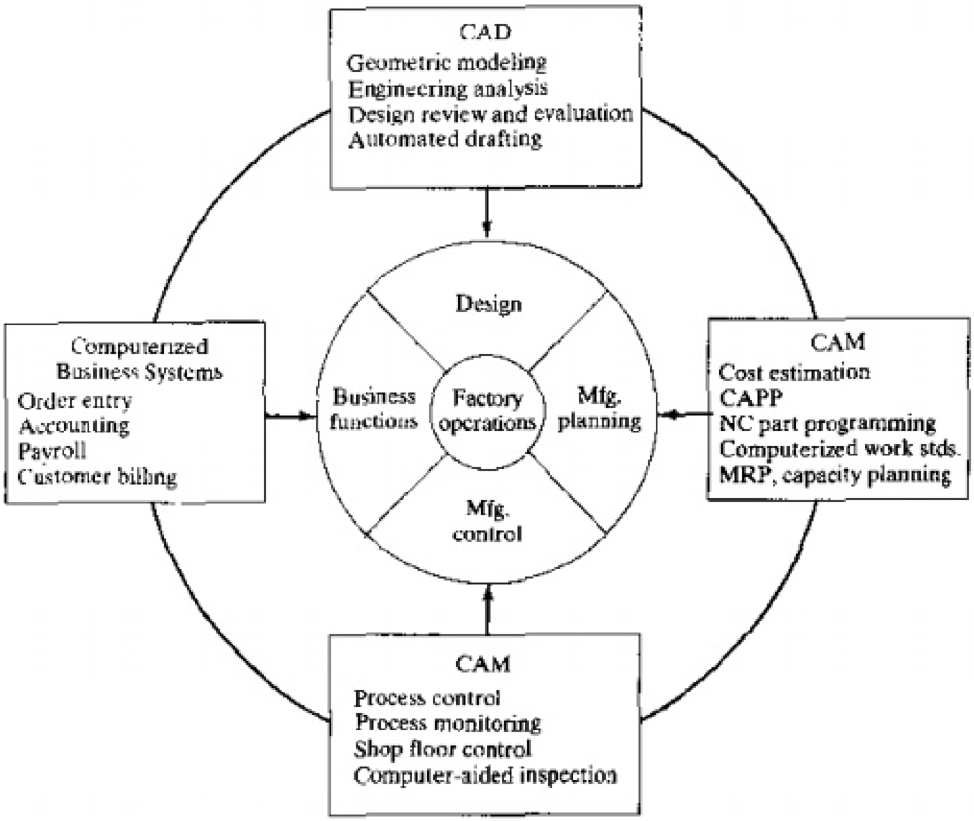
Computer integrated manufacturing includes all of the engineering functions of CAD/CAM, but it also includes the firm's business functions that are related to manufacturing. The ideal CIM system applies computer and communications technology to all of the operational functions and information processing functions in manufacturing from order receipt, through design and production, to product shipment.



The scope of CAD/CAM and CIM.

Fig. 4.2. CIM Wheel

The CIM concept is that all of the firm's operations related to production are incorporated in an integrated computer system to assist. augment. and automate the operations. The computer system b pervasive throughout the firm, touching all activities that support manufacturing. In this integrated computer system, the output of one activity serves as the input to the next activity, through the chain of events that starts with the sales order and culminates with shipment of the product. The components of the integrated computer system are illustrated in Figure 24.8. Customer orders are initially entered by the company's sales force or directly by the customer into a computerized order entry system. The orders contain the specifications describing the product. The specifications serve as the input to the product design department. New products are designed on a CAD system. The components that comprise the product are designed, the bill of materials is compiled, and assembly drawings are prepared. The output of the design department serves as the input to manufacturing engineering, where process planning. tool design, and similar activities are accomplished to prepare for production. Many of these manufacturing engineering activities are supported by the (1M system. Process planning is performed using CAPP. Tool and fixture design is done on a CAD system, making use of the product model generated during product design. The output from manufacturing engineering provides the input to production planning and control. where material requirements planning and scheduling are performed using the computer system. And so it goes. through each step in the manufacturing cycle. Pull implementation of C1M results in the automation of the information flow through every aspect of the company's organization.



Computerized elements of a CIM system.

Fig. 4.3. Elements of CIM system

4.6. HIERARCHICAL COMPUTER STRUCTURES AND NETWORKING

A hierarchical network design involves dividing the network into discrete layers. Each layer, or tier, in the hierarchy provides specific functions that define its role within the overall network. This helps the network designer and architect to optimize and select the right network hardware, software, and features to perform specific roles for that network layer. Hierarchical models apply to both LAN and WAN design. The benefit of dividing a flat network into smaller, more manageable blocks is that local traffic remains local. Only traffic that is destined for other networks is moved to a higher layer. For example, the flat network has now been divided into three separate broadcast domains.

A typical enterprise hierarchical LAN campus network design includes the following three layers:

- Access layer: Provides workgroup/user access to the network
- Distribution layer: Provides policy-based connectivity and controls the boundary between the access and core layers
- Core layer: Provides fast transport between distribution switches within the enterprise campus.

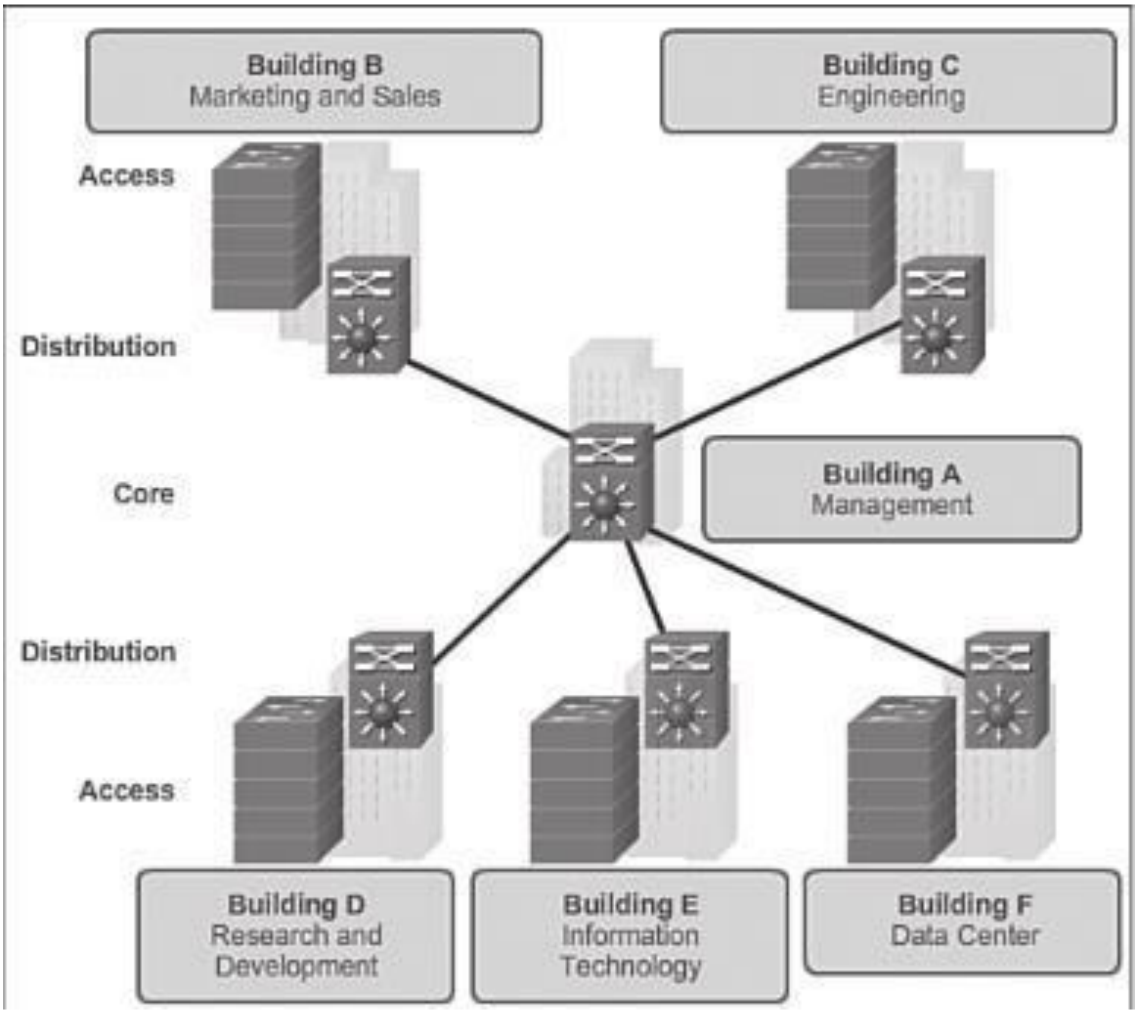


Fig. 4.4. LAN Environment

In a LAN environment, the access layer highlighted grants end devices access to the network. In the WAN environment, it may provide steelworkers or remote sites access to the corporate network across WAN connections. The access layer serves a number of functions, including:

- Layer 2 switching
- High availability
- Port security
- QoS classification and marking and trust boundaries
- Address Resolution Protocol (ARP) inspection
- Virtual access control lists (VACLs)
- Spanning tree
- Power over Ethernet (PoE) and auxiliary VLANs for VoIP

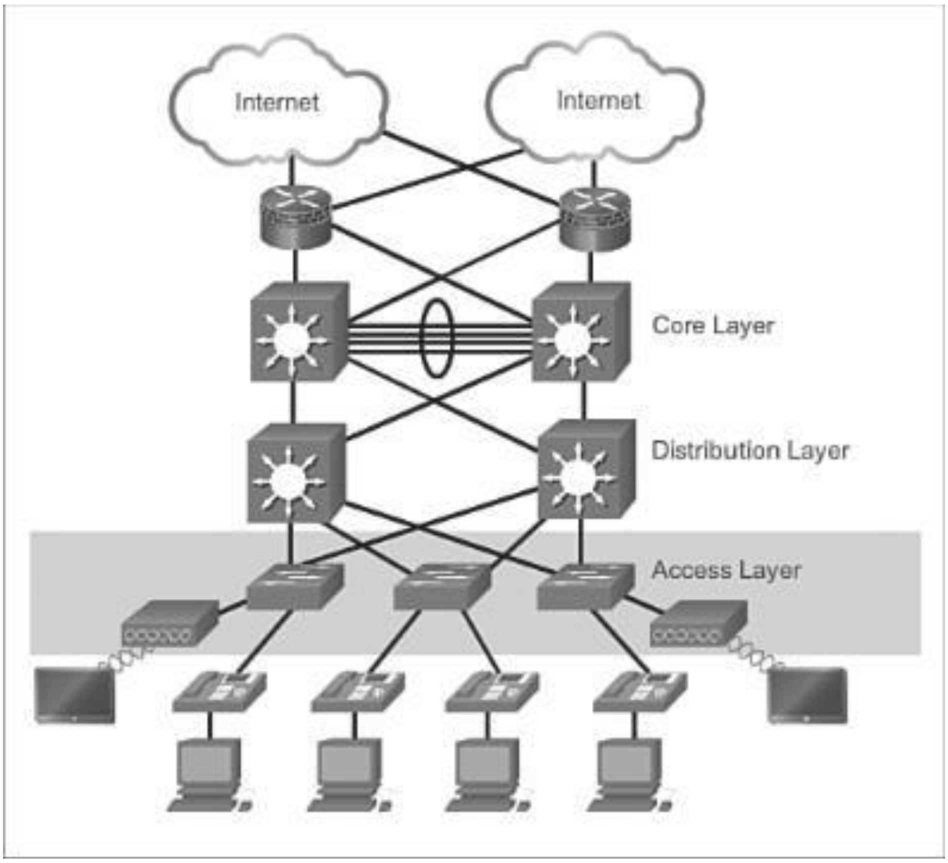


Fig. 4.5. Access System

The distribution layer aggregates the data received from the access layer switches before it is transmitted to the core layer for routing to its final destination.

The distribution layer device is the focal point in the wiring closets. Either a router or a multilayer switch is used to segment workgroups and isolate network problems in a campus environment.

A distribution layer switch may provide upstream services for many access layer switches. The distribution layer can provide:

- Aggregation of LAN or WAN links.
- Policy-based security in the form of access control lists (ACLs) and filtering.
- Routing services between LANs and VLANs and between routing domains (e.g., EIGRP to OSPF).
- Redundancy and load balancing.
- A boundary for route aggregation and summarization configured on interfaces toward the core layer.
- Broadcast domain control, because routers or multilayer switches do not forward broadcasts. The device acts as the demarcation point between broadcast domains.

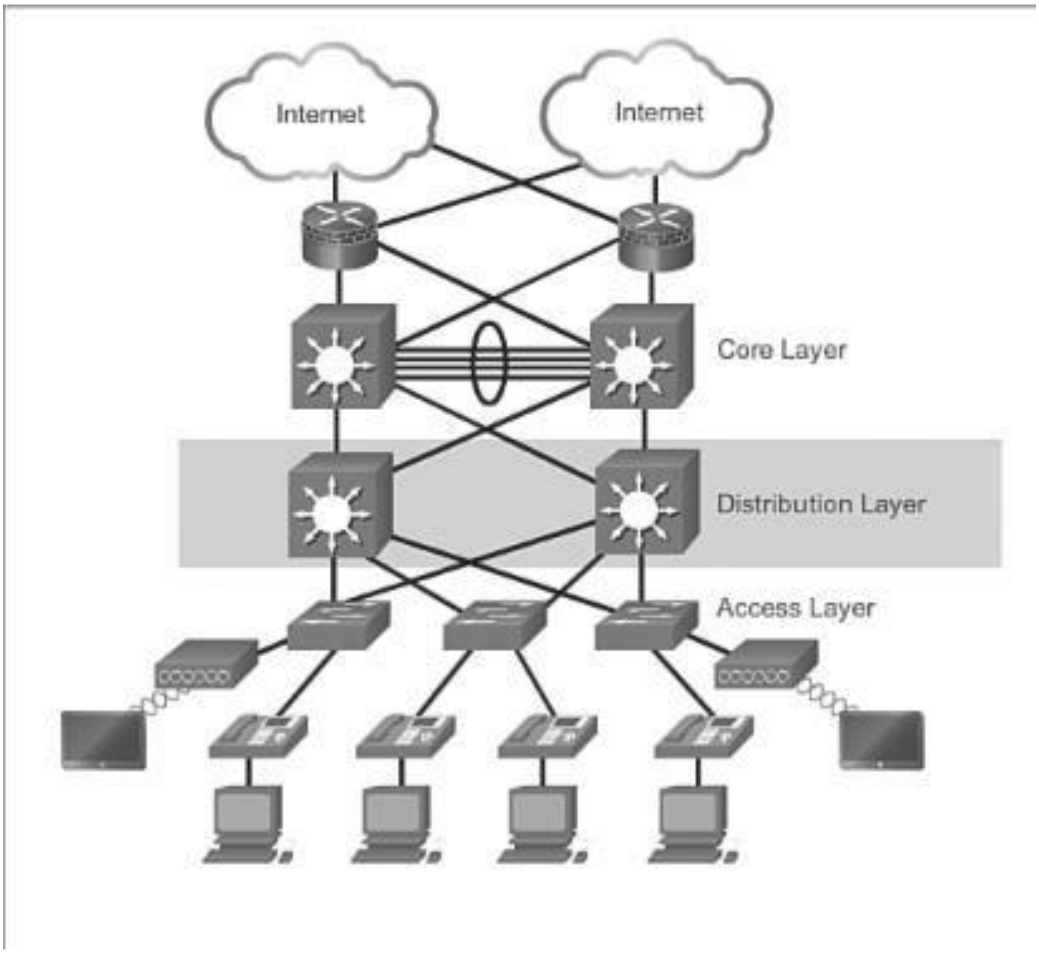


Fig. 4.6. Distribution System

The core layer is also referred to as the network backbone. The core layer consists of high-speed network devices such as the Cisco Catalyst 6500 or 6800. These are designed to switch packets as fast as possible and interconnect multiple campus components, such as distribution modules, service modules, the data center, and the WAN edge.

The core should be highly available and redundant. The core aggregates the traffic from all the distribution layer devices, so it must be capable of forwarding large amounts of data quickly. Considerations at the core layer include:

- Providing high-speed switching (i.e., fast transport)
- Providing reliability and fault tolerance
- Scaling by using faster, and not more, equipment
- Avoiding CPU-intensive packet manipulation caused by security, inspection, quality of service (QoS) classification, or other processes

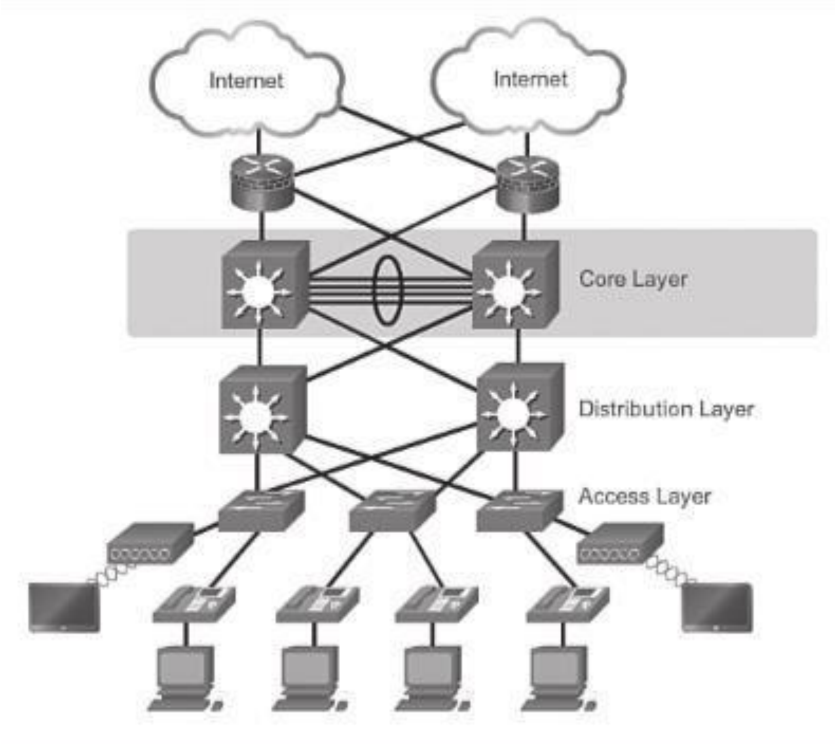


Fig. 4.7. Core System

4.7. LOCAL AREA NETWORK

A computer network spanned inside a building and operated under single administrative system is generally termed as Local Area Network (LAN). Usually, LAN covers an organization offices, schools, colleges or universities. Number of systems connected in LAN may vary from as least as two to as much as 16 million. LAN provides a useful way of sharing the resources between end users. The resources such as printers, file servers, scanners, and internet are easily sharable among computers.

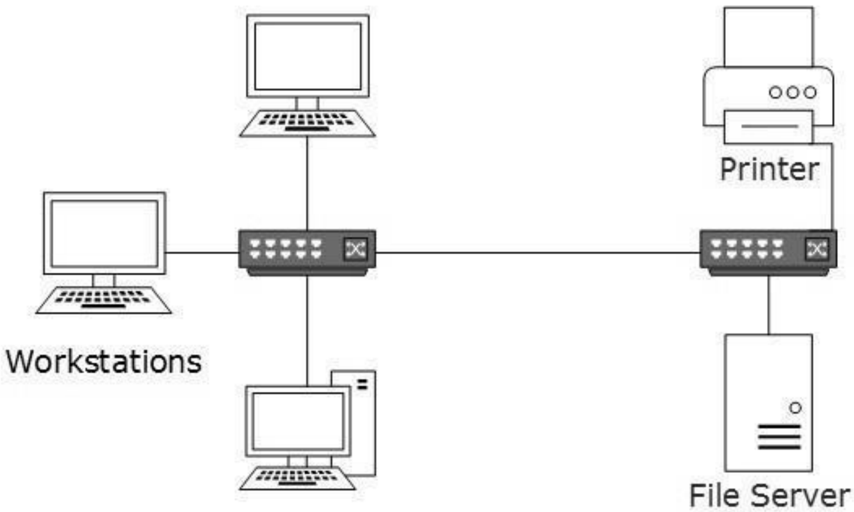


Fig. 4.8. Local area network environment

LANs are composed of inexpensive networking and routing equipment. It may contains local servers serving file storage and other locally shared applications. It mostly operates on private IP addresses and does not involve heavy routing. LAN works under its own local domain and controlled centrally.

4.7.1. Metropolitan Area Network

The Metropolitan Area Network (MAN) generally expands throughout a city such as cable TV network. It can be in the form of Ethernet, Token-ring, ATM, or Fiber Distributed Data Interface (FDDI). Metro Ethernet is a service which is provided by ISPs. This service enables its users to expand their Local Area Networks. For example, MAN can help an organization to connect all of its offices in a city.

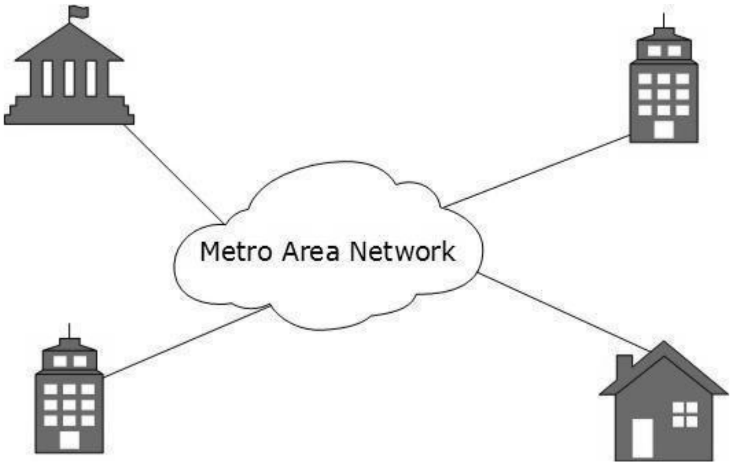


Fig. 4.9. MAN System

Backbone of MAN is high-capacity and high-speed fiber optics. MAN works in between Local Area Network and Wide Area Network. MAN provides uplink for LANs to WANs or internet.

4.7.2. Wide Area Network

As the name suggests, the Wide Area Network (WAN) covers a wide area which may span across provinces and even a whole country. Generally, telecommunication networks are Wide Area Network. These networks provide connectivity to MANs and LANs. Since they are equipped with very high speed backbone, WANs use very expensive network equipment.

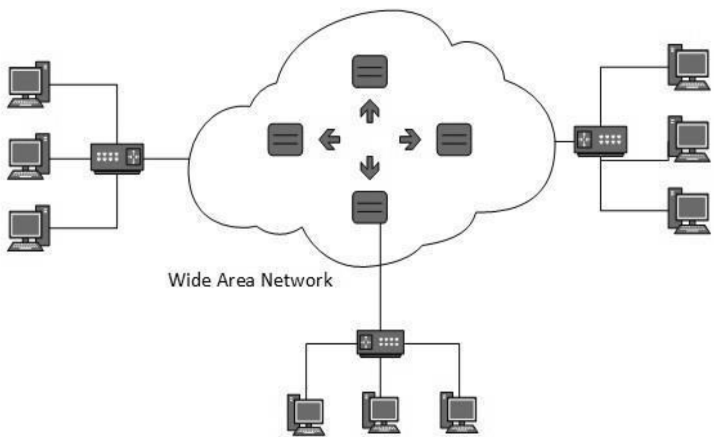


Fig. 4.10. WAN System

WAN may use advanced technologies such as Asynchronous Transfer Mode (ATM), Frame Relay, and Synchronous Optical Network (SONET). WAN may be managed by multiple administration.

4.7.3. Internet Work

A network of networks is called an internetwork, or simply the internet. It is the largest network in existence on this planet. The internet hugely connects all WANs and it can have connection to LANs and Home networks. Internet uses TCP/IP protocol suite and uses IP as its addressing protocol. Present day, Internet is widely implemented using IPv4. Because of shortage of address spaces, it is gradually migrating from IPv4 to IPv6.

Internet enables its users to share and access enormous amount of information worldwide. It uses WWW, FTP, email services, audio, and video streaming etc. At huge level, internet works on Client-Server model.

LAN uses Ethernet which in turn works on shared media. Shared media in Ethernet create one single Broadcast domain and one single Collision domain. Introduction of switches to Ethernet has removed single collision domain issue and each device connected to switch works in its separate collision domain. But even Switches cannot divide a network into separate Broadcast domains.

Virtual LAN is a solution to divide a single Broadcast domain into multiple Broadcast domains. Host in one VLAN cannot speak to a host in another. By default, all hosts are placed into the same VLAN.

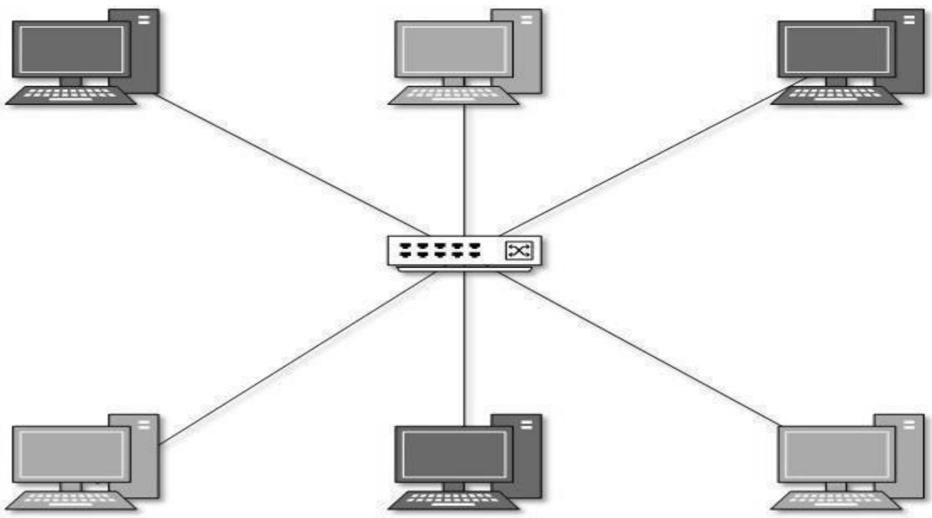


Fig. 4.11. Internet Work System

In this diagram, different VLANs are depicted in different color codes. Hosts in one VLAN, even if connected on the same Switch cannot see or speak to other hosts in different VLANs. VLAN is Layer-2 technology which works closely on Ethernet. To route packets between two different VLANs, a Layer-3 device such as Router is required.

4.8. NETWORK TOPOLOGY

A Network Topology is the arrangement with which computer systems or network devices are connected to each other. Topologies may define both physical and logical aspect of the network. Both logical and physical topologies could be same or different in a same network.

4.8.1. Point – to – Point

Point-to-point networks contains exactly two hosts such as computer, switches, routers, or servers connected back to back using a single piece of cable. Often, the receiving end of one host is connected to sending end of the other and vice versa.

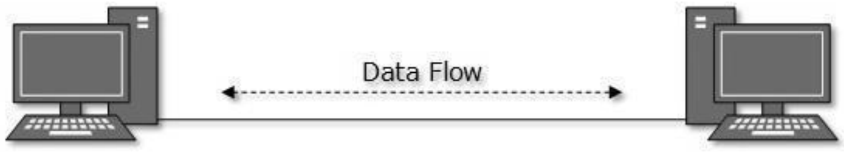


Fig. 4.12. Point-to-point System

If the hosts are connected point-to-point logically, then may have multiple intermediate devices. But the end hosts are unaware of underlying network and see each other as if they are connected directly.

4.8.2. Bus Topology

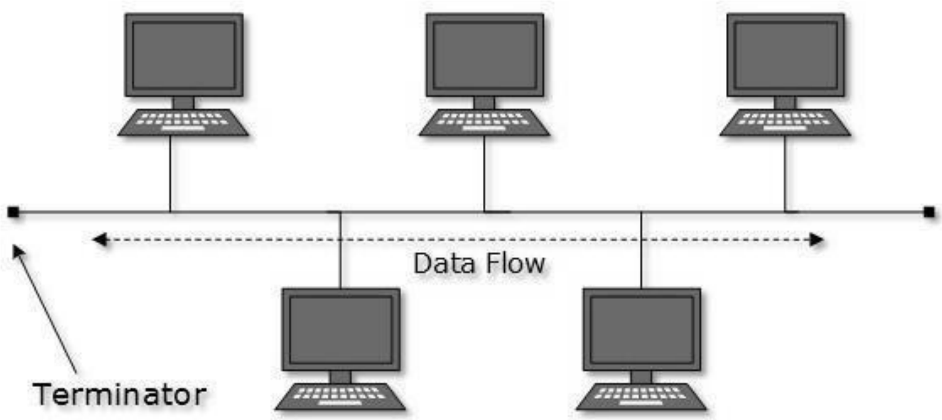


Fig. 4.13. Bus System

In case of Bus topology, all devices share single communication line or cable. Bus topology may have problem while multiple hosts sending data at the same time. Therefore, Bus topology either uses CSMA/CD technology or recognizes one host as Bus Master to solve the issue. It is one of the simple forms of networking where a failure of a device does not affect the other devices. But failure of the shared communication line can make all other devices stop functioning. Both ends of the shared channel have line terminator. The data is sent in only one direction and as soon as it reaches the extreme end, the terminator removes the data from the line.

4.8.3 Star Topology

All hosts in Star topology are connected to a central device, known as hub device, using a point-to-point connection. That is, there exists a point to point connection between hosts and hub. The hub device can be any of the following: Layer-1 device such as hub or repeater, Layer-2 device such as switch or bridge, and Layer-3 device such as router or gateway

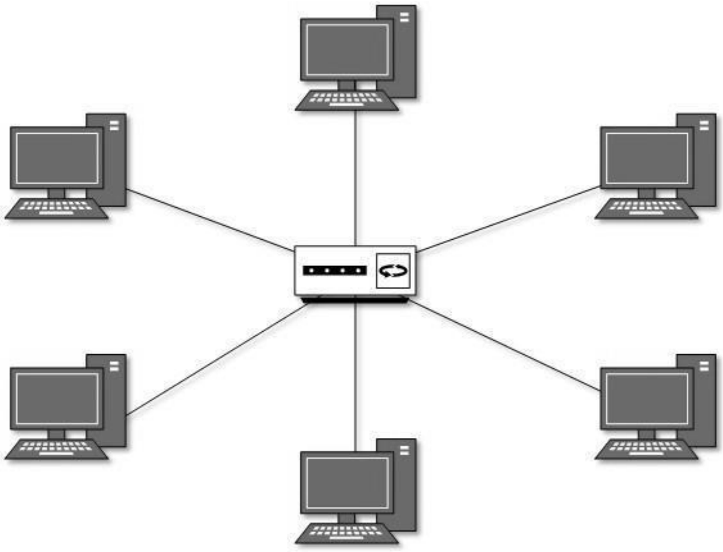


Fig. 4.14. Star System

As in Bus topology, hub acts as single point of failure. If hub fails, connectivity of all hosts to all other hosts fails. Every communication between hosts takes place through only the hub. Star topology is not expensive as to connect one more host, only one cable is required and configuration is simple.

4.8.4. Ring Topology

In ring topology, each host machine connects to exactly two other machines, creating a circular network structure. When one host tries to communicate or send message to a host which is not adjacent to it, the data travels through all intermediate hosts. To connect one more host in the existing structure, the administrator may need only one more extra cable.

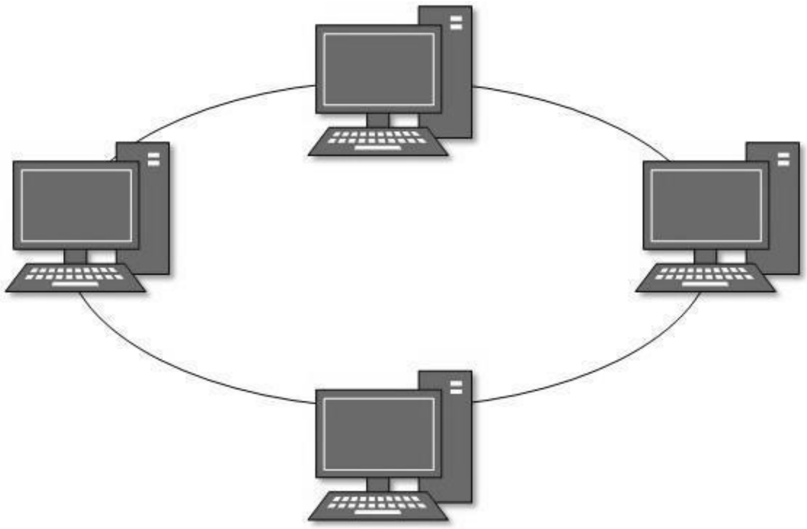


Fig. 4.15. Ring System

Failure of any host results in failure of the whole ring. Thus, every connection in the ring is a point of failure. There are methods which employ one more backup ring.

4.8.5. Mesh Topology

In this type of topology, a host is connected to one or multiple hosts. This topology has hosts in point-to-point connection with every other host or may also have hosts which are in point-to-point connection with few hosts only.

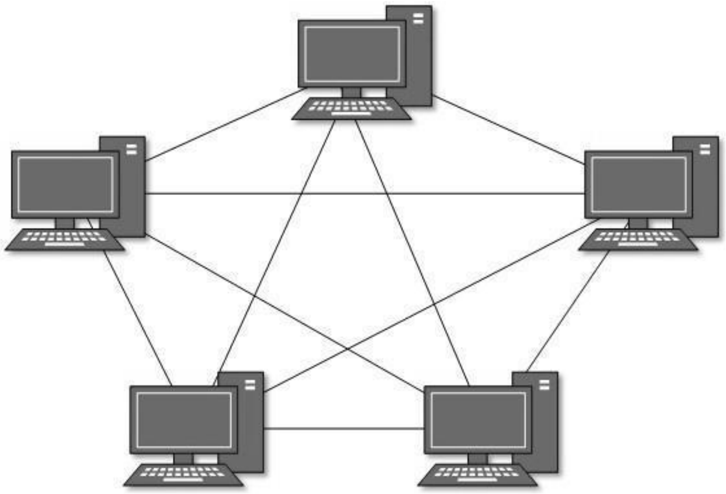


Fig. 4.16. Star System

Hosts in Mesh topology also work as relay for other hosts which do not have direct point-to-point links. Mesh technology comes into two types:

Full Mesh: All hosts have a point-to-point connection to every other host in the network. Thus for every new host n(n-1)/2 connections are required. It provides the most reliable network structure among all network topologies.

Partially Mesh: Not all hosts have point-to-point connection to every other host. Hosts connect to each other in some arbitrarily fashion. This topology exists where we need to provide reliability to some hosts out of all.

4.8.5. Tree Topology

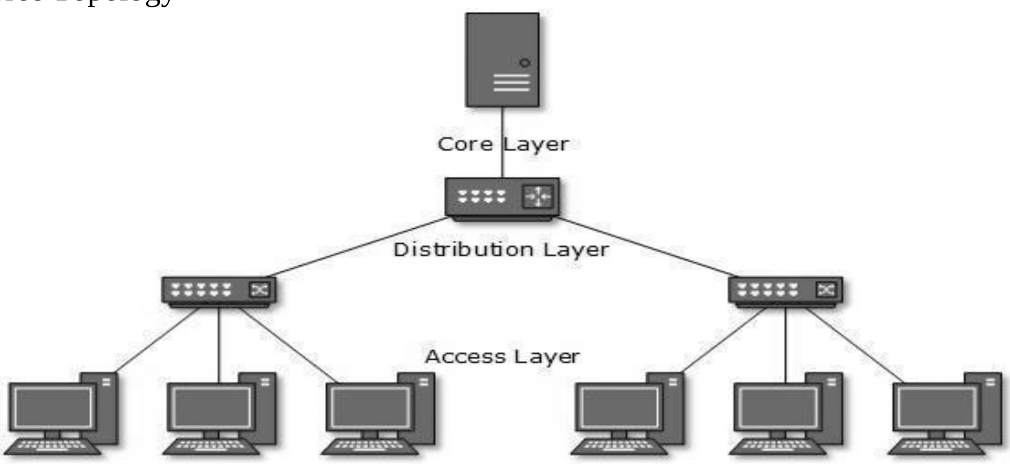


Fig. 4.17. Tree System

Also known as Hierarchical Topology, this is the most common form of network topology in use presently. This topology imitates as extended Star topology and inherits properties of Bus topology. This topology divides the network into multiple levels/layers of network. Mainly in LANs, a network is bifurcated into three types of network devices. The lowermost is access-layer where computers are attached. The middle layer is known as distribution layer, which works as mediator between upper layer and lower layer. The highest layer is known as core layer. All neighboring hosts have point-to-point connection between them. Similar to the Bus topology, if the root goes down, then the entire network suffers even though it is not the single point of failure. Every connection serves as point of failure, failing of which divides the network into unreachable segment.

4.8.6. Daisy Topology

This topology connects all the hosts in a linear fashion. Similar to Ring topology, all hosts are connected to two hosts only, except the end hosts. Means, if the end hosts in daisy chain are connected then it represents Ring topology.

Fig. 4.18. Daisy System

Each link in daisy chain topology represents single point of failure. Every link failure splits the network into two segments. Every intermediate host works as relay for its immediate hosts.

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UNIT – 5 – CAPP & SHOP FLOOR CONTROL - SME1205

5. COMPUTER AIDED PROCESS PLANNING AND SHOP FLOOR CONTROL

5.1. PROCESS PLANNING

Process planning involves determining the most appropriate manufacturing and assembly processes and the sequence in which they should be accomplished to produce a given part or product according to specifications set forth in the product design documentation. Process planning is usually accomplished by manufacturing engineers. (Other titles include industrial engineer, production engineer. and process engineer.) The process planner must be familiar with the particular manufacturing processes available in the factory and be able to interpret engineering drawings. Based on the planner's knowledge, skill, find experience, the processing steps arc developed in the most logical sequence to make each part.

Following is a list of the many decisions and details usually included within the scope of process planning.

- Interpretation of design drawings. The part or product design must be analyzed (materials, dimensions, tolerances, surface finishes, etc.) at the start of the process planning procedure.
- Processes and sequence. The process planner must select which processes are required and their sequence. A brief description of ail processing steps must be prepared.
- Equipment selection. In general, process planners must develop plans that utilize existing equipment in the plant. Otherwise, the component must be purchased, or an investment must be made in new equipment.
- Tools, dies, molds, flxtures, and gages. The process planner must decide what tooling is required for each processing step. The actual design and fabrication of these tools is usually delegated to a tool design department and tool room, or an outside vendor specializing in that type of tool is contracted.
- Work standards. Work measurement techniques are used to set time standards for each operation.
- Cutting tools and cutting conditions. These must be specified for machining operations, often with reference to standard handbook recommendations

For individual parts, the processing sequence is documented on a form called a route sheet. (Not all companies use the name route sheet; another name is "operation sheet.") Just as engineering drawings are used to specify the product design, route sheets are used to spec ify the process plan. They are counterparts. one for product design, the other for manufacturing. A typical route sheet, illustrated in Figure 25.1, includes the following information: (1) all operations to be performed on the work part, listed in the order in which they should be performed; (2) a brief description of each operation indicating the processing to be accomplished, with references to dimensions and tolerances on the part drawing; (3) the specific machine, on which the work is to be done; and (4) any special tooling, such as dies, molds, cutting tools. jigs or fixtures, and gages. Some companies also include setup times, cycle time standards, and other data. It is called a route sheet because the processing sequence defines the route that the part must follow in the factory.

Some of the guidelines in preparing a route sheet are listed.

- Operation numbers for consecutive processing steps should be listed as 10, 20, 30, etc, This allows new operations to be inserted if necessary.

- A new operation and number should be specified when a work part leaves one workstation and is transferred to another station
- A new operation and number should be specified if a part is transferred to another work holder (e.g., jig or fixture), even if it is on the same machine tool
- A new operation and number should be specified if the workpart is transferred from one worker to another, as on a production line

A typical processing sequence to fabricate an individual part consists of:
(I) basic process,
(2) secondary processes,
(3) operations to enhance physical properties, and
(4) finishing opera/jam.

A basic process determines the starting geometry of the work part. Metal casting. plastic molding, and rolling of sheet metal arc examples of basic processes. The starting geometry must often be refined by secondary processes, operations that transform the starting geometry into the geometry (or close to the final geometry).The secondary processes that might be used are closely correlated to the basic process that provides the starting geometry. When sand casting is the basic process, machining operations are generally the secondary processes. When a rolling mill produces sheet metal, stamping operations such as punching and bending are the secondary processes. when plastic injection molding is the basic process, secondary operations are often unnecessary, because most of the geometric features that would otherwise require machining can be created by the molding operation. Plastic molding and other operations that require no subsequent secondary processing are called net shape processes. Operations that require some but not much secondary processing (usually machining) are referred to as near net shape processes. Some impression die forgings are in this category. These parts can often be shaped in the forging operation (basic process) so that minimal machining (secondary processing) is required.

Once the geometry has been established, the next step for some parts is to improve their mechanical and physical properties. Operations to enhance properties do not alter the geometry of the part; instead. They alter physical properties. Heat treating operations on metal parts are the most common example. Similar heating treatments are performed on glass to produce tempered glass. For most manufactured parts, this property enhancing operations arc not required in the processing sequence. Finally ,finishing operations usually provide a coating on the work part (or assembly) surface. Examples include electroplating, thin film deposition techniques, and painting. The purpose of the coating is to enhance appearance, change color, or protect the surface from corrosion. abrasion, and .>0 forth. Finishing operations are not required on many parts: for example, plastic moldings rarely require finishing. When finishing is required, it is usually the final step in the processing sequence.

In addition to the route sheet, a more detailed description of each operation is usually prepared. This is filed in the particular production department office where the operation is performed. It lists specific details of the operation, such as cutting conditions and tooling (if the operation is machining) and other instructions that may be useful to the machine operator. The descriptions often include sketches of the machine setup.

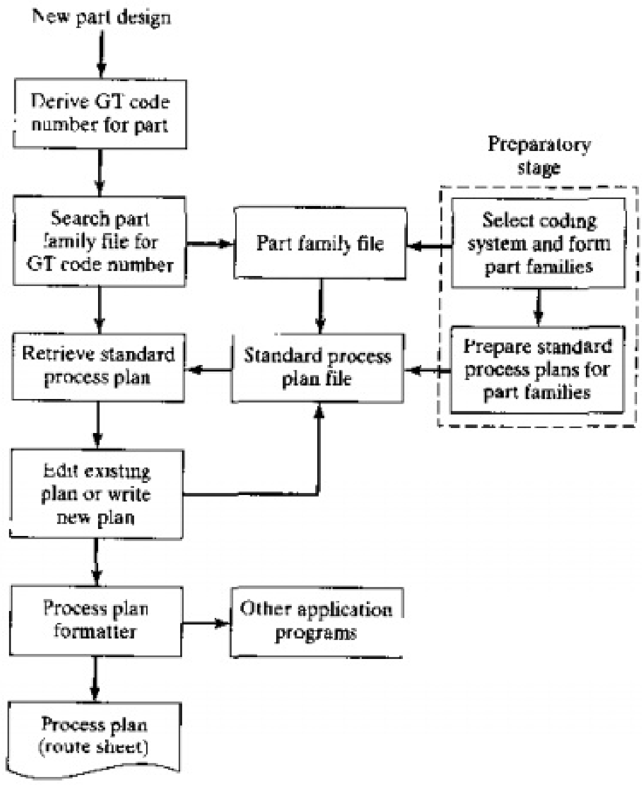
5.2. COMPUTER AIDED PROCESS PLANNING

There is much interest by manufacturing firms in automating the task of process planning using computer-aided process planning (CAPP) systems. The shop trained people who are familiar with the details of machining and other processes are gradually retiring, and

these people will be unavailable in the future to do process planning. An alternative way of accomplishing this function is needed, and CAPP systems are providing this alternative. CAPP is usually considered to be part of computer-aided manufacturing (CAM). However, this lends to imply that CAM is a standalone system. In fact, a synergy results when CAM is combined with computer-aided design to create a CAD/CAM system. In such a system, CAPP becomes the direct connection between design and manufacturing.
Computer-aided process planning systems are designed around two approaches. These approaches are called: (1) retrieval CAPP systems and (2) generative CAPP systems.

5.2.1. RETRIEVAL CAPP

A retrieval CAPP system, also called a variant CAPP system, is based on the principles of group technology (GT) and parts classification and coding. In this type of CAPP, a standard process plan (route sheet) is stored in computer files for each part code number. The standard route sheets are based on current part routings in use in the factory or on an ideal process plan that has been prepared for each family. It should be noted that the development of the data base of these process plans requires substantial effort.



General procedure for using one of the retrieval CAPP systems.

Fig 5.1. Retrieval CAPP

Before the system can be used for process planning, a significant amount of information must be compiled and entered into the CAPP data files. This is what Chang et al., refer to as the "preparatory phase:' It consists of the following steps: (1) selecting an appropriate classification and coding scheme for the company, (2) forming part families for the parts produced hy the company; and (3) preparing standard process plans for the part families. It should be mentioned that steps (2) and (3) continue as new parts are designed and added to the company's design data base. After the preparatory phase has been completed, the system is ready for use, For a new component for which the process plan is to be determined. the first step is to derive the GT code number for the part. With this code number, a search is made of the part family, file to determine if a standard route sheet exists for/he given part code. If the file contains a process plan for the part it is retrieved (hence. the word "retrieval" for this CAPP system) and displayed for the user. The standard process plan is examined to determine whether any modifications are necessary. It might be that although the new part has the same code number. there are minor differences in the processes required to make it. The user edits the standard plan accordingly. This capacity to alter an existing process plan is what gives the retrieval system its alternative name: variant CAPP system. The process planning session concludes with the process plan formatter, which prints alit the route sheet in the proper format. The formatter may call other application programs into use: for example, to determine machining conditions for the various machine tool operations in the sequence. to calculate standard times (or the operations (e.g., for direct labor incentives). or to compute cost estimates for the operations. One of the commercially available retrieval CAPP systems is MultiCapp, from OIR the Organization for Industrial Research. It is an online computer system that permits the user to create new plans. or retrieve and edit existing process plans, as we have explained above.

5.2.2. GENERATIVE CAPP

Generative CAPP systems represent an alternative approach to automated process planning. Instead of retrieving and editing an existing plan contained in a computer data base, a generative system creates the process plan based on logical procedures similar to the procedures a human planner would use. In a fully generative CAPP system, the process sequence is planned without human assistance and without a set of predefined standard plans. The problem of designing a generative CAPP system is usually considered part of the field of expert systems, a branch of artificial intelligence. An expert system is a computer program that is capable of solving complex problems that normally require a human with years of education and experience.

There are several ingredients required in a fully generative process planning system. First. the technical knowledge of manufacturing and the logic used by successful process planners must be captured and coded into a computer program. In an expert system applied to process planning, the knowledge and logic of the human process planners is incorporated into a so called "knowledge base. The second ingredient in generative process planning is a computer-compatible description of the part to be produced. This description contains all of the pertinent data and information needed to plan the process sequence, Two possible ways of providing this description are: (l) the geometric model of the part that is developed on a CAD system dur10g product design and (2) a GT code number of the part that defines the part features in significant detail. The third ingredient in a generative CAPP system is the capability to apply the process knowledge and planning logic contained in the knowledge base to a given part description. In other words, the CAPP system uses its knowledge base to solve a specific problem-planning the process for a new part. This problem-solving procedure is referred to as the "inference engine’ in the terminology of expert systems. By using its knowledge base and inference engine, the CAPP system synthesizes a new process plan from scratch for each new part it is presented.

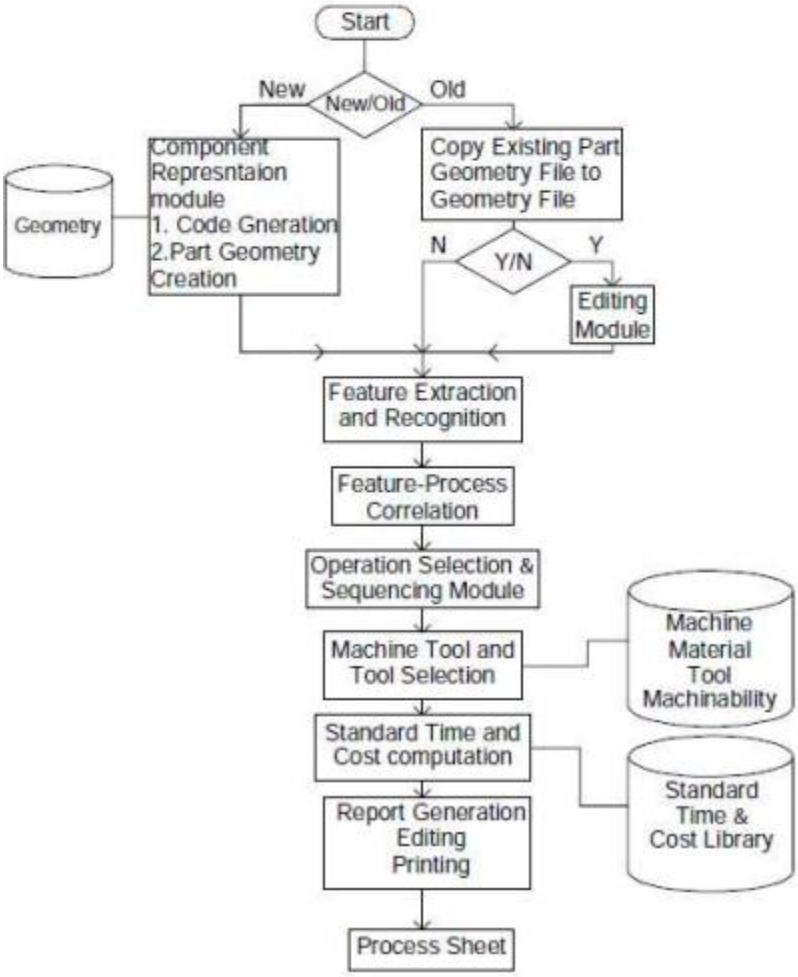


Fig 5.2. Generative CAPP

5.2.3. BENEFITS OF CAPP

The benefits derived from computer -automated process planning include the following:

- Process rationalization and standardization. Automated process planning leads to more logical and consistent process plans than when process planning is done completely manually. Standard plans tend to result in lower manufacturing costs and higher product quality.
- Increased productivity of process planners. The systematic approach and the availability of standard process plans in the data files permit more work to be accomplished by the process planners.
- Reduced lead time for process planning. Process planners working with a CAPP system can provide route sheets in a shorter lead time compared to manual preparation.
- Improved legibility. Computer-prepared route sheets are neater and easier to read than manually prepared route sheets
- Incorporation o other application programs The CAPP program can be interfaced With other application programs, such as cost estimating and work standards.

5.3. AGGREGATE PLANNING AND MASTER PRODUCTION SCHEDULE

Aggregate planning is a high-level corporate planning activity. The aggregate production indicates production output levels for the major product lines of the company.

The aggregate plan must be coordinated with the plans of the sales and marketing departments. Because the aggregate production plan includes products that are currently in production, it must also consider the present and future inventory levels of those products and their component parts. Because new products currently being developed will also be included in the aggregate plan. the marketing plans and promotions for current products and new products must be reconciled against the total capacity resources available to the company.

	Week									
Product line	1	2	3	4	5	6	7	8	9	10
M model line	200	200	200	150	150	120	120	100	100	100
N model line	80	60	50	40	30	20	10			
P model line							70	130	25	100

(a) Aggregate production plan

	Week									
Product line models	1	2	3	4	5	6	7	8	9	10
Model M3	120	120	120	100	100	80	80	70	70	70
Model M4	80	80	80	50	50	40	40	30	30	30
Model N8	80	60	50	40	30	20	10			
Model P1								50		100
Model P2							70	80	25	

(b) Master production schedule

(a) Aggregate production plan and (b) corresponding MPS for a hypothetical product line.

Fig 5.3. APP & MPS

The production quantities of the major product lines listed in the aggregate plan must he converted into a very specific schedule of individual products, known as the master production schedule (MPS).lt is a list or the products to be manufactured, when they should be completed and delivered, and in what quantities. The master schedule must be based on an accurate estimate of demand and a realistic assessment of the company's production capacity. products included in the MPS divide into three categories: (1) firm customer orders, (2) forecasted demand, and (3) spare parts. Proportions in each category vary for different companies, and in some cases one or more categories are omitted. Companies producing assembled products will generally have to handle all three types.

5.4. MATERIAL REQUIREMENTS PLANNING (MRP)

Material requirements planning (MRP) is a computational technique that converts the master schedule for end products into a detailed schedule for the raw materials and components used in the end products. The detailed schedule identifies the quantities of each raw material and component item. It also indicates when each item must be ordered and delivered to meet the master schedule for final products. MRP is often thought of as a method of inventory control. Even though it is an effective tool for minimizing unnecessary inventory investment, MRP is also useful in production scheduling and purchasing of material. Whereas demand for the firm's end products must often be forecasted, the raw materials and component parts should not be forecasted. Once the delivery schedule for end products i; established, the requirements for components and raw materials can be directly calculated.

For example. even though demand for automobiles in a given month can only he forecasted. once the quantity is established and production is scheduled, we know that five tires will be needed to deliver the car (don't forget the spare).MRP is the appropriate technique for determining quantities of dependent demand items. These items constitute the inventory of manufacturing: raw materials, work-in-process (WIP), component parts, and subassemblies. That is why MRP is such a powerful technique in the planning and control of manufacturing inventories. we first examine the inputs to the MRP sys· tern. We then describe how MRP works, the output reports generated by the MRP computations and finally the benefits and pitfalls that have been experienced with MRP systems in industry.

5.4.1. Inputs to MRP

To function. the MRP program must operate on data contained in several files. These files serve as inputs to the MRP processor They are:

(I) MPS,

(2) bill of materials file and other engineering and manufacturing data.

(3) inventory record file.

The MPS lists what end product, and how many of each are to be produced and when they are to be ready for shipment. Manufacturing firms generally work toward monthly delivery schedules, but the master schedule in our figure uses weeks as the time periods.

The bill of materials (BOM)file is used to compute the raw material and component requirements for end products listed in the master schedule. It provides information on the product structure by listing the component parts and subassemblies that make up each product.

The inventory record file is referred to as the item master file in a computerized inventory system. The types of data contained in the inventory record are divided into three segments: (1) Item master data. This provides the item's identification (part number) and other data about the part such as order quantity and lead times. (2) Inventory status. This gives a time phased record of inventory status. In MRP, it is important to know not only the current level of inventory, but also any future changes that will occur against the inventory. Therefore, the inventory status segment lists the gross requirements for the item, scheduled receipts, on hand status, and planned order releases, (3) Subsidiary data. Thc third file segment provides subsidiary data such as purchase orders, scrap or rejects, and engineering changes.

Period		1	2	3	4	5	6	7
Item: **Raw material M4**								
Gross requirements								
Scheduled receipts				**40**				
On hand	**50**	**50**	**50**	**90**				
Net requirements								
Planned order releases								

Initial inventory status of material

Fig 5.4. MRP

5.4.2. How MRP Works

The MRP processor operates on data contained in the MPS, the 80M file, and the inventory record file. The master schedule specifies the period-by-period list of final products required. The 80M defines what materials and components are needed for each product. And the inventory record file contains data on current and future inventory status of each product, component, and material. The MRP processor computes how many of each component and raw material are needed each period by "exploding" the end product requirements into successively lower levels in the product structure. Several complicating factors must be taken into account during the 'MRP computations. First. the quantities of components and subassemblies listed in the solution of Example 26.1 do not account for any of those items that may already be stocked in inventory or arc expected to be received a, future orders. Accordingly, the computed quantities must be adjusted for any inventories on hand or on order, a procedure called netting. For each time bucket, net requirements = gross requirements less on-hand inventories and less quantities on order. Second. quantities of common use items must be combined during parts explosion to determine the total quantities required for each component and raw material in the schedule. Common use items arc raw materials and components that are used on more than one product. MRP collects these common use items from different products to effect economics in ordering the raw materials and producing the components. Third. lead times for each item must be taken into account. The lead time for a job is the time that must be allowed to complete the job from start to finish. There are two kinds of lead times in MRP: ordering lead times and manufacturing lead times. Ordering lead time for an item is the time required from initiation of the purchase requisition 10 receipt of the item from the vendor. If the item is a raw material that is stocked by the vendor.fhe ordering lead time should be relatively short, perhaps a few days or a few weeks. If the item is fabricated, the lead time may be substantial, perhaps several months. Manufacturing lead time is the time required to produce the item in the company's own plant, from order release to completion, once the raw materials for the item are available. The scheduled delivery of end products must be translated into time phased requirements for components and materials by factoring in the ordering and manufacturing lead times.

5.4.3. MRP Outputs and Benefits

The MRP program generates a variety of outputs that can be used in planning and managing plant operations. The outputs include:

(I) planned order releases. which provide the authority to place orders that have been planned by the MRP system

(2) report of planned order releases in future period

(3) rescheduling notices, indicating changes in due dates for open orders

(4) cancelation notices, indicating that certain open orders have been canceled because of changes in the MPS

(5) reports on inventory status

(6) performance reports of various types. indicating costs. Item usage, actual versus planned lead times.

(7) exception reports. showing deviations from the schedule, orders that are overdue, scrap.

(8) inventory forecasts. indicating projected inventory levels in future periods.

Many benefits are claimed for a well designed MRP system. Benefits reported by users include the following

(1) reduction in inventory,

(2) quicker response to changes in demand than is possible with a manual requirements planning system.

(3) reduced setup and product changeover costs,

(4) better machine utilization,

(5) improved capacity to respond to changes in the master Schedule,

(6) as an aid in developing the master schedule.

5.5. INVENTORY CONTROL

Inventory control is concerned with achieving an appropriate compromise between two opposing objectives:

(1) minimizing the cost of holding inventory.

(2) maximizing service to customers. On the one hand, minimizing inventory cost suggests keeping inventory to a minimum in the extreme, zero inventory. On the other hand, maximizing customer service implies keeping large stocks on hand from which the customer can choose and immediately take possession.

The types of Inventory of greatest interest in PPC arc raw materials purchased components, in-process inventory (WIP) and finished products. The major costs of holding inventory are

(1) investment costs,

(2) storage costs,

(3) cost of possible obsolescence or spoilage.

The three costs are referred to collectively as carrying costs or holding costs:

Companies can minimize holding costs by minimizing the amount of inventory on hand. However, when inventories are minimized, customer service may suffer inducing customers to take their business elsewhere. This also has a cost, called the stock-out cost. Most companies want to minimize stock-out cost and provide good customer service. Thus, they are caught on the horns of an inventory control dilemma: balancing carrying costs against the cost of poor customer service.

5.5.1. Order Point Inventory Systems

Order point systems are concerned with two related problems that must be solved when managing inventories of independent demand items: (1) how many unit ordered? And (2) when should the order be placed? The first problem is often solved using economic order quantity formulas. The second problem can be solved using reorder point methods.

5.5.2. Economic Order Quantity Formula.

The problem of deciding on the most appropriate quantity to order or produce arises when the demand rate for the item is fairly constant, and the rate at which the item is produced is significantly greater than its demand rate. This is the typical make-to-stock situation.

Reorder Point Systems. Determining the economic order quantity is not the only problem that must be solved in controlling inventories in make-to-stock situations, the other problem is deciding when to reorder. One of the most widely used methods is the reorder point system. In a reorder point system, when the inventory level for a given stock item falls to some point specified as the reorder point, then an order is placed to restock the item. The reorder point is specified at a sufficient quantity level 10 minimize the probability of a stock-out between when the reorder point is reached and the new order is received. Reorder point triggers can be implemented using computerized inventory control systems that continuously monitor the inventory level as demand occurs and automatically generate an order for a new batch when the level declines below the reorder point.

Work-in-Process Inventory Costs: Work-in-process (WIP) represents a significant inventory cost for many manufacturing firms. In effect, the company is continually investing in raw materials, processing those materials, and then delivering them to customers when processing has been completed. The problem is that processing takes time, and the company pays a holding cost between start of production and receipt of payment from the customer for goods delivered.

5.6. CAPACITY PLANNING

A realistic master schedule must be consistent with the production capabilities and limitations of the plant that will produce the product. Accordingly the firm must know its production capacity and must plan for changes in capacity to meet changing production requirements specified in the master schedule. In Chapter 2, we defined production capacity and formulated ways for determining the capacity of a plant Capacity planning is concerned with determining what labor and equipment resources are required to meet the current MPS as well as long-term future production needs of the firm. Capacity planning also serves to identify the limitations of the available production resources so that an unrealistic Master schedule is not planned.

Capacity planning is typically accomplished in two stages, first, when the MRS is established: and second, when the MRP computations are done. In the MPS stage, a rough-cut capacity planning (REEP) calculation is made to assess the feasibility of the master schedule. Such a calculation indicates whether there is a significant violation of production capacity in the MPS. On the other hand, if the calculation

shows no capacity violation, neither does it guarantee that the production schedule can be met. This capacity calculation is malic at the MRP schedule is prepared Called capacity requirements planning (CRP). This detailed calculation determines, whether there is sufficient production capacity in the individual departments and work cells to complete the specific parts and assemblies that have been scheduled by MRP. If the schedule is not compatible with capacity, then adjustments must be made either in plant capacity or in the master schedule.

Capacity adjustments can be divided into short term adjustments and long-term adjustments. A capacity adjustment for the short term includes:

- Employment levels. Employment in the plant can be increased or decreased in response to changes in capacity requirements,
- Temporary workers. Increases in employment level can also be made by using workers from a temporary agency. When the busy period is passed, these workers move to positions at other companies where their services are needed.
- Number of work shifts. The number of shifts worked per production period can be increased or decreased.
- Labour hours. The number of labour hours per shift can be increased or decreased, through the use of overtime or reduced hours.
- Inventory stockpiling. This tactic might be used to maintain steady employment levels during slow demand periods
- Order backlogs. Deliveries of the product to the customer could be delayed during busy periods when production resources are insufficient to keep up with demand.
- Subcontracting. This involves the letting of jobs to other shops during busy periods OR the taking in of extra work during slack periods

Capacity planning adjustments for the long term include possible changes in production capacity that generally require long lead times. These adjustments include the following types of decisions

- New equipment Investments. This involves investing in more machines or more productive machines to meet increased future production requirements, or investing in new types of machines to match future changes in product design.
- New plant construction. Building a new factory represents a major investment for the company. However, it also represents a significant increase in production capacity for the firm.
- Purchase of existing plants from other companies.
- Acquisition of existing companies. This may be done to increase productive capacity. However, there are usually more important reasons for taking over an existing company, for example, to achieve economies of scale that result from increasing market share and reducing staff.

- Plant closings. This involves the closing of plants that will not be needed in the future

5.7. SHOP FLOOR CONTROL

Shop floor control deals with managing the work-in-process. This consists of the release of production orders to the factory, controlling the progress of the orders through the various work stat ons, and getting the current information of the status of the orders. This can be shown in the form of a factory information system. . The input to the shop floor control system is the collection of production plans. These can be in the form of master schedule, manufacturing capacity planning and ERP data. The factory production operations are the processes to be controlled.

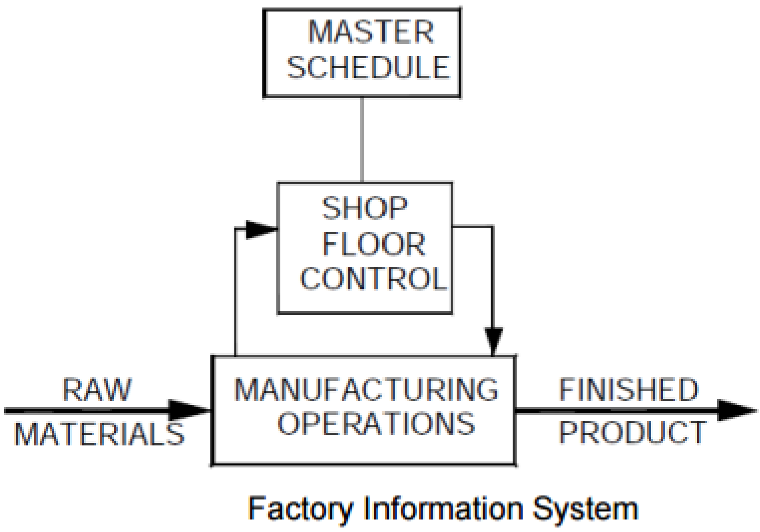


Fig 5.4. Factory information system

A typical shop floor control system consists of three phases. In a computer integrated manufacturing system these phases are managed by computer software. These three phases connected with the production management. In today's implementation of shop floor control, these are executed by a combination of computers and human resources. The following sections describe the important activities connected with this task.

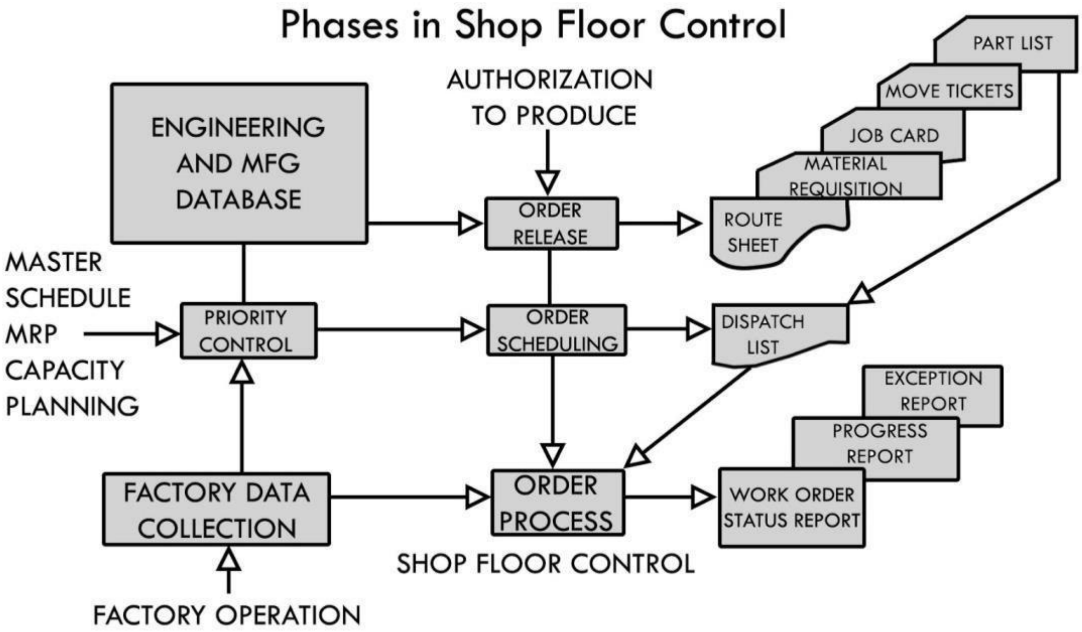


Fig 5.5. Shop floor control system

5.7.1. Order Release

The order release in shop floor control provides the documentation needed to process a production order. In a typical factory which works on manual processing of data these documents move with the production order and are used to track the progress through the shop. In a CIM factory, more automated methods are used to track the progress of the production orders. The order release is connected with two inputs. Authorization proceeds through the various planning functions (MRP, capacity planning). These provide timing and scheduling information. The engineering and manufacturing database provides the product structure and process planning information needed to prepare the various documents that accompany the order through the shop.

The documents in the shop floor order may consists of the following documents

(i) Route Sheet

(ii) Material requisition to draw necessary materials from the stores

(iii) Job cards or other means to report direct labour time given to the order.

(iv) Instructions to material handling personnel to transport parts between the work centres in the factory

(v) Parts list for assembly, in the case of assembly operations.

5.7.2. Order Scheduling

This module assigns the production orders to various work centres, machine tools, welding stations, moulding machines etc., in the plant. It follows directly from the order release module. Order scheduling executes the dispatch function in production planning and control. The order scheduling module prepares a dispatch list that indicates which production order should be accomplished at the various work centres. It provides the information on the relative priorities of the various jobs by showing the due dates for each job. By following the dispatch list in making work assignments and allocating resources to different jobs the master schedule can be best achieved.

The order schedule module addresses to two important activities in shop floor production control.

(I)Machine loading (ii) Job sequencing. Allocating the orders to the work centres is termed as machine loading or shop loading, which refers to the loading of all machines in the plant. In most cases each work centre will have a queue of orders waiting to be processed. This queue problem can be solved by job sequencing. This involves determining the order in which the jobs will be processed through a given work centre. To determine this sequence, priorities are given to jobs in the queue and the jobs are processed according to the priorities. Several queuing models are available in operations management to solve this problem. This control of priorities is an important input to the order scheduling module. Rules to establish the priorities are: (i) Earliest due date: These are given high priority (ii) Shortest processing time: Shorter processing time orders are given high priority. (iii) Least slack time: Orders with least slack time are given high priority. Fluctuations in market demand, equipment breakdown, cancellation of the order by customer and defective raw material or delay in the receipt of materials affect the priority. The priority control plan reviews the relative priorities of the orders and adjusts the dispatch list accordingly.

5.7.3. Order Progress

The order progress module in the shop floor control system monitors the status of the various orders in the plant work-in-process and other characteristics that indicate the progress and performance of production. The function of the order progress module is to provide the information that is useful in managing the factory based on the data collected from the factory.

The order progress report includes:

(i) Work order status reports: These reports indicate the status of the production orders. Typical information in the report includes the current work centre where each order is located, processing hours remaining before completion of each order, whether the job is on-time or behind schedule, and priority level.

(ii) Progress report: A progress report records the performance of the shop during the period of master schedule and reports the number of operations completed and not completed during the time period.

(iii) Exception reports: These reports bring out the deviations from the production schedule (ex. overdue jobs).

The above reports are useful to production management in making the decisions about allocation of resources, authorization of the overtime hours, and other capacity issues, and in identifying areas of problems in the plant that adversely affect the implementation of the master production schedule.

5.8. FACTORY DATA COLLECTION (FDC)

There are several of data collection techniques to gather data from the shop floor. Some of the data are keyed by the employees and the rest are recorded automatically. Later the data is compiled on a fully automated system that requires no human intervention. These methods are collectively called as shop floor data collection systems. These data collection systems consist of various paper documents, terminals and automated devices located through the plant in a plant. The shop floor data collection system serves as an input to the order progress module in shop floor. Examples of the data collection in shop floor are:

(i) To supply data to the order progress module in the shop floor control system.

(ii) To provide up to date information to the production supervisors and production control personnel.

(iii) To enable the management to monitor implementation of master schedule. To carry out this, the factory data collection system inputs the data to the computer system in the plant.

The shop floor data collection systems can be classified into two groups. (i) On-line data collection systems (ii) Off-line data collection systems.

5.8.1. On-Line Data Collection Systems

In an on-line system, the data are directly entered to the computer and are available to the order progress module. The advantage lies in the fact that the data file representing 72 the status of the shop is always at the current state. As and when the changes in the order progress module are reported they can be fed to computer and in turn to the status file. In this way the production personnel are provided with most up-to-data information.

5.8.2. Off-Line (Batch) Data Collection Systems

In this the data are collected temporarily in a storage device or a stand-alone computer system to be entered and processed by plant computer in a batch mode. In this mode there is delay in the entry and processing of the data. The delay may vary depending upon the situation. So this system cannot provide real time information of shop floor status. The advantage of this system is that it is easier to install and implement.

Data collection techniques include manual procedures and computer terminals located on the shop floor. The manual data collection methods require the production workers to fill out paper forms indicating order progress data. These forms are compiled using a combination of clerical and computerized methods. The manual data collection methods rely on the co-operation and clerical accuracy of the employees to record a data property on a proper document. Errors may creep in this type of method. The common forms of errors that can be checked and rectified are wrong dates, incorrect order numbers and incorrect operation numbers. These can be detected and corrected. There are, however, other errors which are difficult to identify. Another problem is that there may be a delay in submitting the order progress for compiling. The reason is that there will be always a time lapse between when occurrence of events and recording of events. These problems necessitate the location of the data collection equipment in the factory itself. The various input techniques include manual input by push-button pads or keyboards. Error checking routines can be incorporated to detect the syntax errors in the input. The data entry methods also include more automated technologies, such as bar code reader, magnetic card readers etc. An important type of equipment used in shop floor data entry is keyboard based systems. There are various types of such systems. They are discussed in the following sections.

- Centralized Terminal A single terminal is located centrally in the shop floor. This requires the employees to go to the terminal and input the data. So employee’s time will be wasted and in a big shop, this becomes inconvenient.
- Satellite Terminals These are multiple data collection centers located throughout the shop floor. In this arrangement a balance is to be struck between the minimization of the investment cost and maximization of the convenience of the employees in the plant.
- Work Centre Terminals The most convenient arrangements to the employees are to have a data collection terminal at each work centre. This reduces the time to go to the central terminal. This can be applied when the amount of data to be collected is very large.

- Automatic Data Collection System The recent trend in industry towards use of more automation necessitates putting in human participation is unavoidable in many cases. The advantages of the automatic data collection methods are:
  (i) The accuracy of data collected increases
  (ii) The time required by the workers to make the data entry can be reduced.
  The basic elements in data collection systems are:
  (i) Machine readable media
  (ii) Terminal configuration
  (iii) Software for data collection.

- Machine Readable Media Typical machine readable media include:
  (i) Bar Code Technology
  (ii) Optical Character Recognition (OCR)
  (iii) Magnetic Ink Character
  (iv) Voice Recognition (VR)