LECTURE NOTES ON ADVANCE MANUFACTURING PROCESS

MECHANICAL BRANCH

6TH SEM

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INTRODUCTION

Robots are devices that are programmed to move parts, or to do work with a tool. Robotics is a multidisciplinary engineering field dedicated to the development of autonomous devices, including manipulators and mobile vehicles.

Roboticists develop man-made mechanical devices that can move by themselves, whose motion must be modelled, planned, sensed, actuated and controlled, and whose motion behaviour can be influenced by "programming". Robots are called "intelligent" if they succeed in moving in safe interaction with an unstructured environment, while autonomously achieving their specified tasks

Definition

The term comes from a Czech word, *robota*, meaning "forced labor." The word *robot* first appeared in a 1920 play by Czech writer Karel Capek, R.U.R.: Rossum's Universal Robots. In the play, the robots eventually overthrow their human creators.

An automatically controlled, reprogrammable, multipurpose, manipulator programmable in three or more axes, which may be either, fixed in place or mobile for use in industrial automation applications.

An industrial robot is defined by ISO as an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes. The field of robotics may be more practically defined as the study, design and use of robot systems for manufacturing (a top-level definition relying on the prior definition of robot). Typical applications of robots include welding, painting, assembly, pick and place (such as packaging, palletizing and SMT), product inspection, and testing; all accomplished with high endurance, speed, and precision.

Robot Anatomy

The anatomy of robot is also known as structure of robot. The basic components or sections in anatomy of robots are as follows.

The RIA (Robotics Industries Association) has officially given the definition for Industrial Robots. According to RIA, "An Industrial Robot is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or special devices through variable programmed motions for the performance of a variety of tasks."

The *Anatomy* of Industrial Robots deals with the assembling of outer components of a robot such as wrist, arm, and body. Before jumping into Robot Configurations, here are some of the key facts about robot anatomy

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- ***End Effectors*****:** A hand of a robot is considered as end effectors. ***The*** grippers and tools are the two significant types of end effectors. The grippers are used to pick and place an object, while the tools are used to carry out operations like spray painting, spot welding, etc. on a work piece.

- ***Robot Joints*****:** The joints in an industrial robot are helpful to perform sliding and rotating movements of a component.

- ***Manipulator*****:** The manipulators in a robot are developed by the integration of links and joints. In the body and arm, it is applied for moving the tools in the work volume. It is also used in the wrist to adjust the tools.

- ·***Kinematics*****:** It concerns with the assembling of robot links and joints. It is also used to illustrate the robot motions.

Robot configurations

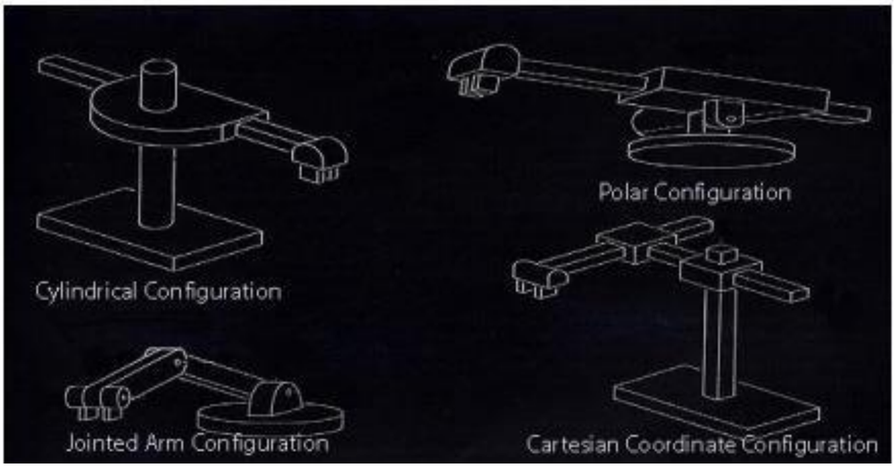
Robot Co-ordinate System

A coordinate system defines a plane or space by axes from a fixed point called the origin. Robot targets and positions are located by measurements along the axes of coordinate systems. A robot uses several coordinate systems, each suitable for specific types of jogging or programming.

The Robots are mostly divided into four major configurations based on their appearances, sizes, etc. such as:

- ·Cylindrical Configuration,
- ·Polar Configuration,

- ·Jointed Arm Configuration, and
- ·Cartesian Co-ordinate Configuration.



Cylindrical Configuration:

This kind of robots incorporates a slide in the horizontal position and a column in the vertical position. It also includes a robot arm at the end of the slide. Here, the slide is capable of moving in up & down motion with the help of the column. In addition, it can reach the work space in a rotary movement as like a cylinder.

Example: GMF Model M1A Robot.

Advantages:
- Increased rigidity, and
- Capacity of carrying high payloads.

Disadvantages:

- Floor space required is more, and
- Less work volume.

Polar Configuration:

The polar configuration robots will possess an arm, which can move up and down. It comprises of a rotational base along with a pivot. It has one linear & two rotary joints that allows the robot to operate in a spherical work volume. It is also stated as Spherical Coordinate Robots.
Example: Unimate 2000 Series Robot.

Advantages: Long reach capability in the horizontal position.

Disadvantages:

·Vertical reach is low.

Jointed Arm Configuration:

The arm in these configuration robots looks almost like a human arm. It gets three rotary joints and three wrist axes, which form into six degrees of freedoms. As a result, it has the capability to be controlled at any adjustments in the work space. These types of robots are used for performing several operations like *spray painting*, *spot welding*, *arc welding*, and more.

Example: Cincinnati Milacron T3 776 Robot

Advantages:

- Increased flexibility,
- Huge work volume, and
- Quick operation.

Disadvantages:

- Very expensive,
- Difficult operating procedures, and
- Plenty of components.

Cartesian Co-ordinate configuration:

These robots are also called as *XYZ robots*, because it is equipped with three rotary joints for assembling XYZ axes. The robots will process in a rectangular work space by means of this three joints movement. It is capable of carrying high payloads with the help of its rigid structure. It is mainly integrated in some functions like pick and place, material handling, loading and unloading, and so on. Additionally, this configuration adds a name of Gantry Robot.

Example: IBM 7565 Robot.

Advantages:

- Highly accurate & speed,
- Fewer cost,
- Simple operating procedures, and
- High payloads.

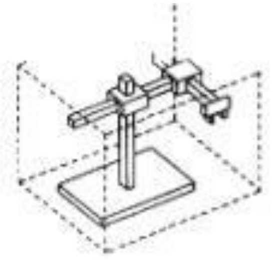
Disadvantages:

- Less work envelope, Reduced flexibility.

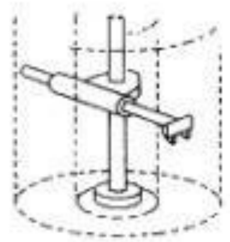
Work Envelop

It is the shape created when a manipulator reaches forward, backward, up and down. These distances are determined by the length of a robot's arm and the design of its axes. Each axis contributes its own range of motion.

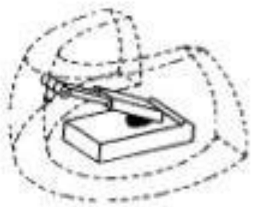
A robot can only perform within the confines of this work envelope. Still, many of the robots are designed with considerable flexibility. Some have the ability to reach behind themselves. Gantry robots defy traditional constraints of work envelopes. They move along track systems to create large work spaces.



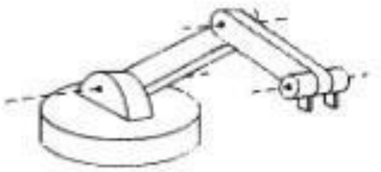
Rectangular Coordinate Robot



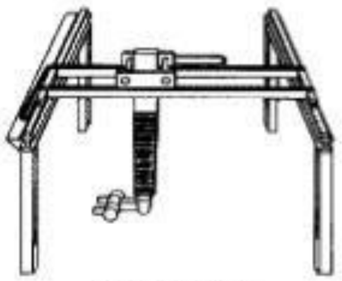
Cylindrical Coordinate Robot



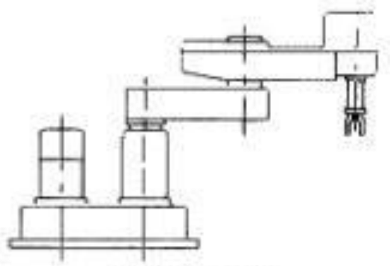
Sperical Coordinate Robot



Articulated Arm Robot



Gantry Robot

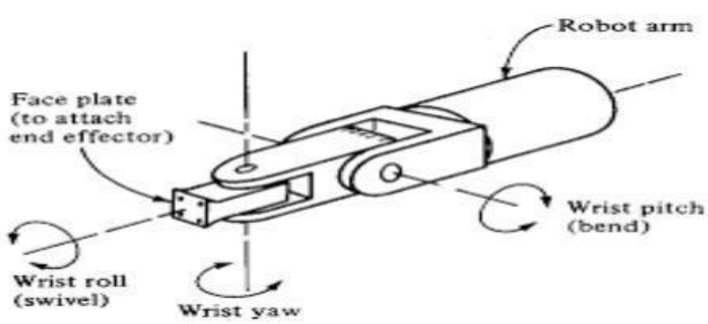


SCARA Robot

Wrist Configurations

Roll- This is also called wrist swivel, this involves rotation of the wrist mechanism about the arm axis

Pitch- It involves up & down rotation of the wrist. This is also called as wrist bend.



Robot Parts and Functions

The controller is the "brain" of the industrial robotic arm and allows the parts of the robot to operate together. It works as a computer and allows the robot to also be connected to other systems. The robotic arm controller runs a set of instructions written in code called a program. The program is inputted with ateach pendant. Many of today's industrial robot arms use an interface that resembles or is built on the Windows operating system.

Industrial robot arms can vary in size and shape. The industrial robot arm is the part that positions the end effectors. With the robot arm, the shoulder, elbow, and wrist move and twist to position the end effector in the exact right spot. Each of these joints gives the robot another degree of freedom. A simple robot with three degrees of freedom can move in three ways: up & down, left & right, and forward & backward. Many industrial robots in factories today are six axis robots

The end effector connects to the robot's arm and functions as a hand. This part comes in direct contact with the material the robot is manipulating. Some variations of an effector are a gripper, a vacuum pump, magnets, and welding torches. Some robots are capable of changing end effectors and can be programmed for different sets of tasks.

The drive is the engine or motor that moves the links into their designated positions. The links are the sections between the joints. Industrial robot arms generally use one of the following types of drives: hydraulic, electric, or pneumatic. Hydraulic drive systems give a robot great speed and strength. An electric system provides a robot with less speed and strength. Pneumatic drive systems are used for smaller robots that have fewer axes of movement. Drives should be periodically inspected for wear and replaced if necessary.

Sensors allow the industrial robotic arm to receive feedback about its environment. They can give the robot a limited sense of sight and sound. The sensor collects information and sends it electronically to the robot controlled. One use of these sensors is to keep two robots that work closely together from bumping into each other. Sensors can also assist end effectors by adjusting for part variances. Vision sensors allow a pick and place robot to differentiate between items to choose and items to ignore

Need of Robot and its Application

Industrial Applications Industrial robots are used to assemble the vehicle parts.As the assembly of the machine parts is a repetitive task to be performed, the robots are conveniently used instead of using mankind (which is more costly and less précised compared to robots.)

Auto Industry: The auto industry is the largest users of robots, which automate the production of various components and then help, assemble them on the finished vehicle. Car production is the primary example of the employment of large and complex robots for producing products. Robots are used in that process for the painting, welding and assembly of the cars. Robots are good for such tasks because the tasks can be accurately defined and must be performed the same every time, with little need for feedback to control the exact process being performed.

Material Transfer, Machine Loading And Unloading There are many robot applications in which the robot is required to move a work part or other material from one location to another. The most basic of these applications is where the robot picks the part up from one position and transfers it to another position. In other applications, the robot is used to load and/or unload a production machine of some type. Material transfer applications are defined as operations in which the primary objective is to move a part from one location to another location. They are usually considered to be among the most straightforward of robot applications to implement. The applications usually require a relatively unsophisticated robot, and interlocking requirements with other equipments are typically uncomplicated. These are the pick ad place operations. The machine loading and unloading applications are material handling operations in which the robot is used to service a production machine by transferring parts to and/or from the machine. Robots have been successfully applied to accomplish the loading and/or unloading function in the production operations

- Die casting
- Plastic moulding
- Forging and related operations
- Machining operations
- Stamping press operations

The other industrial applications of robotics include processing operations such as spot welding, continuous arc welding; spray coating, also in assembly of machine parts and their inspection.

Robotic arm The most developed robot in practical use today is the robotic arm and it is seen in applications throughout the world. We use robotic arms to carry out dangerous work such as when dealing with hazardous materials. We use robotic arms to carry out work in outer space where man cannot survive and we use robotic arms to do work in the medical field such as conducting experiments without exposing the research. Some of the most advanced robotic arms have such amenities as a rotating base, pivoting shoulder, pivoting elbow, rotating wrist and gripper fingers. All of these amenities allow the robotic arm to do work that closely resembles what a man can do only without the risk.

Medical Applications Medical robotics is a growing field and regulatory approval has been granted for the use of robots in minimally invasive procedures. Robots are being used in performing highly delicate, accurate surgery, or to allow a surgeon who is located remotely from their patient to perform a procedure using a robot controlled remotely. More recently, robots can be used autonomously in surgery.

WHAT IS FMS?

A flexible manufacturing system (FMS) is a highly automated machine cell, consisting of a group of processing workstations (usually CNC machine tools), interconnected by an automated material handling and storage system, and controlled by a distributed computer system. The reason the FMS is called flexible is that it is capable of processing a variety of different part styles simultaneously at the various workstations, and the mix of part styles and quantities of production can be adjusted in response to changing demand patterns. The FMS is most suited for the mid-variety, mid-volume production range

Need of FMS due to its benefits

A number of benefits can be expected in successful FMS applications. The principal benefits are the following:

***Increased machine** utilization.* FMSs achieve a higher average utilization than machines in a conventional batch production machine shop. Reasons for this include:

(1) 24 hr/day operation. (2) Automatic tool changing machine tools. (3) Automatic pallet changing at workstations. (4) Queues of parts at stations, and (5) dynamic scheduling of production that takes into account irregularities from normal operations. It should be possible to approach *80-90%* asset utilization by implementing FMS technology .

Fewer machines required Because of higher machine utilization. Fewer machines are required.

Reduction in factory floor space required. Compared with a job shop of equivalent capacity, an fMS generally requires less floor area. Reductions in floor space requirements are estimated to he 40-50%.

Greater responsiveness to change. An FMS improves response capability to part design changes. Introduction of new parts, changes in production schedule and product mix. machine breakdowns. and cutting tool failures. Adjustments can be made in the production schedule from one day to the next to respond to rush orders and special customer requests.

Reduced inventory requirements, Because different parts are processed together rather than separately in batches. Work-in-process (WIP) is less than in a batch production mode. The inventory of starting and finished parts can be reduced as well. Inventory reductions of 60-80% are estimated.

Lower manufacturing lead times. Closely correlated with reduced WIP is the time spent in process by the parts. This means faster customer deliveries

***Reduced direct labor** requirements* and *higher labor productivity.* Higher production rates and lower reliance on direct labor translate to greater productivity per labor hour with an FMS than with conventional production methods. Labor savings of 30-.50%, arc estimated

Opportunity for unattended production. The high level of automation in an FMS allows it to operate for extended periods of time without human attention. In the most optimistic scenario, parts and tools are loaded into the system at the end of the day shift, and the FMS continues to operate throughout the night so that the finished parts can be unloaded the next morning.

Flexible Manufacturing Systems (FMS) Components

FMS COMPONENTS

As indicated in out definition. There are several basic components of an FMS: (1) workstations,

(2) Material handling and storage system,

(3) Computer control system.

In addition, even though an FMS is highly automated, people are required to manage and operate the system.

1. Workstations

The processing or assembly equipment used in an FMS depends on the type of work accomplished by the system. In a system designed for machining operations, the principle types of processing station are CNC machine tools. Following are the types of workstations typically found in an FMS.

Load/Unload Stations. The load/unload station is the physical interface between the FMS and the rest of the factory. Raw work-parts enter the system at this point, and finished parts exit the system from here. Loading and unloading can be accomplished either manually or by automated handling systems. Manual loading and unloading is prevalent in most FMSs today. The load/unload station should be ergonomically designed to permit convenient and safe movement of work parts. For parts that are too heavy to lift by the operator, mechanized cranes and other handling devices are installed to assist the operator.

The load/unload station should include a data entry unit and monitor for communication between the operator and the computer system. Instructions must be given to the operator regarding which part to load onto the next pallet to adhere to the production schedule. In cases when different pallets are required for different parts, the correct pallet must be supplied to the station. In cases where modular fixturing is used, the correct fixture must be specified. and the required components and tools must be available at the workstation to build it. 'When the part loading procedure has been completed. the handling system must proceed to launch the pallet into the system; however, the handling system must be prevented from moving the pallet while the operator is still working. All of these circumstances require communication between the computer system and the operator at the load/unload station

Machining Stations. The most common applications of FMSs arc machining operations, The workstations used in these systems are therefore predominantly CNC machine tools. Most common is the *CNC machining center* . in particular. the horizontal rnachining center. CNC machining centers possess features that make them compatible with the FMS, including automatic tool changing and tool storage, use of palletized work-parts, CNC, and capacity for distributed numerical control (DNC. Machining centers can be ordered with automatic pallet changers that can be readily interfaced with the FMS part handling system. Machining centers are generally used for non-rotational parts. For rotational parts, *turning centers* are used; and for parts that are mostly rotational hut require multi-tooth rotational cutters (milling and drilling), *mi11·turn centers* can be used.

***Other Processing* Stations**. The FMS concept has been applied to other processing operations in addition to machining. One such application is sheet metal fabrication processes. The processing workstations consist of press-working operations, such as punching, shearing, and certain bending and forming processes. Also, flexible systems are being developed to automate the forging process. Forging is traditionally a very labor-intensive operation. The workstations in the system consist principally of a heating furnace, a forging press. and a trimming station.

Assembly. Some FMSs are designed to perform assembly operations. Flexible automated assembly systems are being developed to replace manual labor in the assembly of products typically made in batches. Industrial robots are often used as the automated workstations in these flexible assembly systems. They can be programmed to perform tasks with variations in sequence and motion pattern to accommodate the different product styles assembled in the system. Other examples of flexible assembly workstations are the programmable component placement machines widely used in electronics assembly.

Other Stations and Equipment. Inspection can be incorporated into an FMS, cither by including, an inspection operation at a processing workstation or by including a station specifically designed for inspection. Coordinate measuring machines, special inspection probes that can be used in a machine tool spindle and machine vision are three possible technologies for performing inspection on an FMS.

2. Material Handling and Storage System

The second major component of an FMS is its material handling and storage system.

Functions of the Handling System. The material handling and storage system in an FMS performs the fol1owing functions:

Random, independent movement of work-parts between stations. This means that parts must be capable of moving from anyone machine in the system *to* any *other* machine to provide various routing alternatives for the different parts and to make machine substitutions when certain stations are busy.

Handle a variety of work-part configurations. For prismatic parts, this is usually accomplished by using modular pallet fixtures in the handling system. The fixture is located on the top face of the pallet and is designed to accommodate different part configurations by means of common components, quick change features, and other devices that permit a rapid build-up of the fixture for a given part. The base of the pallet is designed for the material handling system. For rotational parts, industrial robots are often used to load and unload the turning machines and to move parts between stations.

Temporary storage. The number of parts in the FMS will typically exceed the number of parts actually being processed at any moment. Thus, each station has a small queue of parts waiting to be processed. which helps to increase machine utilization.

Convenient access for loading and unloading work-parts. The handling system must include locations for load/unload stations.

Compatible with computer control. The handling system must be capable of being controlled directly by the computer system to direct it to the various workstations, load/unload stations, and storage areas

Material Handling Equipment. The types of material handling systems used to transfer parts between stations include a variety of conventional material transport equipment ,inline transfer mechanisms and industrial robots .The material handling function in an FMS is often shared between two systems: (1) a primary handling system and (2) a secondary handling system. The ***primary handling system*** establishes the basic layout of the FMS and is responsible for moving work-parts between stations in the system.

The *secondary handling system* consists of transfer devices, automatic pallet changers. and similar mechanisms located at the workstations in the FMS. The function of the secondary handling system is to transfer work from the primary system to the machine tool or other processing station and to position the parts with sufficient accuracy and repeatability to perform the processing or assembly operation. Other purposes served by the secondary handling system include: (1) reorientation of the work-part if necessary to present the surface that is to be processed and (2) buffer storage of parts to minimize work change time and maximize station utilization. In some FMS installations, the positioning and requirements at the individual workstations are satisfied by the primary work handling system. In these cases, the secondary handling system is not included,

FMS Layout Configurations. The material handling system establishes the FMS layout. Most layout configurations found in today's FMSs can he divided into five categories: (1) inline layout, (2) loop lay out, (3) ladder layout. (4) Open field layout, and (5) robot-cantered cell.

In the *inline layout*, the machines and handling system are arranged in a straight line, as illustrated in Figure 1, In its simplest form. The parts progress from one workstation to the next in a well defined sequence, with work always moving in one direction and no back flow.

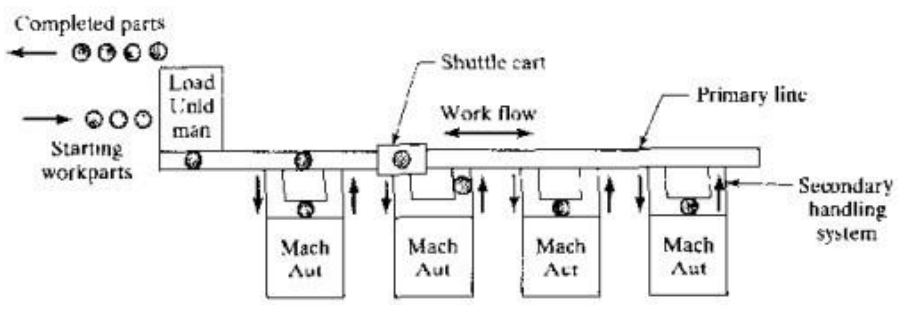


Figure 1

In the *loop layout*, the workstations are organized in a loop that is served by II part handling system in the same shape, as shown in Figure 2. Parts usually flow in one direction around the loop, with the capability to stop and be transferred to any station

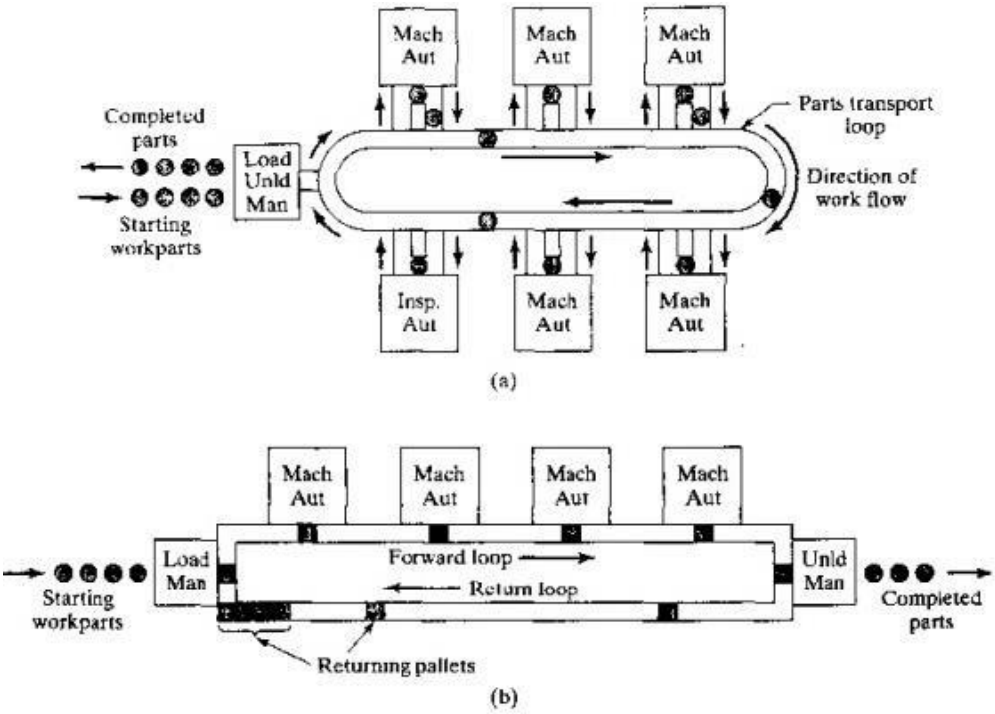


Figure2:Loop Layout

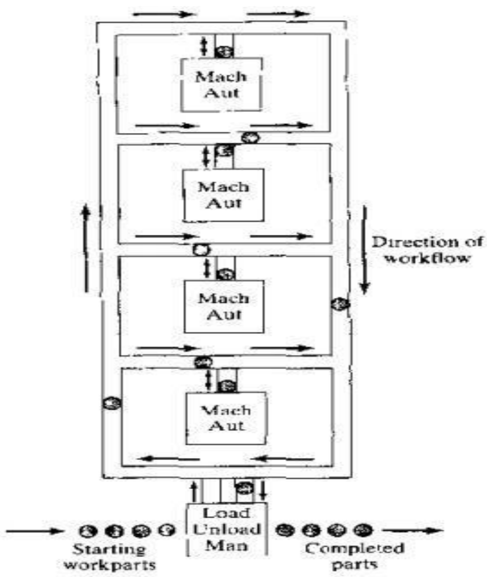


Fig. 3Ladder layout

The *ladder layout* consists of a loop with rungs between the straight sections of the loop, on which workstations are located, as shown in Figure.The rungs increase the possible ways of getting from one machine to the next, and obviate the need for a secondary handling system. This reduces average travel distance and minimizes congestion in the handling system, thereby reducing transport time between workstations.

The *open field layout* This layout type is generally appropriate for processing a large family of parts. The number of different machine types may be limited, and parts are routed to different workstations depending on which one becomes available first.

The *robot-centered cell* uses one or more robots as the material handling system. Industrial robots can be equipped with grippers that make them well suited for the handling of rotational parts, and robot centered FMS layouts are often used to process cylindrical or disk shaped parts

3. Computer Control System

The FMS includes a distributed computer system that is interfaced to the workstations, material handling system, and other hardware components. A typical FMS computer system consists of a central computer and microcomputers controlling the individual machines and other components. The central computer coordinates the activities of the components to achieve smooth overall operation of the system. Functions performed by the FMS computer control system can be grouped into the following categories:

Workstation control. In a fully automated FMS, the individual processing or assembly stations generally operate under some form of computer control. For a machining system, CNC is used to control the individual machine tools.

Distribution of control instructions to workstations. Some form of central intelligence is also required to coordinate the processing at individual stations. In a machining FMS, part programs must be downloaded to machines, and DNC is used for this purpose, The DNC system stores the programs, allows submission of new programs and editing of existing programs as needed, and performs other DNC functions

Production control. The part mix and rate at which the various parts are launched into the system must be managed. Input data required for production control includes desired daily production rates per part. Numbers of raw work-parts available, and number of applicable pallets.' The production control function is accomplished by routing an applicable pallet 10 the load/unload area and providing instructions to the operator for loading the desired work-part.

Traffic control. This refers to the management of the primary material handling system that moves work parts between stations. Traffic control is accomplished by actuating switches at branches and merging points. Stopping parts at machine tool transfer locations, and moving pallets to load/unload stations.

Shuttle control. This control function is concerned with the operation and control of the secondary handling system at each workstation. Each shuttle must be coordinated with the primary handling system and synchronized with the operation of the machine tool it serves

Work-piece monitoring. The computer must monitor the status of each cart and/or pallet in the primary and secondary handling systems as well as the status of each of the various workpiece types.

Tool control. In a machining system, cutting tools are required. Tool control is concerned with managing two aspects of the cutting tools:

Tool location. This involves keeping track of the cutting tools at each workstation, If one or mere tools required to process a particular workpiece is not present at the station that is specified in the part's routing, the tool control subsystem takes one or both of the following actions: (a) determines whether an alternative workstation that has the required tool is available and/or (b) notifies the opera tor responsible for tooling in the system that the tool storage unit at the station must be loaded with the required cutter(s).

Tool life monitoring. 1.nthis aspect of tool control, a tool life isspecif.ied to the computer for each cutting tool in the FMS. A record of the machining time usage maintained for each of the tools, and when the cumulative machining time reaches the specified life of the tool, the operator is notified that a tool replacement is needed.

Performance monitoring and reporting. The computer control system is programmed to collect data on the operation and performance of the FMS. This data is periodically summarized, and reports are prepared for management on system performance.

Diagnostics. This function is available to a greater or lesser degree on many manufacturing systems to indicate the probable source of the problem when a malfunction occurs. It can also be used to plan preventive maintenance in the system and to identify Impending failures. The purpose of the diagnostics function is to reduce breakdowns and downtime and increase availability of the system.

The modular structure of the FMS application software for system control is illustrated in Figure 4. It should be noted that an FMS possesses the characteristic architecture or a DNC system. As in other DNC systems. Two-way communication is used. Data and commands an: sent from the central computer to the individual machines and other hardware components, and data on execution and performance are transmitted from the components hack up to the central computer. In addition, an uplink from the FMS to the corporate host computer is provide

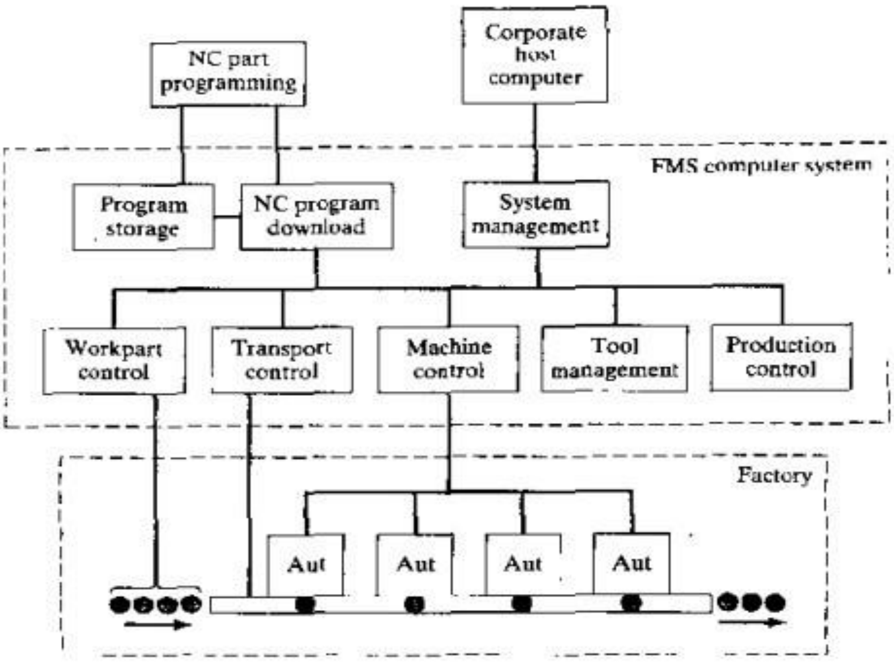


Figure 4 Structure of FMS application software system. Key: NC = numerical control, Aut = automated workstation.

4.Human Resources

One additional component in the FMS is human labor. Humans are needed to manage the operations of the FMS. Functions typically performed by humans include: (1) loading raw workparts into the system, (2) unloading finished parts (or assemblies) from the system. (3) changing and setting tools. (4) equipment maintenance and repair, (5) NC part programming in a machining system, (6) programming and operating the computer system, and (7) overall management of the system

What is CAD?

CAD is the acronym for Computer Aided Design or Computer Aided Drawing. CAD/CAM: Computer Aided Design and Manufacturing. The authors Mikell Groover and Emory Zimmers have defined CAD as, “the use of computer systems to assist in the creation, modification, analysis, or optimization of a design."

To perform the CAD operations the computer systems comprise of the software and the hardware. The hardware consists of all the visible components of the computer like processor, motherboard, mouse, keyboard, graphics card etc. The software consists of the program that can implement computer graphics on the computer system and also carry out a number of engineering functions on the computers.

The CAD software can carry out a number of engineering functions like analysis of stress-strain subjected on the components, dynamics response of the mechanisms, heat-transfer calculations, etc. Not all the CAD software will perform all the functions. Each CAD software is programmed to carry out specific function. Depending upon the type of the firm or the company, they will choose the CAD software that can perform particular application.

However, the most popular CAD software is the ones that can perform design and drawing operations. These CAD software can perform all the designing operations like making various calculations, performing simulations of the designed components, checking them for stress etc. The drawings of these designed components can also be drawn using the CAD software, which help avoiding long and cumbersome process of making the drawings on the drawing board.

Popular CAD Software

These days a number of CAD software are available in the market, some of these include AutoCAD, CADopia, Solid Works, Catia, MathCAD, Quick CAD etc. One of the most popular CAD software being used since years is AutoCAD.

Benefits of using the CAD Software: Advantages of the CAD Software

Benefits of the CAD Software

CAD software is being used on large scale basis by a number of engineering professionals and firms for various applications. The most common application of CAD software is designing and drafting. Here are some of the benefits of implementing CAD systems .

1) Increase in the productivity of the designer: The CAD software helps designer in visualizing the final product that is to be made, it subassemblies and the constituent parts. The product can also be given animation and see how the actual product will work, thus helping the designer to immediately make the modifications if required. CAD software helps designer in synthesizing, analyzing, and documenting the design. All these factors help in drastically improving the productivity of the designer that translates into fast designing, lower designing cost and shorter project completion times.

2) Improve the quality of the design: With the CAD software the designing professionals are offered large number of tools that help in carrying out thorough engineering analysis of the proposed design. The tools also help designers to consider large number of investigations. Since the CAD systems offer greater accuracy, the errors are reduced drastically in the designed product leading to better design. Eventually, better design helps carrying out manufacturing faster and reducing the wastages that could have occurred because of the faulty design.

3) Better communications: The next important part after designing is making the drawings. With CAD software better and standardized drawings can be made easily. The CAD software helps in better documentation of the design, fewer drawing errors, and greater legibility.

4) Creating documentation of the designing: Creating the documentation of designing is one of the most important parts of designing and this can be made very conveniently by the CAD software. The documentation of designing includes geometries and dimensions of the product, its subassemblies and its components, material specifications for the components, bill of materials for the components etc.

5) Creating the database for manufacturing: When the creating the data for the documentation of the designing most of the data for manufacturing is also created like products and component drawings, material required for the components, their dimensions, shape etc.

6) Saving of design data and drawings: All the data used for designing can easily be saved and used for the future reference, thus certain components don't have to be designed again and again. Similarly, the drawings can also be saved and any number of copies can be printed whenever required. Some of the component drawings can be standardized and be used whenever required in any future drawings.

What is CAM? CNC Machines as Part of CAM.

What is CAM?

CAM is the acronym for Computer Aided Manufacturing. CAD/CAM: Computer Aided Design and Manufacturing the authors Mikell Groover and Emory Zimmers have defined CAM as, "the use of computer systems to plan, manage, and control the operations of a manufacturing plant through their direct or indirect computer interface with the plant's resources."

In simple terms using the computers to carry out various manufacturing related activities is called as Computer Aided Manufacturing. The use of the computers can be to plan the manufacturing of the product, to carry out actual manufacturing of the product by linking the computers to machines and programming the computers, etc.

In many cases the CAD and CAM are combined together. This means the product to be manufactured is first designed on the computer and it is also manufactured using the computers systems.

Functions Performed by CAM

The functions performed by the computers systems in CAM applications fall under two broad categories, which have been described below:

1. **Computer monitoring and control**: In these applications the computer is connected directly to the manufacturing process for the purpose of monitoring or controlling the manufacturing process. Here the computer is fed with the program that directs the working of the machine, which is connected to it. Usually in such cases is no operator required to operate the machines, and they have to merely supervise the machine. At a time one operator can take care of more than one number of machines. These machines are also called as Computer Numerically Controlled (CNC) machines. These days the use of CNC machines has become very common. They can carry out the high quality production at a very fast rate that helps the companies remain competitive in the market.

2. **Manufacturing Support Applications:** In these applications the computer systems are used to assist in various productions related activities like production planning, scheduling, making forecasts, giving manufacturing instructions and other relevant information that can help manage company's manufacturing resources more effectively. There is no direct interface between the computers and the manufacturing process in this case.

In present scenario one just can't think of manufacturing any product without the use of computers in some or the other way. Either for designing of the product or manufacturing of the product, the use of computers has become compulsory. Since most of the companies do designing or drawing as well as manufacturing, the CAD/CAM has become an inseparable combination.

Key Differences between CAD and CAM

1. Computer-aided design (CAD) involves the use of computers for transforming the elementary idea of product into a detailed engineering design. The evolution includes the creation of product's geometric models, which can further be manipulated, analyzed and refined. On the other hand, Computer-aided manufacturing (CAM) involves the use of computers for assisting managers, manufacturing engineers, and production workers by automating production tasks and it also controls machines and systems.
2. CAD comprise of processes such as defining the geometric model and translating the definition, interface, design, and analysis algorithm, drafting, detailing and at last documentation. As against, CAM involves processes such as geometric modelling, numerical control programs, interface algorithms, inspection, process planning, assembly and packaging.

3. The CAM system requires control and coordination of the physical process, equipment, material, and labour whereas CAD requires product design conceptualization and analysis.

4. There is numerous CAD software, for example, AutoCAD, Autodesk Inventor, CATIA etcetera. In contrast, Siemens NX, Power MILL, WorkNC, Solid CAM are some the examples for CAM software.

Advantages of CAD

- Minimizes the requirement for huge numbers of an expensive draftsman in designing of a product.
- It can be used directly in order to generate cutting data for CNC machines.
- Scaling, re-scaling modification in drawings and models is easier and automatic and accurate.
- Storage and retrieval of models is easier.
- Design data can be shared in computerised manufacturing management systems.
- Precise 3D models can be examined before making expensive materials.
- It increases the speed of production and requires less labour.
- Multiple copies can be stored, printed and shared electronically, which eliminates the need for storing large paper drawings.

Advantages of CAM

- Manufacturing requires minimum supervision and can be accomplished during unsocial work hours.
- Manufacture is less labour intensive and saves labour cost.
- Machines are accurate, and manufacturing can be repeated consistently with large batches.
- Error occurrence is negligible, and machines can run continuously.
- Prototype models can be prepared very speedily for elaborated inspection before finalising designs for manufacture.
- Virtual machining can be used to evaluate machining routines and outcomes on the screen.

Disadvantages of CAD

- Power cuts and viruses can be problematic for the computerised system.
- Industrial versions of the software could be very expensive to buy especially for the startup costs.
- Traditional drafting skills will be lost as they become unnecessary.
- Expensive training would be required to use the software, which can be time-consuming and costly.

Disadvantages of CAM

- It requires high initial investment and start-up cost.
- Machine maintenance is also costly.
- May result in loss of a workforce with high-level manual skill.

- To assure proper tooling and set up procedures it needs highly trained operatives and technicians.

COMPUTER-INTEGRATED MANUFACTURING (CIM)

Computer-integrated manufacturing (**CIM**) is the manufacturing approach of using computers to control entire production process. This integration allows individual processes to exchange information with each other and initiate actions. Although manufacturing can be faster and less error-prone by the integration of computers, the main advantage is the ability to create automated manufacturing processes. Typically CIM relies of closed-loop control processes, based on real-time input from sensors. It is also known as flexible design and manufacturing.

Computer-integrated manufacturing is used in automotive, aviation, space, and ship building industries. The term "computer-integrated manufacturing" is both a method of manufacturing and the name of a computer-automated system in which individual engineering, production, marketing, and support functions of a manufacturing enterprise are organized. In a CIM system functional areas such as design, analysis, planning, purchasing, cost accounting, inventory control, and distribution are linked through the computer with factory floor functions such as materials handling and management, providing direct control and monitoring of all the operations.

CIM HARDWARE AND CIM SOFTWARE

CIM Hardware comprises the following:

I. Manufacturing equipment such as CNC machines or computerized workcenters, robotic work cells, DNC/FMS systems, work handling and tool handling devices, storage devices, sensors, shop floor data collection devices, inspection machines etc.
II. Computers, controllers, CAD/CAM systems, workstations / terminals, data entry terminals, bar code readers, printers, plotters and other peripheral devices, modems, cables, connectors etc.,

CIM software comprises computer programmes to carry out the following functions:

- Management Information System
- Sales
- Marketing
- Finance
- Database Management
- Modelling and Design
- Analysis
- Simulation
- Communications
- Monitoring
- Production Control
- Manufacturing Area Control
- Job Tracking

- Inventory Control
- Shop Floor Data Collection
- Order Entry
- Materials Handling
- Device Drivers
- Process Planning
- Manufacturing Facilities Planning
- Work Flow Automation
- Business Process Engineering
- Network Management
- Quality Management

NATURE AND ROLE OF THE ELEMENTS OF CIM SYSTEM

Nine major elements of a CIM system are

i. Marketing
ii. Product Design
iii. Planning
iv. Purchase
v. Manufacturing Engineering
vi. Factory Automation Hardware
vii. Warehousing
viii. Finance
ix. Information Management

i. Marketing: The need for a product is identified by the marketing division. The specifications of the product, the projection of manufacturing quantities and the strategy for marketing the product are also decided by the marketing department. Marketing also works out the manufacturing costs to assess the economic viability of the product.

ii. Product Design: The design department of the company establishes the initial database for production of a proposed product. In a CIM system this is accomplished through activities such as geometric modelling and computer aided design while considering the product requirements and concepts generated by the creativity of the design engineer. Configuration management is an important activity in many designs. Complex designs are usually carried out by several teams working simultaneously, located often in different parts of the world. The design process is constrained by the costs that will be incurred in actual production and by the capabilities of the available production equipment and processes. The design process creates the database required to manufacture the part.

iii. Planning: The planning department takes the database established by the design department and enriches it with production data and information to produce a plan for the production of the product. Planning involves several subsystems dealing with materials, facility, process, tools, manpower, capacity, scheduling, outsourcing, assembly, inspection, logistics etc. In a CIM system, this planning process should be constrained by the production costs and by the production equipment and process capability, in order to generate an optimized plan.

iv. Purchase: The purchase departments is responsible for placing the purchase orders and follow up, ensure quality in the production process of the vendor, receive the items, arrange for inspection and supply the items to the stores or arrange timely delivery depending on the production schedule for eventual supply to manufacture and assembly.

v. Manufacturing Engineering: Manufacturing Engineering is the activity of carrying out the production of the product, involving further enrichment of the database with performance data and information about the production equipment and processes. In CIM, this requires activities like CNC programming, simulation and computer aided scheduling of the production activity. This should include online dynamic scheduling and control based on the real time performance of the equipment and processes to assure continuous production activity. Often, the need to meet fluctuating market demand requires the manufacturing system flexible and agile.

vi. Factory Automation Hardware: Factory automation equipment further enriches the database with equipment and process data, resident either in the operator or the equipment to carry out the production process. In CIM system this consists of computer controlled process machinery such as CNC machine tools, flexible manufacturing systems (FMS), Computer controlled robots, material handling systems, computer controlled assembly systems, flexibly automated inspection systems and so on.

vii. Warehousing: Warehousing is the function involving storage and retrieval of raw materials, components, finished goods as well as shipment of items. In today's complex outsourcing scenario and the need for just-in-time supply of components and subsystems, logistics and supply chain management assume great importance.

viii. Finance: Finance deals with the resources pertaining to money. Planning of investment, working capital, and cash flow control, realization of receipts accounting and allocation of funds are the major tasks of the finance departments.

ix. Information Management: Information Management is perhaps one of the crucial tasks in CIM. This involves master production scheduling, database management, communication, manufacturing systems integration and management information systems.