Purushottam School of Engineering and Technology, Rourkela

Lectures notes On

ADVANCE MANUFACTURING & CAD/CAM (MET 603)

(6^{th} sem MECHANICAL)

Department of Mechanical Engg.

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ADVANCE MANUFACTURING & CAD/CAM

Name of the Course: Diploma in MECHANICAL ENGINEERING			
Course code:	MET 603	Semester	6th
Total Period:	60	Examination	3 hrs
Theory periods:	4 P/W	Class Test:	20
Tutorial:	1 P/W	Teacher's Assessment:	10
Maximum marks:	100	End Semester Examination:	70

Rationale:

Today Indian Industries are faced with global Competition and hence the need for improving their manufacturing processes and techniques to the latest world standards.

Course Objectives:

1. Describe the various non traditional manufacturing processes which are specially used in research laboratories.
2. Understanding of CNC and DNC systems as now in industries automation is a major factor.
3. Understanding the robot technology and CAD/CAM

		Periods
1.0	**Non conventional machining process:**	
	Explain the Working principle, advantages, disadvantages and area of application of	14
	1.1 Electro chemical machining process	
	1.2 Electro discharge machining process	
	1.3 Plasma arc machining process	
	1.4 Laser beam machining process	
	1.5 Abrasive jet machining process	
	1.6 Electron beam machining process	
2.0	**Automation:**	6
	2.1 Define Automation	
	2.2 List types of Automation	
	2.3 Explain need for Automation	
3.0	**Numerical Control:**	16
	3.1 Define Numerical Control	
	3.2 Explain the NC system with block diagram.	
	3.3 Describe the types of NC co-ordinate: Point – to – point, Straight Cut, and Contouring.	
	3.4 NC part programming: G code and M-code. Reference Point (Machine Zero, Work zero, Tool zero & Tool offset). Simple part program for lathe.	
	3.5 Explain the Extension of NC with the block diagram: (i) DNC (Direct numerical Control) (ii) CNC (Computer numerical Control) (iii) Adaptive Control	
4.0	**Robot Technology:**	8
	4.1 Defining a robot (ISO) Fields of application of robots	

4.2 Explain Robot anatomy.
4.3 Describe Robot Configuration

5.0 Flexible Manufacturing System (FMS): 8

5.1 Need for FMS
5.2 Explain the components of FMS: Processing Station, Material handling & storage and Computer Control System.

6.0 CAD / CAM and CIM: 8

6.1 Define CAD, CAM and CIM
6.2 Explain the benefits of CAD. CAD software and hardware.
6.3 Explain the benefits of CAM, differentiate between CAD and CAM
6.4 Explain the concept, background. Software and hardware of CIM.

Learning resources			
Sl. No.	***Name of Authors***	***Title of the Book***	***Name of the Publisher***
	O.P khana	Production technology, Vol-II	Dhanpat Rai Publication
	B.S. Raghuwanshi	Workshop Technology, Vol – II	Dhanpat Rai & Co.
	Mikel P.Groover	CAD /CAM	Pearson
	Dr. P.N. Rao	CAD / CAM Principle & application	TMH

Module I

Modern or Non Traditional Manufacturing Processes

Modern or Non-traditional manufacturing processes is defined as a group of processes that remove excess material by various techniques involving mechanical, thermal, electrical or chemical energy or combinations of these energies but do not use a sharp cutting tools as it needs to be used for traditional manufacturing processes.

Extremely hard and brittle materials are difficult to machine by traditional machining processes such as turning, drilling, shaping and milling. Non-traditional machining processes, also called advanced manufacturing processes, are employed where traditional machining processes are not feasible, satisfactory or economical due to special reasons as outlined below.

- Very hard fragile materials difficult to clamp for traditional machining
- When the workpiece is too flexible or slender
- When the shape of the part is too complex

Several types of non-traditional machining processes have been developed to meet extra required machining conditions. When these processes are employed properly, they offer many advantages over non-traditional machining processes. The common non-traditional machining processes are described in this section.

Modern manufacturing processes are classified according to the type of fundamental machining energy employed. A detail classification f the machining process based on the type of energy used , the mechanism of metal removal, the source of energy requirements etc is given below:

Classification of machining processes

Type of Energy	Mechanism of Metal Removal	Transfer Media	Energy source	Processes
Mechanical	Erosion	High velocity particle	Pneumatic/Hydraulic pressure	AJM, USM, WJM
	Shear	Physical contact	Cutting tool	Conventional machining
Electro chemical	Ion displacement	Electrolyte	High current	ECM, ECG
Chemical	Ablative relation	Reactive environment	Corrosive agent	CHM
Thermoelectric	Fusion	Hot gases	Ionized material	IBM, PAM
		Electrons	High voltage	EDM
	Vaporization	Radiation	Amplified light	LBM
		Ion stream	Ionized material	PAM

AJM: Abrasive Jet Machining

CHM:Chemical machining

ECG: Electrochemical Grinding

ECM:Electrochemical Machining

EDM:Electro Discharge Machining

Electrochemical Machining (ECM)

Electrochemical machining(ECM) is a metal-removal process based on the principle of reverse electroplating. In this process, particles travel from the anodic material (workpiece) toward the cathodic material (machining tool). A current of electrolyte fluid carries away the deplated material before it has a chance to reach the machining tool. The cavity produced is the female mating image of the tool shape.

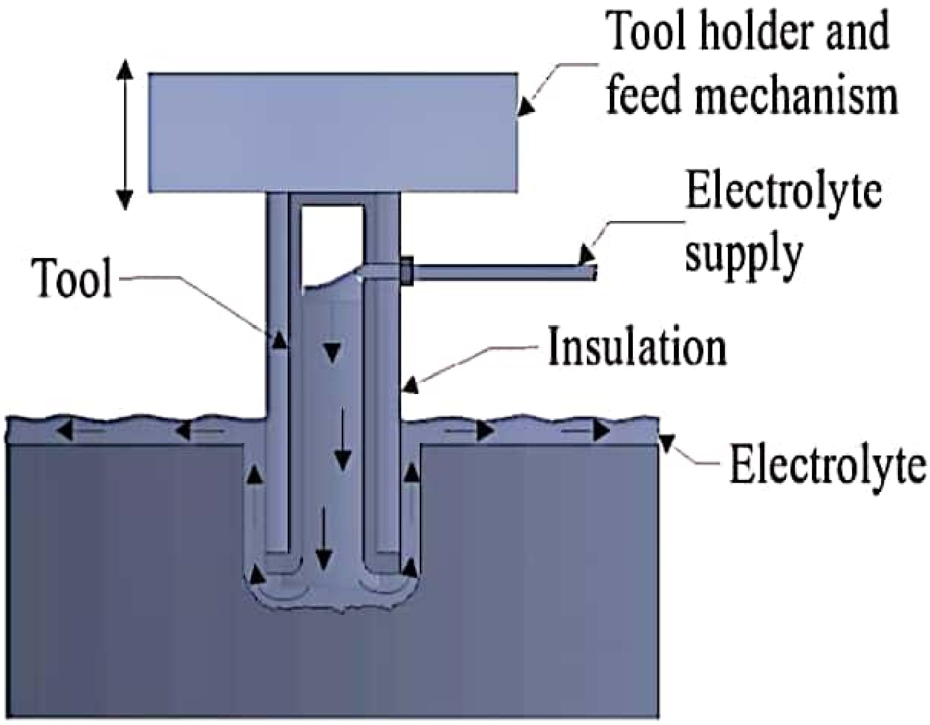


Figure7: ECM process

Similar to EDM, the workpiece hardness is not a factor, making ECM suitable for machining difficult-to –machine materials. Difficult shapes can be made by this process on materials regardless of their hardness. A schematic representation of ECM process is shown in Figure 8. The ECM tool is positioned very close to the workpiece and a low voltage, high amperage DC current is passed between the workpiece and electrode. Some of the shapes made by ECM process is shown in Figure 8.

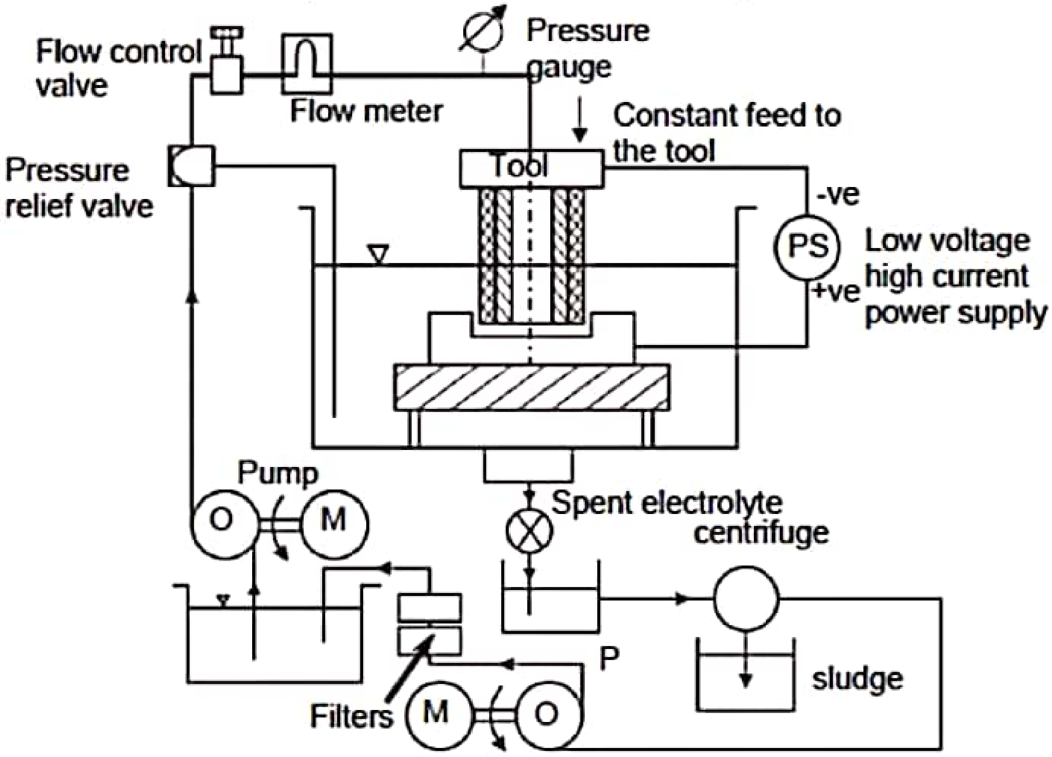
Figure 9: Parts made by ECM

Equipment used in ECM:

The electrochemical machining system has the following modules:

- Power supply
- Electrolyte filtration and delivery system
- Tool feed system
- Working tank

Fig. 4 schematically shows an electrochemical drilling unit.



Schematic diagram of a electro chemical drilling unit

Advantages of ECM

- The components are not subject to either thermal or mechanical stress.
- No tool wear during ECM process.
- Fragile parts can be machined easily as there is no stress involved.
- ECM deburring can debur difficult to access areas of parts.
- High surface finish (up to 25 μm in) can be achieved by ECM process.
- Complex geometrical shapes in high-strength materials particularly in the aerospace industry for the mass production of turbine blades, jet-engine parts and nozzles can be machined repeatedly and accurately.
- Deep holes can be made by this process.

Limitations of ECM

- ECM is not suitable to produce sharp square corners or flat bottoms because of the tendency for the electrolyte to erode away sharp profiles.
- ECM can be applied to most metals but, due to the high equipment costs, is usually used primarily for highly specialised applications.

Material removal rate, MRR, in electrochemical machining:

$MRR = C . I . h$ (cm^3/min)

C: specific (material) removal rate (e.g., 0.2052 cm^3/amp-min for nickel);

I: current (amp);

h: current efficiency (90–100%).

Electrical Discharge Machining (EDM)

Introduction

Electrical discharge machining (EDM) is one of the most widely used non-traditional machining processes. The main attraction of EDM over traditional machining processes such as metal cutting using different tools and grinding is that this technique utilises thermoelectric process to erode undesired materials from the workpiece by a series of discrete electrical

sparks between the workpiece and the electrode. A picture of EDM machine in operation is shown in Figure 12.

Figure 12: Electrical discharge machine

The traditional machining processes rely on harder tool or abrasive material to remove the softer material whereas non-traditional machining processes such as EDM uses electrical spark or thermal energy to erode unwanted material in order to create desired shape. So, the hardness of the material is no longer a dominating factor for EDM process. A schematic of an EDM process is shown in Figure 13, where the tool and the workpiece are immersed in a dielectric fluid.

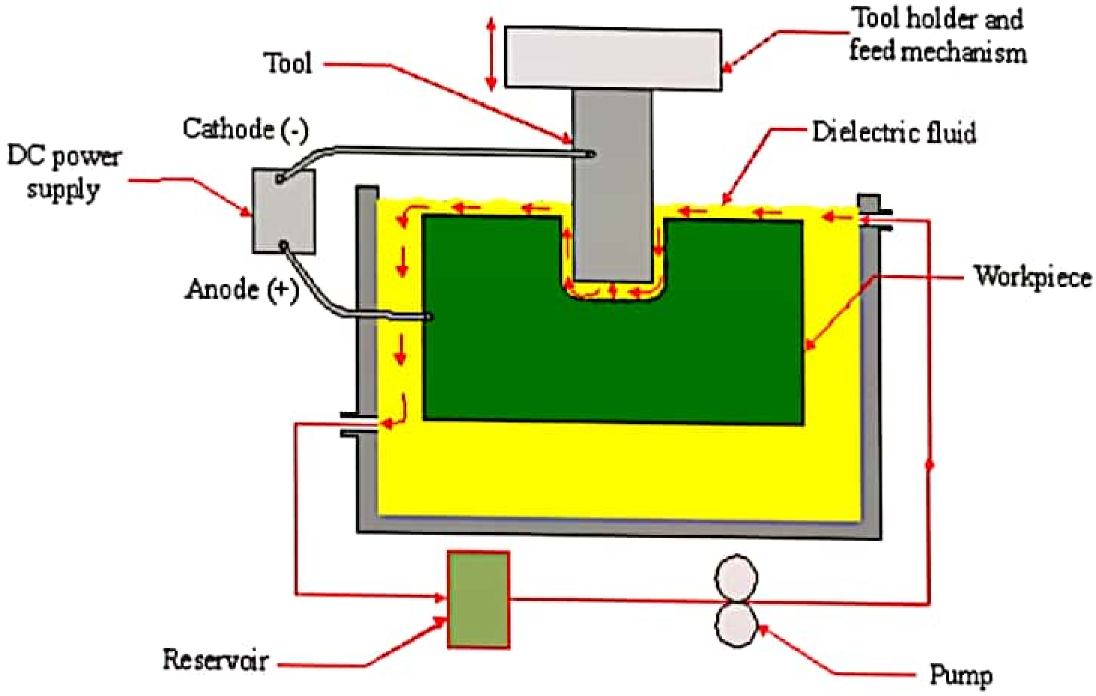


Figure 13: Schematic of EDM process

EDM removes material by discharging an electrical current, normally stored in a capacitor bank, across a small gap between the tool (cathode) and the workpiece (anode) typically in the order of 50 volts/10amps.

EDM – Components

The main components in EDM:

- Electric power supply
- Dielectric medium
- Work piece & tool
- Servo control unit.

The work piece and tool are electrically connected to a DC power supply.

The current density in the discharge of the channel is of the order of 10000 A/cm2 and power density is nearly 500 MW/cm2.

A gap, known as SPARK GAP in the range, from 0.005 mm to 0.05 mm is maintained between the work piece and the tool.

Dielectric slurry is forced through this gap at a pressure of 2 kgf/cm2 or lesser.

EDM – Working Principle

- It is a process of metal removal based on the principle of material removal by an interrupted electric spark discharge between theelectrode tool and the work piece.
- In EDM, a potential difference is applied between the tool and workpiece.
- Essential - Both tool and work material are to be conductors.
- The tool and work material are immersed in a dielectric medium.
- Generally kerosene or deionised water is used as the dielectric medium.
- A gap is maintained between the tool and the workpiece.
- Depending upon the applied potential difference (50 to 450 V) and the gap between the tool and workpiece, an electric field would be established.
- Generally the tool is connected to the negative terminal (cathode) of the generator and the workpiece is connected to positive terminal (anode).
- As the electrons get accelerated, more positive ions and electrons would get generated due to collisions.
- This cyclic process would increase the concentration of electrons and ions in the dielectric medium between the tool and the job at the spark gap.
- The concentration would be so high that the matter existing in that channel could be characterised as "plasma".
- The electrical resistance of such plasma channel would be very less.
- Thus all of a sudden, a large number of electrons will flow from tool to job and ions from job to tool.
- This is called avalanche motion of electrons.
- Such movement of electrons and ions can be visually seen as a spark.
- Thus the electrical energy is dissipated as the thermal energy of the spark.
- The high speed electrons then impinge on the job and ions on the tool.

- The kinetic energy of the electrons and ions on impact with the surface of the job and tool respectively would be converted into thermal energy or heat flux.
- Such intense localized heat flux leads to extreme instantaneous confined rise in temperature which would be in excess of 10,000oC.
- Such localized extreme rise in temperature leads to material removal.
- Material removal occurs due to instant vaporization of the material as well as due to melting.
- The molten metal is not removed completely but only partially.

Electrode Material

Electrode material should be such that it would not undergo much tool wear when it is impinged by positive ions. Thus the localized temperature rise has to be less by tailoring or properly choosing its properties or even when temperature increases, there would be less melting. Further, the tool should be easily workable as intricate shaped geometric features are machined in EDM.

Thus the basic characteristics of electrode materials are:

- High electrical conductivity – electrons are cold emitted more easily and there is less bulk electrical heating
- High thermal conductivity
- Higher density
- High melting point – high melting point leads to less tool wear due to less tool material melting for the same heat load
- Easy manufacturability
- Cost – cheape.g, Graphite ,Electrolytic oxygen free copper ,Tellurium copper – 99% Cu +0.5% tellurium ,Brass

Working principle of EDM

As shown in Figure 12, at the beginning of EDM operation, a high voltage is applied across the narrow gap between the electrode and the workpiece. This high voltage induces an electric field in the insulating dielectric that is present in narrow gap between electrode and workpiece. This cause conducting particles suspended in the dielectric to concentrate at the points of strongest electrical field. When the potential difference between the

Application of EDM

The EDM process has the ability to machine hard, difficult-to-machine materials. Parts with complex, precise and irregular shapes for forging, press tools, extrusion dies, difficult internal shapes for aerospace and medical applications can be made by EDM process. Some of the shapes made by EDM process are shown in Figure 14.

Figure 14: Difficult internal parts made by EDM process

Advantages of EDM

The main advantages of DM are:

- By this process, materials of any hardness can be machined;
- No burrs are left in machined surface;
- One of the main advantages of this process is that thin and fragile/brittle components can be machined without distortion;
- Complex internal shapes can be machined

Limitations of EDM

The main limitations of this process are:

- This process can only be employed in electrically conductive materials;

- Material removal rate is low and the process overall is slow compared to conventional machining processes;
- Unwanted erosion and over cutting of material can occur;
- Rough surface finish when at high rates of material removal.

Dielectric fluids

Dielectric fluids used in EDM process are hydrocarbon oils, kerosene and deionised water. The functions of the dielectric fluid are to:

- Act as an insulator between the tool and the workpiece.
- Act as coolant.
- Act as a flushing medium for the removal of the chips.

The electrodes for EDM process usually are made of graphite, brass, copper and copper-tungsten alloys.

Design considerations for EDM process are as follows:

- Deep slots and narrow openings should be avoided.
- The surface smoothness value should not be specified too fine.
- Rough cut should be done by other machining process. Only finishing operation should be done in this process as MRR for this process is low.

Wire EDM

EDM, primarily, exists commercially in the form of die-sinking machines and wire-cutting machines (Wire EDM). The concept of wire EDM is shown in Figure 15. In this process, a slowly moving wire travels along a prescribed path and removes material from the workpiece. Wire EDM uses electro-thermal mechanisms to cut electrically conductive materials. The material is removed by a series of discrete discharges between the wire electrode and the workpiece in the presence of dielectric fluid, which

PLASMA ARC MACHINING (PAM):

Introduction

A plasma is defined as a superheated, electrically ionized gas. Plasma Arc Cutting(PAC) uses a plasma stream operating at temperatures in the range from 10,000 to 14,000 °C to cut metal by melting. The cutting action takes place by directing the high velocity plasma stream at the work, thus melting it and blowing the molten metal through the kerf. Plasma is encountered in electrical discharges, such as fluorescent tubes and electric arcs, lightning, high temperature combustion flames and the sun. Most application of PAC involve cutting of flat metal sheets and plates. Operations include hole piercing and cutting along a defined path. It was initially employed to cut metals that are difficult to machine by conventional methods. However, in recent years, PAC has also been used to cut plain carbon steel, stainless steel and aluminium.

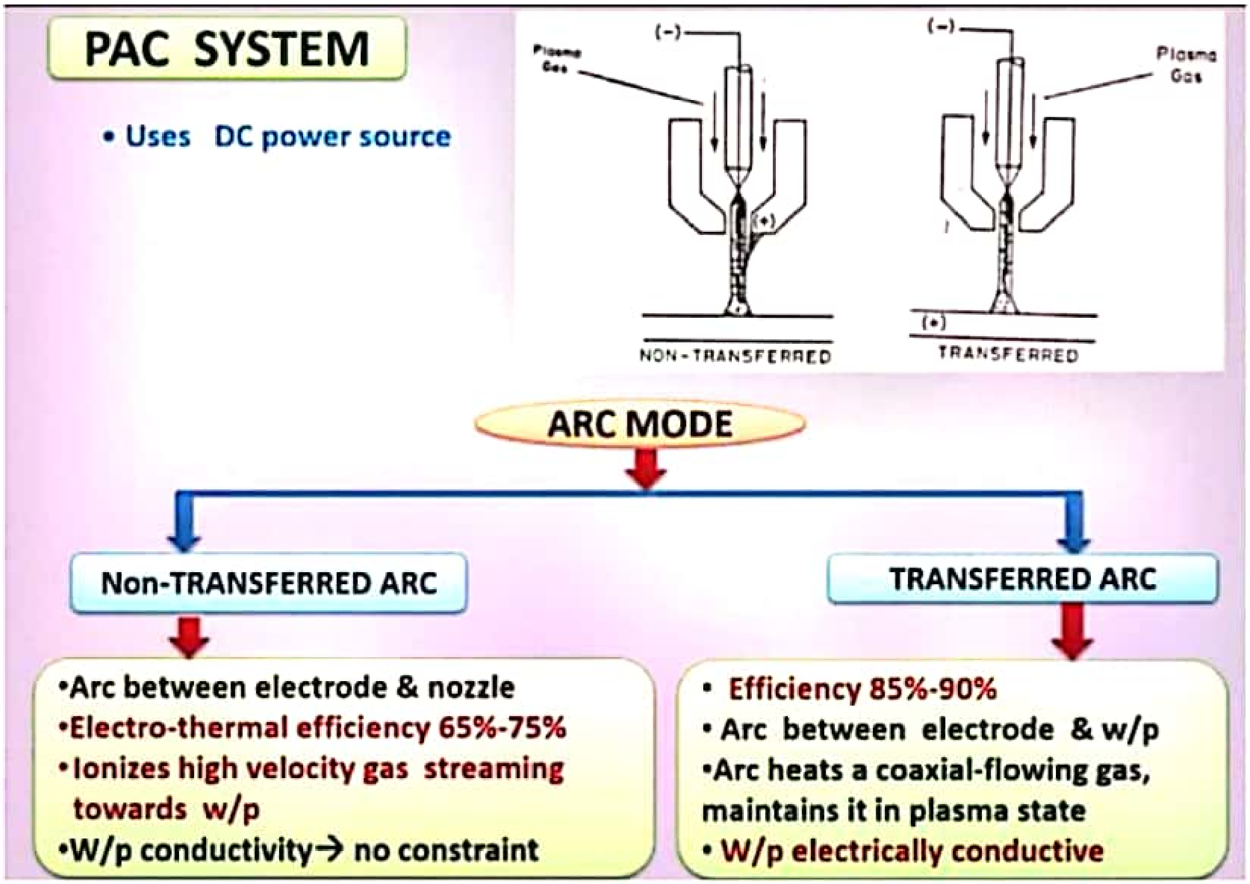
Principle:

When heated to elevated temperatures, gases turn into a distinctly different type of matter, which is plasma. When gases are heated by an applied electric field, an igniter supplies the initial electrons, which accelerate in the field before colliding and ionizing the atoms. The free electrons, in turn, get accelerated and cause further ionization and heating of the gases. The avalanche continues till a steady state is obtained in which the rate of production of the free charges is balanced by recombination and loss of the free charges to the walls and electrodes. The actual heating of the gas takes place due to the energy liberated when free ions and electrons recombine into atoms or when atoms recombine into molecules

Types of Plasma Arc Cutting system:

There are different types of plasma arc cutting operations are here. So there are 2 main configurations are there.

- non-transferred mode,
- transfer mode



So this plasma gas is flowing surrounding this cathode. So this surrounding this cathode this plasma gas is coming and it is passing, this high velocity plasma gas is passing through this nozzle here. So it is passing through the nozzle. When it is passing through this nozzle, it is ionized, this plasma gas high pressurized, high velocity plasma gas is ionized and using this non-transferred mode any kind of material whether it is electrically conducting or electrically non-conducting, any kind of material can be cut or machined. So this non-transferred arc, arc between electrode and nozzle so this is arc is generated between this electrode and this nozzle.

So here electrode this cathode and nozzle is connected to the anode and electrothermal efficiency of this kind of non-transferred arc is 65 to 70%. So it has a very low efficiency, low efficiency than this transferred mode. So ionizes high velocity gas streaming towards the workpiece when it is passing through this cathode or electrode and the nozzle so high velocity plasma jet is actually here, it is ionizes. So workpiece conductivity is not a

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constant. So any kind of material, any kind of workpiece material, whether it is electrically conducting or non-conducting, any kind of material can be cut by this plasma, non-transferred mode of plasma arc cutting operation.
But in this transferred mode you can see here this is the electrode here and this positive terminal is connected to the workpiece. So here the main constant is that this workpiece should be electrically conducting material. So this kind of transferred mode can be used only for electrically conducting mode of electrically conducting workpiece material. So here plasma gas is coming surrounding this electrode and while it is passing through this so it is ionized here in this zone it is ionized while it is passing through this nozzle it is ionized.
So electrical efficiency, electrothermal efficiency of this kind of transfer mode, it is higher than this non-transfer mode, here it is 85 to 90% electrothermal efficiency for transferred mode or plasma arc nozzle. So arcing is generated between the electrode and the workpiece and arc heats of this coaxial-flowing gas so this is coaxial flowing plasma gas okay so maintains it in a plasma state. So here this workpiece is electrically conducting. So these are the 2 modes arc mode, one is the non-transferred and second one is the transferred arc mode.

Equipment

Elements of Plasma Arc system are

- power supply
- Gas supply
- Cooling water system
- Control console
- Plasma tourch

So first one is the power supply. Second one is the gas supply, plasma gas supply system, then cooling water system. So you have to cool down this nozzle as well as the plasma jet you have to cool down and then control console. So this plasma jet can be controlled by using a CNC machining system or this working table may be controlled by using a CNC machining system, CNC system so that any complicated contour can be cut from the workpiece material and also the fifth one is the fifth one of the plasma arc system, plasma arc cutting system is the plasma torch.

Mechanism of material removal:

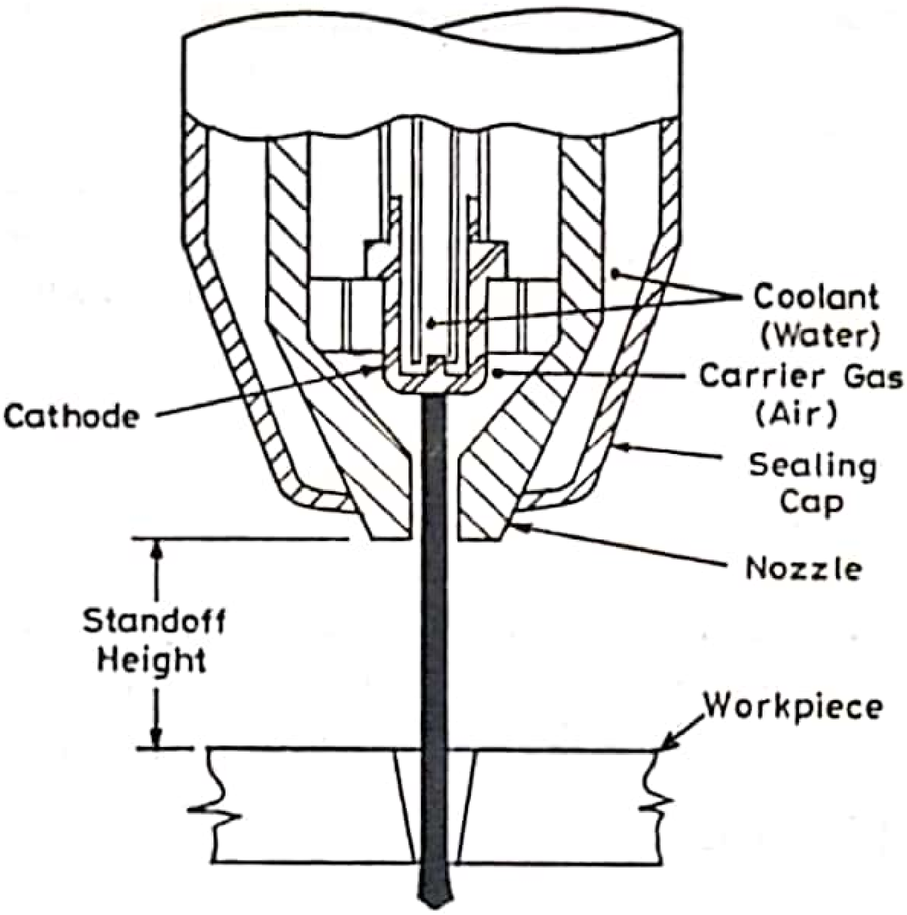

Fig. 9.2 Details of air plasma torch construction [*Benedict*, 1987; Courtesy: W.A. Whitney Corp. Rockford, Ill.]

The metal removal in PAM is basically due to the high temperature produced. The heating of the work piece is, as a result of anode heating, due to direct electron bombardment plus convection heating from the high temperature plasma that accompanies the arc. The heat produced is sufficient to raise the work piece temperature above its melting point and the high velocity gas stream effectively blows the molten metal away.

Process Parameters:

Parameters that govern the performance of PAM can be divided into three categories:

1. Those associated with the design and operation of the torch – electrical power delivered , the gases used to form the plasma, the

flow rate of the gases through the torch, the orifice diameter through the nozzle duct.

2. Those associated with the physical configuration of the set up – torch standoff, angle to the work, depth of cut, feed into the work and speed of the work toward the torch.
3. Environment in which the work is performed – cooling that is done on the bar, any protective type of atmosphere used to reduce oxidation for the exposed high temperature machined surface and any means that might be utilized to spread out or deflect the arc and plasma impingement area.

Gas Cutting	PAM
1.Oxidation of the work piece melted generates the heat to melt the material for (e.g) in cutting steel, fuel gas is used to heat it to 760^0-870^0C at while steel reacts rapidly with oxygen to form iron oxide. The heat generated by the burning iron is sufficient ot melt the iron oxide. 2.Oxy-fuel gas cutting is mostly limited to only ferrous metal especially plain carbon steels. 3.Cutting speed are lower for (e.g) in cutting mild steel 19mm thick can be cut at 500 mm /min. 4.Operating costs are higher 5.Limited to the max. temperature of the chemical reaction (burning) 6.Cost of equipment is lower. Surfaces are less smoother than those cut by PAM	1. Plasma is generated by subjecting a volume of gas to electron bombardment of an electric arc. The anode heating due to direct electron bombardment plus convective heating from the high temp plasma raises the material to the molten point and the high velocity gas stream effectively blows the material away. 2.Because of the high temp involved, the process can be used on almost all material including those white are resistant to oxy- fuel gas cutting 3. Cutting speeds are higher and leave a narrower kerf. They can cut mild steel 19mm thick at the rate of 1775mm /min. 4. Operating costs are lower. Ratio of savings in favor of PAM is about 3:1 5. Seems to be unlimited. The greater the power used, the greater the volume of kerf material that can be removed. 6. High initial cost of the equipment. 7.Surfaces cut by plasma torch are smoother but the edges are rounded.

Advantages

- The main advantage of PAM is speed. For example, mild steel of 6mm thick can be cut at 3m/min
- The plasma arc can be used to cut any metal or even to non conducting materials like concrete etc., since it is primarily a melting process
- Due to high speed of cutting the deformation of sheet metals is reduced while the width of the cut is minimum
- Owing to the high productivity of the plasma arc cutting coupled with the tendency to use cheap and easily available plasma-forming media (air, water, ammonia etc.,), PAC is finding ever increasing application.
- Smooth cuts free from contaminants are obtained in the process
- Profile cutting of metals especially of stainless steel and aluminium can be very easily done by PAM
- Operating costs are less when compared to oxy-fuel torch
- Can be automated

Limitations

- The main disadvantage of PAC is the high initial cost of the equipment. However, it can be made economical, if the quantity involved is large and the thickness is up to 50mm.
- Well-attached drops on the underside of the cut can be a problem and there will be heat affected zone (HAZ). The depth of HAZ depends on the material and its thickness
- Smoke and noise
- Sharp corners are difficult to produce because of the wide diameter of the plasma stream
- Burr is often produced
- Taper on the work-piece may occur

Applications

- Chiefly used to cut stainless steel and aluminium alloys. It is preferred to oxy-fuel cutting because it produces comparatively smoother cuts and is free from contamination

Laser–Beam Machining (LBM)

Laser-beam machining is a thermal material-removal process that utilizes a high-energy, coherent light beam to melt and vaporize particles on the surface of metallic and non-metallic workpieces. Lasers can be used to cut, drill, weld and mark. LBM is particularly suitable for making accurately placed holes. A schematic of laser beam machining is shown in Figure 17.

Different types of lasers are available for manufacturing operations which are as follows:

- CO_2 (pulsed or continuous wave): It is a gas laser that emits light in the infrared region. It can provide up to 25 kW in continuous-wave mode.
- Nd:YAG: Neodymium-doped Yttrium-Aluminum-Garnet ($Y_3Al_5O_{12}$) laser is a solid-state laser which can deliver light through a fibre-optic cable. It can provide up to 50 kW power in pulsed mode and 1 kW in continuous-wave mode.
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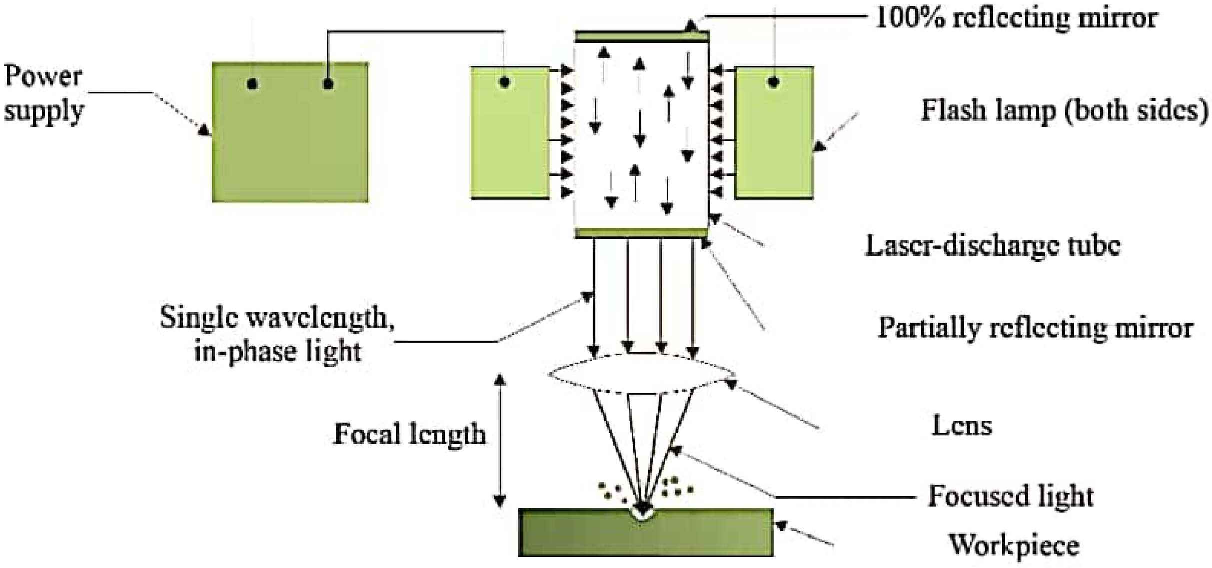


Figure 17: Laser beam machining schematic

Laser beam cutting (drilling)

- In drilling, energy transferred (e.g., via a Nd:YAG laser) into the workpiece melts the material at the point of contact, which subsequently changes into a plasma and leaves the region.
- A gas jet (typically, oxygen) can further facilitate this phase transformation and departure of material removed.
- Laser drilling should be targeted for hard materials and hole geometries that are difficult to achieve with other methods.

A typical SEM micrograph hole drilled by laser beam machining process employed in making a hole is shown in Figure 18.

Figure 18: SEM micrograph hole drilled in 250 micro meter thick Silicon Nitride with 3rd harmonic Nd: YAG laser

Laser beam cutting (milling)

- A laser spot reflected onto the surface of a workpiece travels along a prescribed trajectory and cuts into the material.

Advantage of laser cutting

- No limit to cutting path as the laser point can move any path.
- The process is stress less allowing very fragile materials to be laser cut without any support.
- Very hard and abrasive material can be cut.
- Sticky materials are also can be cut by this process.
- It is a cost effective and flexible process.
- High accuracy parts can be machined.
- No cutting lubricants required
- No tool wear
- Narrow heat effected zone

Limitations of laser cutting

- Uneconomic on high volumes compared to stamping
- Limitations on thickness due to taper
- High capital cost
- High maintenance cost
- Assist or cover gas required

Applications

- LBM can make very accurate holes as small as 0.005 mm in refractory metals ceramics, and composite material without warping the workpieces.
- This process is used widely for drilling and cutting of metallic and non-metallic materials.
- Laser beam machining is being used extensively in the electronic and automotive industries.

Electron Beam Machining (EBM)

In electron beam machining process there is a bombardment of high velocity stream of electrons on the work-piece surface so this electrons are bombarded on the work piece surface with a very high velocity, around 66% velocity of the sunlight so because of this bombardment of electrons on the work piece surface the materials into a small area on the work piece surface it melts and vaporizes and temperature rises to a very high temperature. So material on the work piece surface melts and vaporizes and machining is going on.

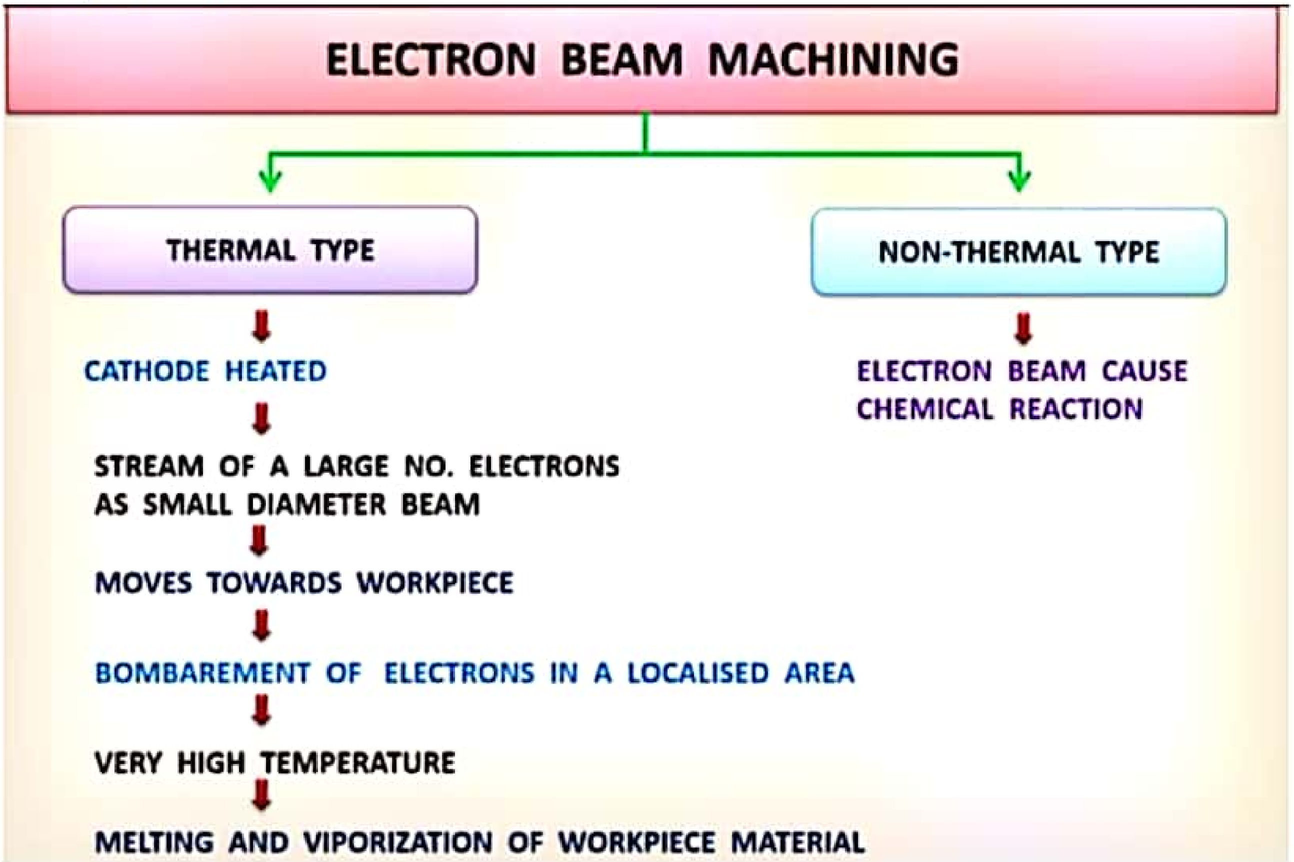
So this process actually it is used for machining thousands of holes on a thin sheet which is used in aerospace industry, food processing industry, cloth industries and very high aspect ratio for making of very high aspect ratio holes, thousands of holes on a work piece surface irrespective of the material property like metallurgical property, mechanical property of the material.

So this material maybe electrically conducting or electrically non-conducting or maybe ceramics, metals, or any kind of metal, any kind of ceramics it works. So here there is a filament which is heated with a very high temperature. So because of this heating of this filament so electrons emanates from that cathode, cathode filament or these filament may be heated from a radiation from a another body, from the radiation from a another body on a solid block of cathode, on a solid block of filament also it can be generated. So these electrons emits from the cathode, cathode filament and it passes through a magnetic lens to coincide to concentrate or to reduce the diameter of the electron beam and it bombards on the work piece surface.

Types of EBM

Electron beam machining process there are 2 types of methods are there. One is the **thermal type**. Another one is the **non-thermal type**. So in normal in non-thermal type this electron beams are used for generating chemical reactions. So for generating chemical reactions the electron beams are used. So this non-thermal type we are not going to discuss. We are going to discuss only thermal type of electron beam machining process.

In thermal type this cathode is heated to a very high temperature. So this stream of large number of electrons comes as a small diameter beam, electron beam.

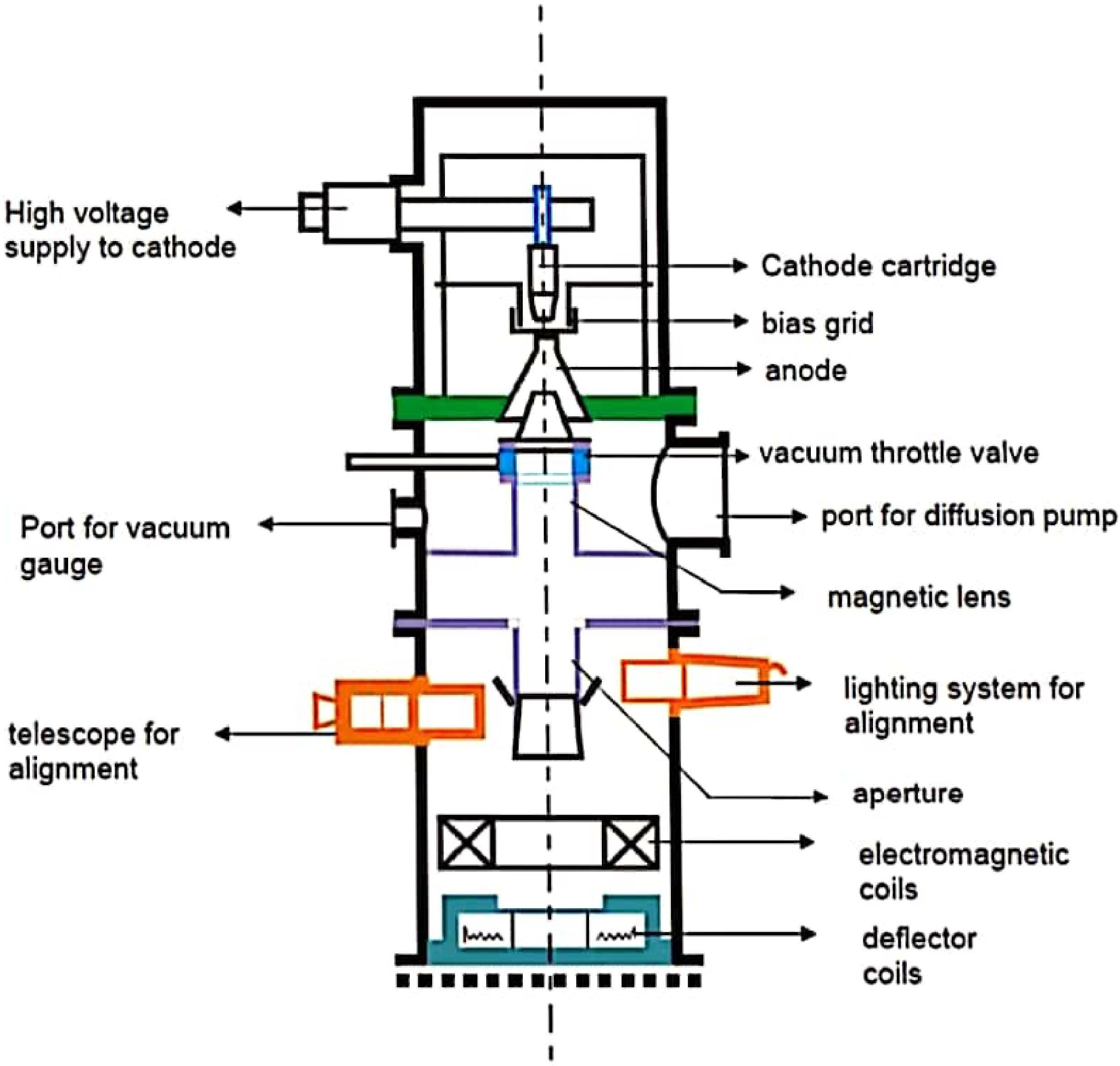


So this stream of large number of electrons emits from the cathode, from a heated cathode. It comes out as a small diameter beam. So it moves towards the workpiece with a very high velocity and it bombards, machining is going on due to the bombardment of these electrons on a very small localized area. So as it is bombarded on a very small localized area, huge amount of temperature is generated on the workpiece surface. So machining is going on due to the melting and vaporization of this material from the workpiece surface from a much localized area.

Equipment and working of EBM

Fig. below shows the schematic representation of an electron beam gun, which is the heart of any electron beam machining facility. The basic functions of any electron beam gun are to generate free electrons at the cathode, accelerate them to a sufficiently high velocity and to focus them over a small spot size. Further, the beam needs to be manoeuvred if required by the gun.

The cathode as can be seen in Fig. is generally made of tungsten or tantalum. Such cathode filaments are heated, often inductively, to a temperature of around 2500^0C. Such heating leads to thermo-ionic emission of electrons, which is further enhanced by maintaining very low vacuum within the chamber of the electron beam gun. Moreover, this cathode cartridge is highly negatively biased so that the thermo-ionic electrons are strongly repelled away form the cathode. This cathode is often in the form of a cartridge so that it can be changed very quickly to reduce down time in case of failure.



Electron beam gun

Advantages

- EBM provides very high drilling rates when small holes with large aspect ratio are to be drilled.
- Moreover it can machine almost any material irrespective of their mechanical properties. As it applies no mechanical cutting force, work holding and fixturing cost is very less.

- Further for the same reason fragile and brittle materials can also be processed.
- The heat affected zone in EBM is rather less due to shorter pulses.
- EBM can provide holes of any shape by combining beam deflection using electromagnetic coils and the CNC table with high accuracy.

Limitations

- The primary limitations are the high capital cost of the equipment and necessary regular maintenance applicable for any equipment using vacuum system.
- Moreover in EBM there is significant amount of non-productive pump down period for attaining desired vacuum.
- However this can be reduced to some extent using vacuum load locks.
- Though heat affected zone is rather less in EBM but recast layer formation cannot be avoided.

APPLICATIONS

- More popular → aerospace, insulation, food processing & chemical, clothing, etc.
- Hundreds to thousands of holes (simple & complex shaped) in a workpiece (perforation of sheets) ← complex shaped, difficult to machine material

Example :

- Drilling thousands of holes (dia < 1 mm) in very thin plates used for **turbine engine combustor dome**
- Many thousand holes (dia < 1 mm) in cobalt alloy fibre spinning head of thickness 5 mm Drilling by EBM claimed 100 times faster than EDM
- Holes in filters & screens ← food processing industry
- Fine gas orifice in space nuclear reactor
- Holes in wire drawing dies
- Cooling holes in turbine blades
- Metering holes in injector nozzles of diesel engine

Abrasive Jet Machining

ABRASIVE JET MACHINING (AJM): Introduction, Equipment, Variables in AJM: Carrier Gas, Type of abrasive work material, stand off distance (SOD), nozzle design, shape of cut. Process characteristics-Material removal rate, Nozzle wear, Accuracy & surface finish. Applications, advantages & Disadvantages of AJM.

Abrasive jet machcuining is an extended version of water jet cutting; in which the water jet contains abrasive particles such as silicon carbide or aluminium oxide in order to increase the material removal rate above that of water jet machining. Almost any type of material ranging from hard brittle materials such as ceramics, metals and glass to extremely soft materials such as foam and rubbers can be cut by abrasive water jet cutting. The narrow cutting stream and computer controlled movement enables this process to produce parts accurately and efficiently. This machining process is especially ideal for cutting materials that cannot be cut by laser or thermal cut. Metallic, non-metallic and advanced composite materials of various thicknesses can be cut by this process. This process is particularly suitable for heat sensitive materials that cannot be machined by processes that produce heat while machining.

The schematic of abrasive water jet cutting is shown in Figure 15 which is similar to water jet cutting apart from some more features underneath the jewel; namely abrasive, guard and mixing tube. In this process, high

velocity water exiting the jewel creates a vacuum which sucks abrasive from the abrasive line, which mixes with the water in the mixing tube to form a high velocity beam of abrasives.

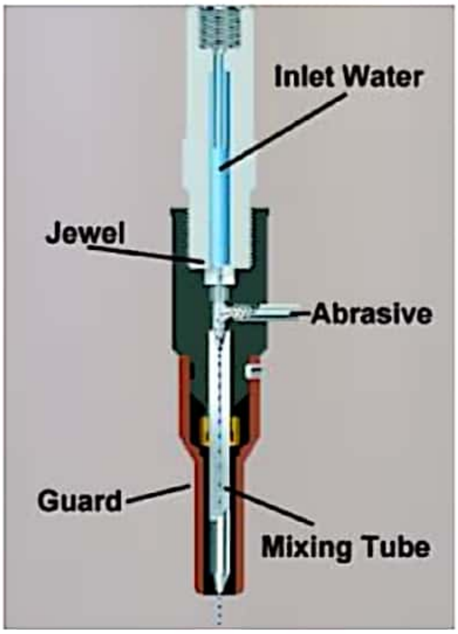


Figure 4: Abrasive water jet machining
(http://www.waterjets.org/about_abrasivejets.html)

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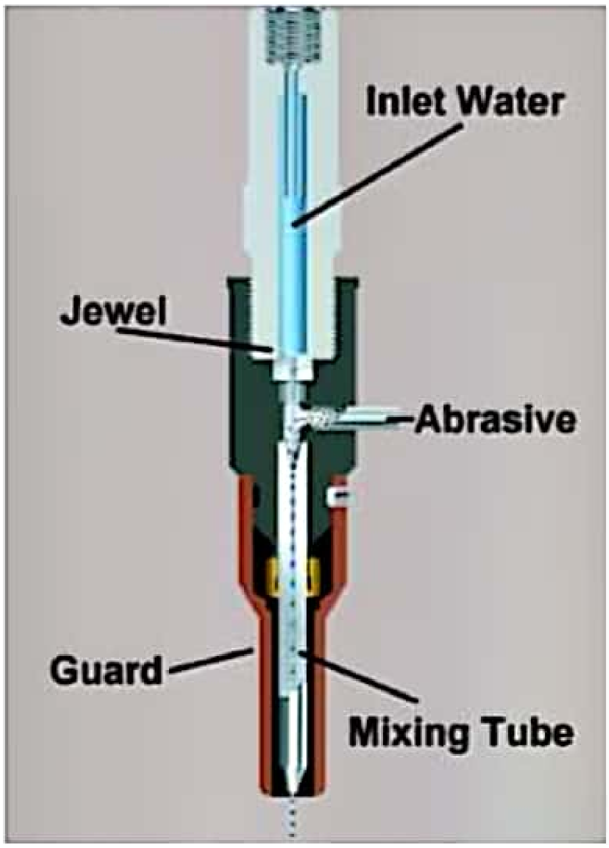


Figure 4: Abrasive water jet machining
(http://www.waterjets.org/about_abrasivejets.html)

Applications

Abrasive water jet cutting is highly used in aerospace, automotive and electronics industries. In aerospace industries, parts such as titanium bodies for military aircrafts, engine components (aluminium, titanium, heat resistant alloys), aluminium body parts and interior cabin parts are made using abrasive water jet cutting.

In automotive industries, parts like interior trim (head liners, trunk liners, door panels) and fibre glass body components and bumpers are made by this process. Similarly, in electronics industries, circuit boards and cable stripping are made by abrasive water jet cutting.

Advantages of abrasive water jet cutting

- In most of the cases, no secondary finishing required
- No cutter induced distortion
- Low cutting forces on workpieces
- Limited tooling requirements
- Little to no cutting burr
- Typical finish 125-250 microns
- Smaller kerf size reduces material wastages
- No heat affected zone
- Localises structural changes
- No cutter induced metal contamination
- Eliminates thermal distortion
- No slag or cutting dross
- Precise, multi plane cutting of contours, shapes, and bevels of any angle.

Limitations of abrasive water jet cutting

- Cannot drill flat bottom
- Cannot cut materials that degrades quickly with moisture
- Surface finish degrades at higher cut speeds which are frequently used for rough cutting.
- The major disadvantages of abrasive water jet cutting are high capital cost and high noise levels during operation.

2.0 Automation

Automation is the creation of technology and its application in order to control and monitor the production and delivery of various goods and services. It performs tasks that were previously performed by humans. Automation is being used in a number of areas such as manufacturing, transport, utilities, defense, facilities, operations and lately, information technology.

Automation can be performed in many ways in various industries. For example, in the information technology domain, a software script can test a software product and produce a report. There are also various software tools available in the market which can generate code for an application. The users only need to configure the tool and define the process. In other industries, automation is greatly improving productivity, saving time and cutting costs.

Automation is evolving quickly and business intelligence in applications is a new form of high-quality automation. In the technology domain, the impact of automation is increasing rapidly, both in the software/hardware and machine layer. However, despite advances in automation, some manual intervention is always advised, even if the tool can perform most of the tasks.

Different types of automation tools exist:

- ANN – Artificial Neural Network.
- DCS – Distributed Control System.
- HMI – Human Machine Interface.
- SCADA – Supervisory Control and Data Acquisition.
- PLC – Programmable Logic Controller.
- Instrumentation.
- Motion control.
- Robotics.

Need for Automation

1. **Reduce Worker Fatigue and Effort or Labor Intensive Operation –** Typically, humans dislike banal, repetitive tasks. However, computer systems perform them without complaint. Tasks that lack variability provide a place for automated systems to shine, but this also holds true for systems utilizing advanced sensors and integration. If the task requires conditions not suited to human comfort or focus, consider automation.
2. **Prevent Products or Materials from Being Damaged or Destroyed –** Humans make mistakes when they fatigue. This embodies the sentiment of the "human condition." Mistakes using tools mean damaging raw materials, components, assemblies, and end products.
3. **Prevent Non-conforming Product from Shipping** – Computers controlling robots do not forget steps. Neglecting to put in a screw requires a human touch. A machine not doing it yields an error to be addressed. Does the process require doing something in a specific order to improve yield? Automated systems will not violate the instruction set. Moreover, automated systems may employ inspection capabilities. Tune the system and allow the data to roll in without preference or bias.
4. **Increase Efficiency –** Improving processes for efficiency makes a company more competitive, but do people always do the same thing, in the same way, every time they do it? No, human variation exists. Automated systems allow for improvements that benefit from consistent execution. Perfect planning and training do not defend against the human touch.
5. **Collect Better Data** – Remove the accidental data entry or missed data point from logging. Make the method of collecting sensor and process data regulated.
6. **Improve Metrics** – Sending reliable data directly to a database provides an ongoing resource. Does the process improve with changes? Why do I see more failures now than in the past? Leveraging data can provide these answers beyond a simple list of pass/fail statistics from the past. Correlation of associated process data with pass/fail records provides insight rather than guessing "what is causing this?".
7. **Devise the Right Process Improvements –** Automated systems now collect reliable data. The database provides a searchable forum. What

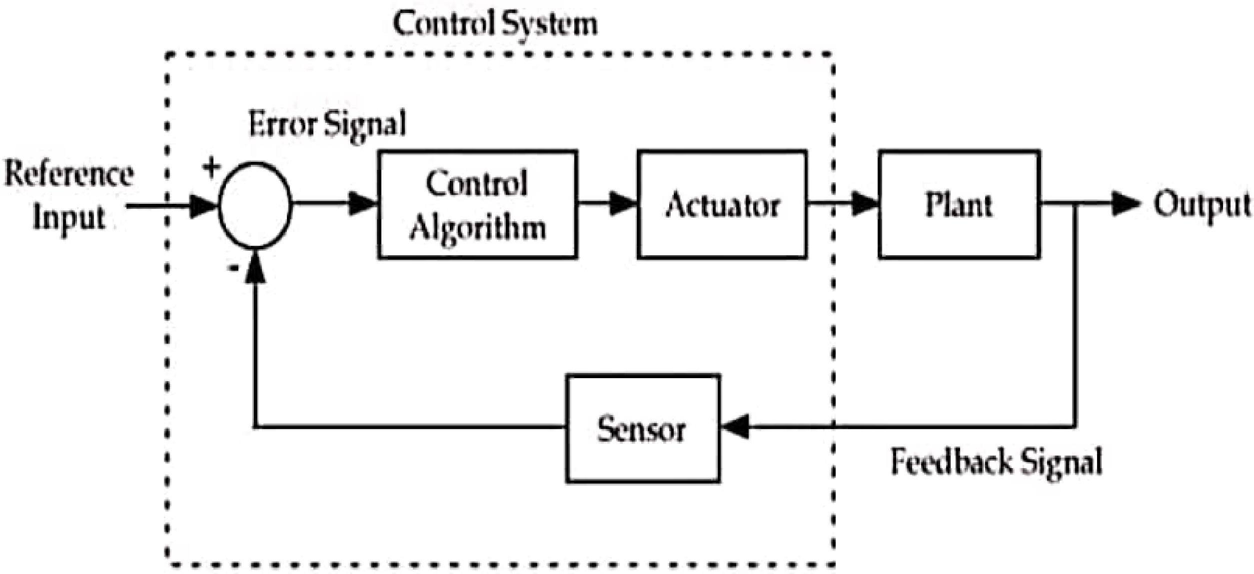
comes next? Equipped with copious amounts of reliable data, engineers make the most of this information. Where problems existed, light shines on the problem. Rather than just changing to seek "continuous improvement," make changes with better information.

8. **Save Money** – Why instrument that test stand? Why log that data? Why spend the money now? Simply, inventing in **industrial automation** yields cost savings through making processes more regular and collecting data for making confident decisions.

3.0 Numerical control

Numerical control, popularly known as the NC is very commonly used in the machine tools. Numerical control is defined as the form of programmable automation, in which the process is controlled by the number, letters, and symbols. In case of the machine tools this programmable automation is used for the operation of the machines.In other words, the numerical control machine is defined as the machined that is controlled by the set of instructions called as the program. In numerical control method the numbers form the basic program instructions for different types of jobs; hence the name numerical control is given to this type of programming. When the type of job changes, the program instructions of the job also change. It is easier to write the new instructions for each job, hence NC provides lots of flexibility in its use.

The NC technology can be applied to wide variety of operations like drafting, assembly, inspection, sheet metal working, etc. But it is more prominently used for various metal machining processes like turning, drilling, milling, shaping etc. Due to NC all the machining operations can be performed at the fast rate resulting in bulk manufacturing becoming quite cheaper.


Control System
Error Signal
Reference
Input
+
-
Control
Algorithm
Actuator
Plant
Output
Sensor
Feedback Signal

Positioning Control System

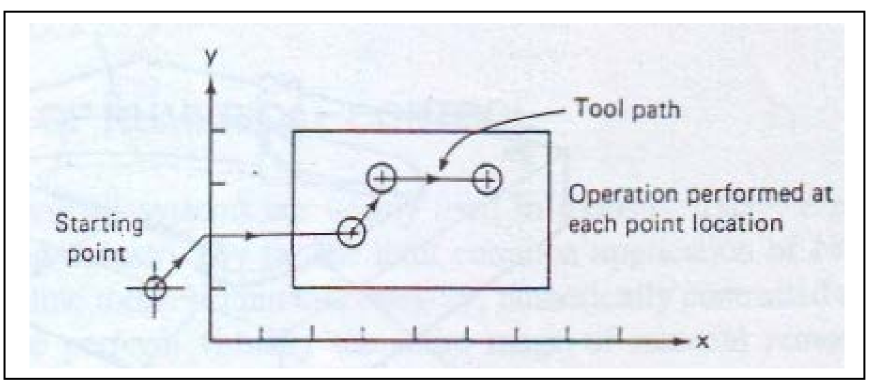
In order to accomplish the machining process, the cutting tool and workpiece must be moved relative to each other. In NC, there are three basic types of motion control system (Point-to-point, Straight cut and Contouring).

Point-to-point systems represent the lowest level of motion control between the tool and workpiece. Contouring represents the highest level of control.

1-Point-to-point Positioning Control: -

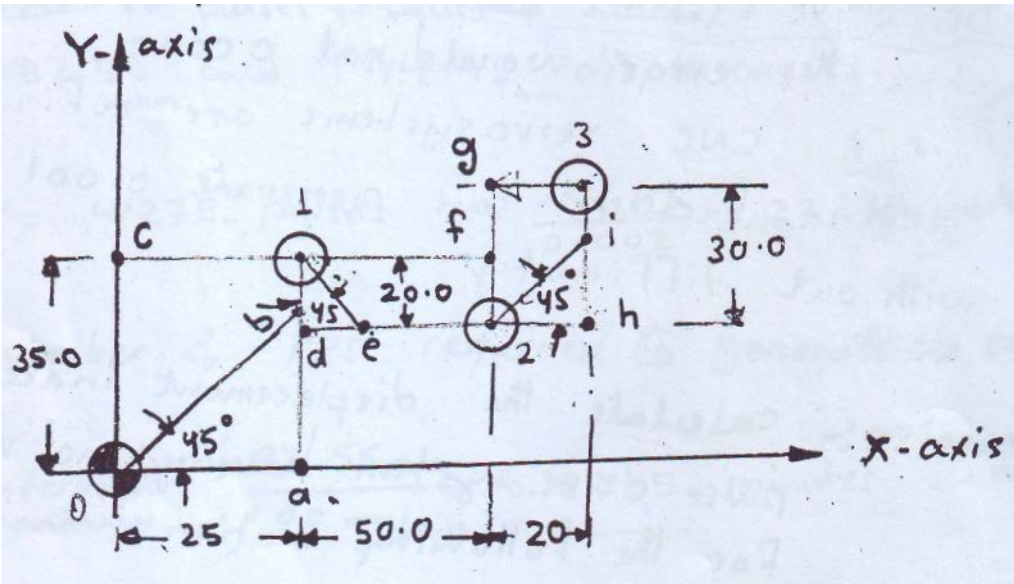
Point-to-point (PTP) is also sometimes called a positioning system. In PTP, the objective of the machine tool control system is to move the cutting tool to a predefined location. The principle function of the PTP is to position the tool form one point to another within coordinate system. The positioning may be linear in the x-y plane or linear and rotary if the machine has a rotary table. Each tool axis is controlled independently, therefore; the programmed motion always in rapid travers. Once the tool reaches the desired location, the machining operation is performed at that position (machining can only take place after positioning is completed).

NC drill presses are a good example of PTP systems. The spindle must first be positioned at a particular location on the workpiece. This is done under PTP control. Then the drilling of the hole is performed at the location, and so forth. Since no cutting is performed between holes, there is no need for controlling the relative motion of the tool and workpiece between hole locations. Figure (1) illustrates the point-to-point type of control.



Fig(1): Point-to-point (positioning) NC system

Positioning systems are the simplest machine tool control systems and are therefore the least expensive of the three types. However, for certain processes, such as drilling operations, tapping, riveting and spot welding, PTP is perfectly suited to the task and any higher level of control would be unnecessary. Example bellow illustrate path of three drilled holes.



Path of three drilled holes				
Programmed	Tool path		Motion	
	Sequential	Simultaneous	from	to
x25.0 y35.0	0-a-1	0-b-1	0	1
x50.0 y-20.0	1-d-2	1-e-2	1	2
x20.0 y30.0	2-h-3	2-i-3	2	3

Sequential: - the system will move in one axis at a time.

Simultaneous: - both axes start at the same time, the tool path will be approximately.

<u>2-Straight-cut Positioning Control:</u> -

Straight-cut control systems are capable of moving the cutting tool parallel to one of the major axes at a controlled rate suitable for machining. It is therefore appropriate for performing milling operations to fabricate workpieces of rectangular configurations. Most of the straight-cut systems an fitted with manually adjustable feed control, this feed control is shared by all the programmable axes of the NC machine, because of this shared feed control feature; the system can also perform milling operation at 45° to the primary axes of the machine. An example of a straight cut operation is shown in Figure (2). An NC machine capable of straight cut movements is also capable of PTP movements.

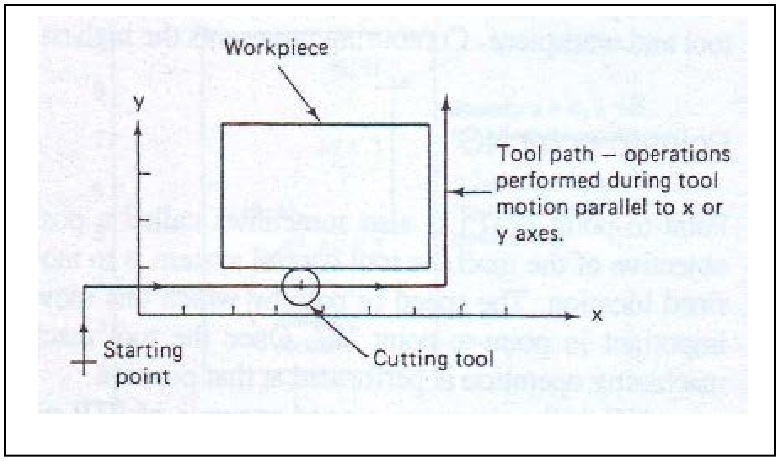
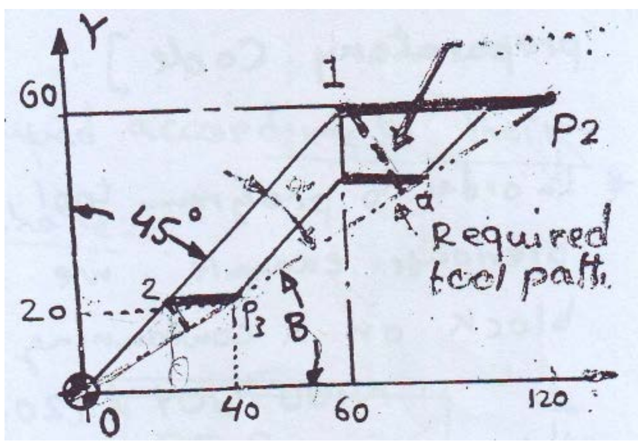


Fig (2): Straight-cut system

Example: - the coordinate of P_2 are x120mm and y60.0mm programming these dimension would result in a tool path from 0 to 1 to P2 with the following error:



Error: distance 1a = 01sinα

$\sqrt{x_1^2 + y_1^2} * sin\alpha = \sqrt{2y_1^2} * sin\alpha$

$\alpha = 45° - \beta; \quad \beta = 26.565° \quad \rightarrow xycoordinates; \ \alpha = 18.435°$

$Error = \sqrt{2y^2} * sin18.435 = \sqrt{2 * 60^2} * \sin 18.435 = 26.8328\, mm$ ----------------too large

Reducing the programmed increments to x40.0mm y20.0mm, will result the tool path of 0 to 2 to p3.

$Error = \sqrt{2y^2} * sin18.435 = \sqrt{2 * 20^2} * \sin 18.435 = 8.944\ mm$

This value 8.944 is proportionally less, but still for too large. Reducing the programmed increments to x0.5 y0.25.

$Error = \sqrt{2y^2} * sin18.435 = \sqrt{2 * 0.25^2} * \sin 18.435 = 0.039\ mm$. This value is efficient.

In order to program tool path from point 0 to p1 in the previous example, we would require a single tape block on a contouring system:

N100 G01 x120.0 y60.00 F…..

Using the straight cut system, the program shown bellow will require 240 tape blocks and will only yield a tolerance of 0.039mm.

N1…….. x0.50 y0.25 from point (0, 0) to point (x0.5, y0.25)

N2…….. x0.50 y0.25 to point (x1, y0.5)

N1…….. x0.50 y0.25 to point (x1.5, y0.75)

-

-

-

N1…….. x0.50 y0.25 to (x120, y60)

Example: - calculate the increments to be programmed to produce the tool path with less than 0.03mm error from P_1 (11.32, 9.82) to P_2 (113.82, 64.32)?

3-Contouring (continuous) Path CNC System: -

Contouring is the most complex, the most flexible, and the most expensive type of machine tool control. It is capable of performing both PTP and straight-cut operations. In addition, the distinguishing feature of contouring NC systems is their capacity for simultaneous control of more than one axis movement of the machine tool. The path of the cutter is continuously controlled to generate the desired geometry of the workpiece. Contouring system generates a continuously controlled tool path by the capability of computing the points of the path (interpolating). For this reason, contouring systems are also called continuous-path NC systems. All NC contouring system have the ability to perform linear and circular or parabolic interpolation features which recorded in the NC computer under a (G preparatory code). Figure (3) illustrates the versatility of continuous path NC. Milling and turning operations are common examples of the use of contouring control.

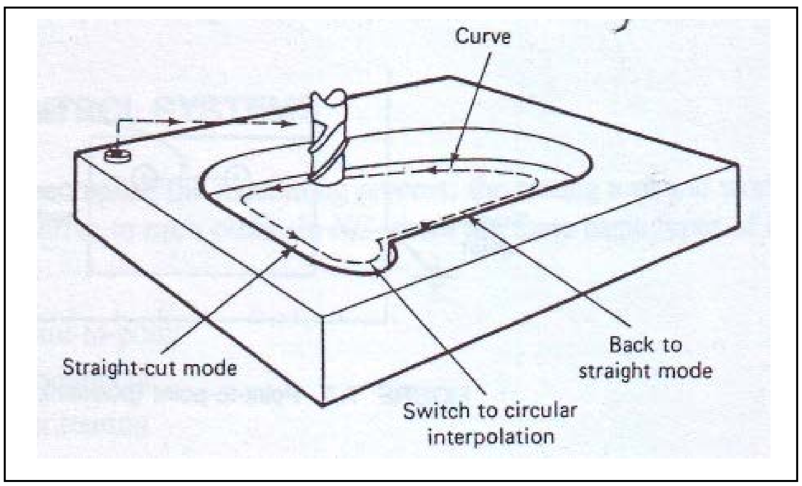


Fig (3): contouring (continuous path) NC system for two dimensional operations

Accuracy and repeatability

Two of the important features of a numerical control system are its accuracy and repeatability. The accuracy of an NC system is related to its control resolution. The term control resolution refers to the MCU's capability to divide the range of a given axis movement into closely spaced points that can be identified by the controller.

If n represents the number of bits for an axis, the number of control points is given by

$$\text{number of control points} = 2n$$

The control resolution is therefore defined as the distance between adjacent control points, and can be determined by

$$CR = \text{range of axis movement}/2^n$$

Accuracy is a measure of the control system's capacity to position the machine table at a desired location, which is defined by a set of axis coordinate values.

$$\text{Accuracy} = (CR/2) + 3\ (\text{std. dev. of mech. error})$$

The definition of accuracy is pictured in Fig (12).

Repeatability is defined in terms of the ability of the control system to return to a given location that was previously programmed into the controller. Repeatability affects the capacity of the NC machine tool to produce parts that do not vary in machined dimensions from one part to the next. repeatability can define:

$$\text{Repeatability} = \pm 3\ (\text{std. dev. of mech. error})$$

$$= 6\ (\text{std. dev. of mech. error})$$

Our definition of repeatability is illustrated in Fig (12).

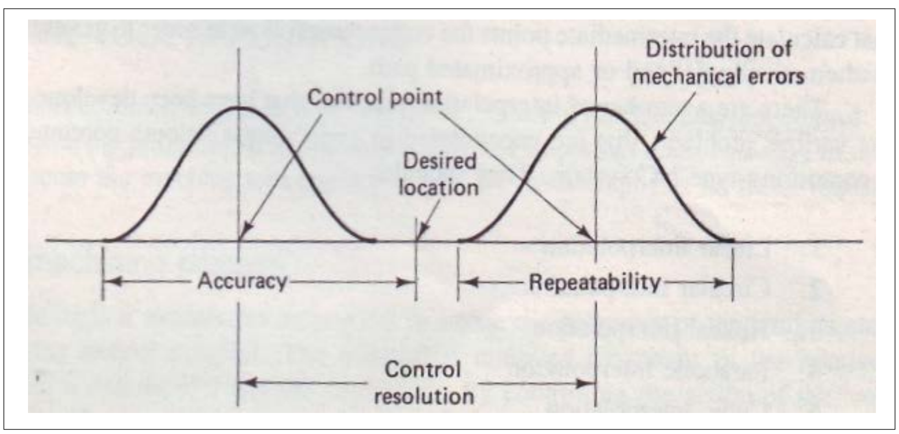


Fig (12) Accuracy and repeatability for linear axis

Example:

A two-axis NC control system used as an x-y positioning table has a bit storage capacity of 12 bits for each axis. Both x and y axes have a range of 15 in. The mechanical accuracy of the machine table can be characterized by a normal distribution with standard deviation = 0.0003 in. for both axes. Determine (a) the control resolution, (b) the accuracy, and (c) the repeatability of the NC system.

Solution:

(a) The control resolution is determined by

CR = 15.0 in/212 = 15/4096 = 0.00366 in.

(b) The accuracy is defined as

Accuracy = 0.00366/2+ 3(0.0003) = 0.00273 in.

(c) The repeatability, by our definition, is

Repeatability = 6(0.0003) = 0.0018 in.

Economic of NC

There are a number of reasons why NC systems are being adopted so widely by the metalworking industry. It has been estimated that 75% of manufacturing is carried out in lost sizes of 50 or less. As indicated above, these small lot sizes are the typical applications for NC. Following are the advantages of numerical control when it is utilized in these small production quantities:

1-Reduced nonproduction time: - It accomplishes this decrease in nonproductive time by means of fewer setups, less setup time, reduced workpiece handling time, automatic tool changes on some machines, and so on.

2- Reduced fixturing: - NC requires simpler fixtures because the positioning is done by the NC program rather than the fixture or jig.

3- Reduced lead time: - Jobs can be set up more quickly with NC.

4- Greater manufacturing flexibility: - NC adapts better to changes in jobs, production schedules, and so on.

5- Easier to accommodate engineering design changes on the workpiece: -

6- Improved accuracy and reduced human error; - NC is ideal for complicated parts where the chances of human mistakes are high.

Where is NC most appropriate?

It is clear from the advantages listed above that NC is appropriate only for certain parts, not all parts. The general characteristics of jobs for which NC is most appropriate are the following:

1-Parts are processed frequently and in small to medium lot sizes.

2- Part geometry is complex.

3- Close tolerances must be held on the workpart.

4- Many operations must be performed on the part in its processing.

5- Much metal needs to be removed (for machining applications).

6- Engineering design changes are likely.

7- It is an expensive part where mistakes in processing would be costly.

8- Parts require 100% inspection.

Computer Controls in NC (3 types)

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

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

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

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

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

Problems with Conventional NC

1. Part programming mistakes

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

② Non-optimal speeds and feeds

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

③ Punched tape :-

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

④ Tape reader :-

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

⑤ Controller :-

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

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

⑥ NC Controller technology

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

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

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

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

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

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

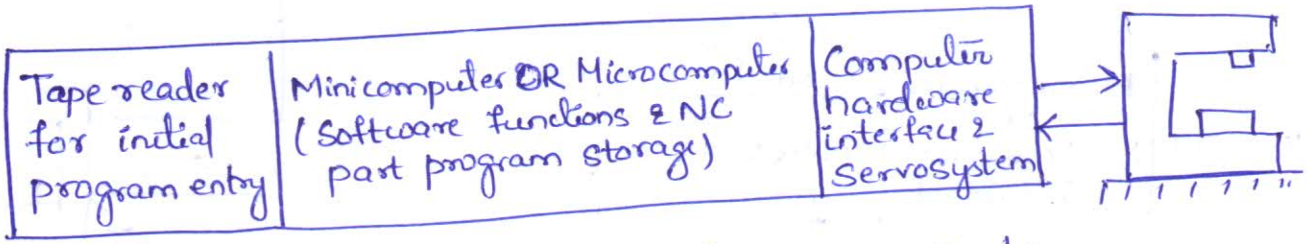
- The next development in NC control marked the introduction of digital computers in NC controller technology. All of the previous controls were made up of hard-wired components. The functions that were performed by these control systems could not be easily changed due to the fixed nature of the hard-wired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

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

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

Computer Numerical Control

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



General Configuration of CNC System

Functions of CNC

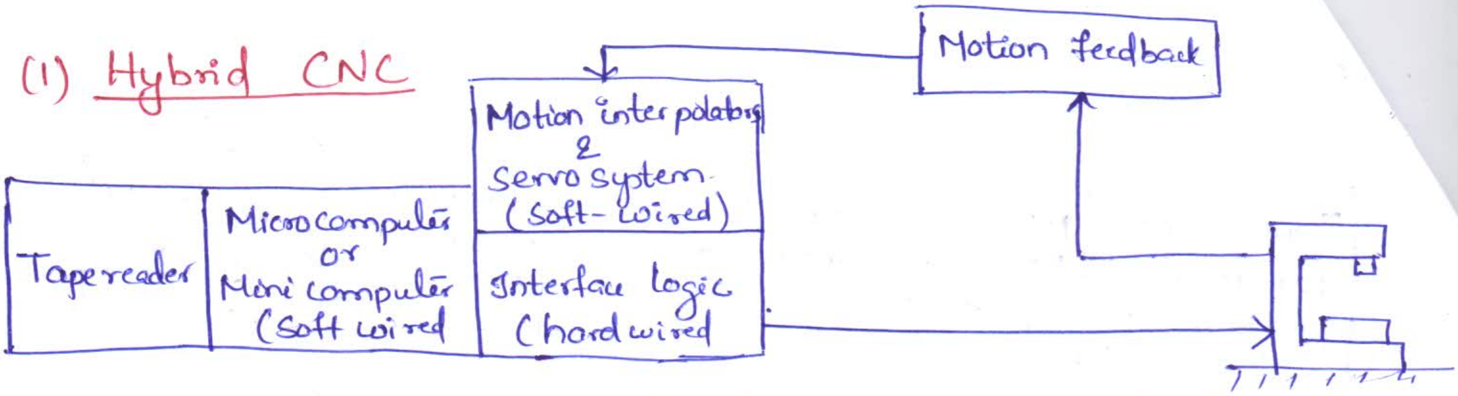
(1) M/c tool control
(2) In-process compensation
(3) Improved programming & operating features
(4) Diagnostics

M/c tool control :-

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

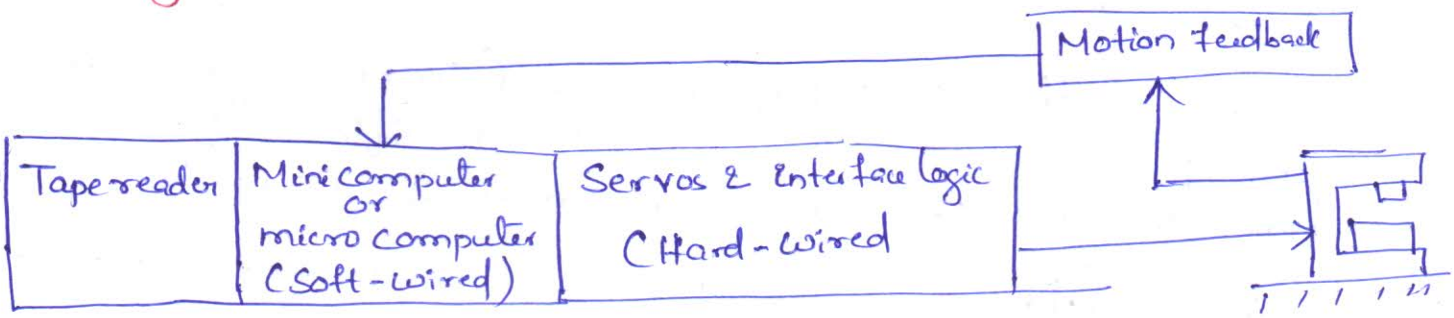
  (1) Hybrid CNC
  (2) Straight CNC

(1) Hybrid CNC



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

Straight CNC :-



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

- The advantage gained in straight CNC is additional flexibility.

IN-PROCESS COMPENSATION

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

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

IMPROVED PROGRAMMING AND OPERATING FEATURES

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

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

DIAGNOSTICS

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

Advantages of CNC

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

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

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

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

(5)

Direct Numerical Control

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

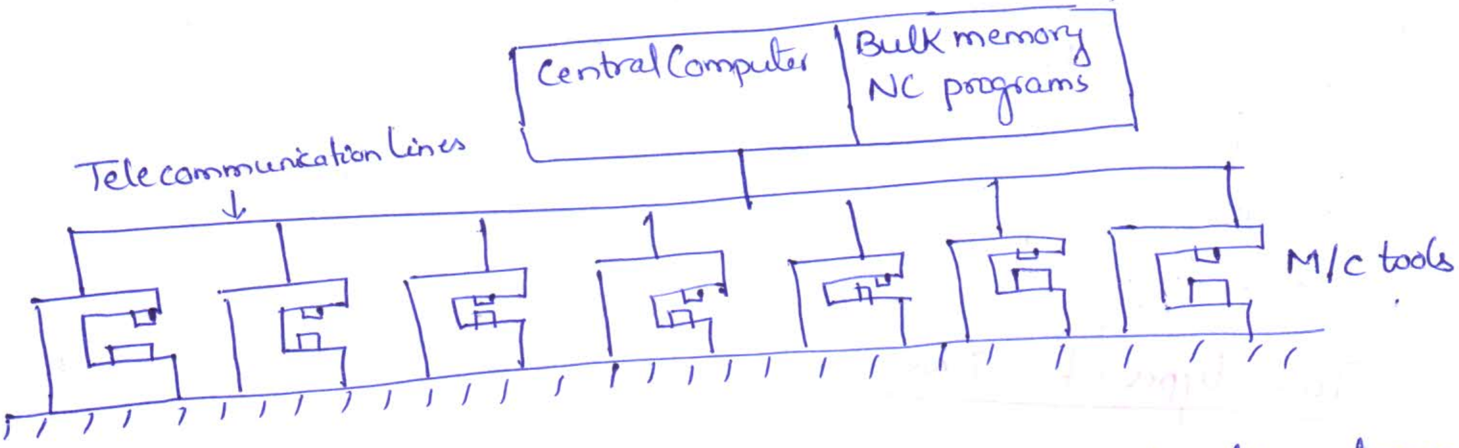
Components of a DNC System

(1) Central Computer

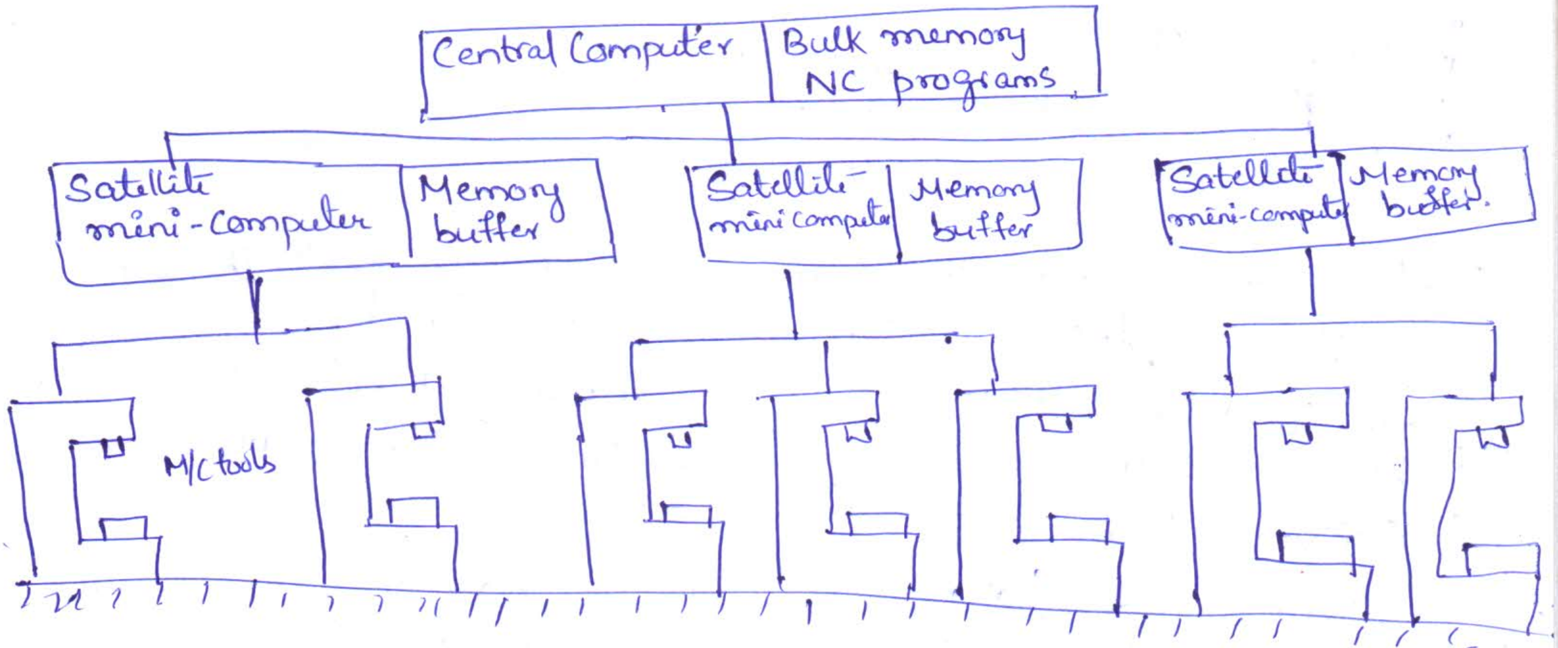
(2) Bulk memory, which stores the NC part programs

(3) Telecommunication lines

(4) Machine tools



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



DNC with satellite mini-computers.

- Sometimes, it is necessary to use satellite computers. These satellites are minicomputers and they take some of the burden off the central computer.

- Each satellite controls several machines. Groups of part program instructions are received from the central computer and stored in buffers. They are then dispensed to the individual machines as required.

- Feedback data from the machines are also stored in the satellite's buffer before being collected at the central computer.

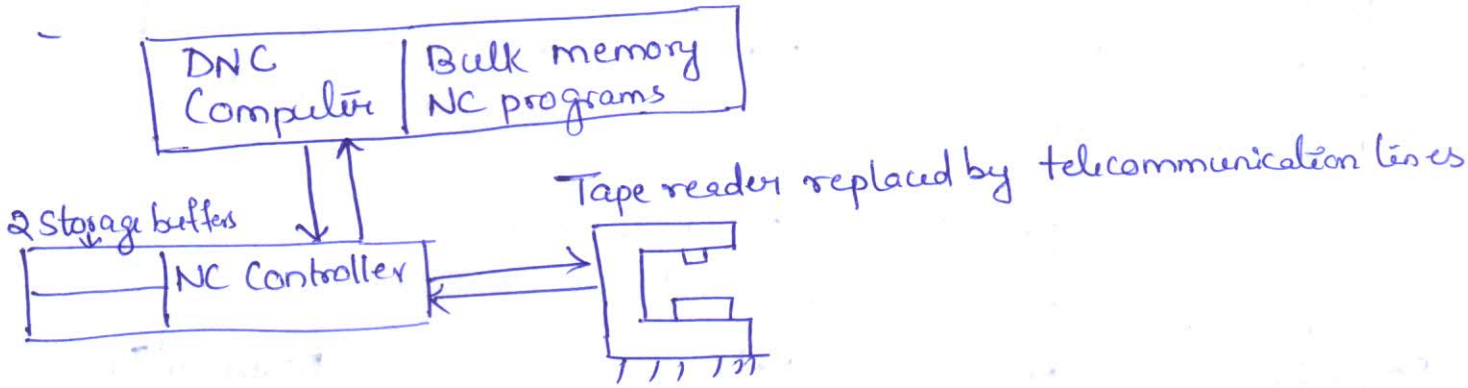
Two types of DNC

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

(2) SPECIALIZED MACHINE CONTROL UNIT

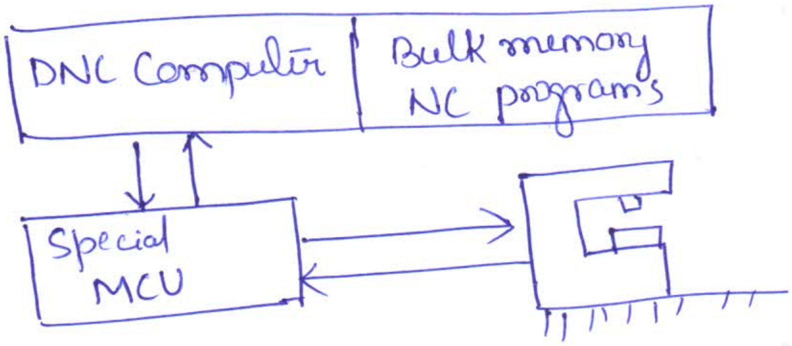
(1) BTR System:-

-



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

2) Special m/c. Control unit



DNC with special MCU

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

Functions of DNC

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

NC without punched tape :-

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

(So it is eliminated)

(2) NC part program storage :-

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

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

- Active storage (Disc) used to store NC programs which are frequently used. The active storage can be readily accessed by the DNC computer to drive an NC m/c in production.
- Secondary storage could be used for NC programs which are not frequently used.
  Ex:- Magnetic tape, floppy disks, punched tape.

3) Data collection, processing & reporting

- DNC involves the transfer of data from the m/c tools back to the central computer. DNC involves a two-way transfer of data.
- The basic purpose is to monitor production.

4) Communications :-

- A communications network is required to accomplish the previous 3 functions of DNC.
- Communication among the various subsystem is a funⁿ that is central to the operation of any DNC system.
- The essential communication links in DNC are betⁿ the following components of the system.
  Central computer & m/c tools
  Central computer & NC part programmer terminals
  Central computer & bulk memory, which stores the NC programs.

Advantages of DNC

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

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

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

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

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

Combined DNC/CNC Systems

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

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

- The second advantage of combining CNC & DNC is redundancy. If the central DNC computer fails, this will not necessarily cause the individual machines in the system to be down. It is possible to provide the necessary backup to permit the CNC machines to operate on a stand-alone basis.
  * This backup capability consists of two elements. The first is a file of punched tapes which duplicate the programs contained in the DNC computer files.
  * The second is that each CNC m/c must be equipped with a tape reader for the purpose of entering the program from the punched tape.

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

Adaptive Control Machining Systems

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

Where to use adaptive control

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

Situations where AC is beneficially applied

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

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

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

Sources of variability in machining

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

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

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

(2) Variable workpiece hardness and variable machinability :-

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

(3) Variable workpiece rigidity :-

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

(4) Tool wear :-

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

(5) Air gaps during cutting :-

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

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

Two types of adaptive control

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

Adaptive control optimization (ACO)

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

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

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

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

which the true process can be measured on-line.

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

Adaptive Control Constraint :- (ACC)

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

Operation of an ACC System

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

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

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

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

The typical hardware components are :-

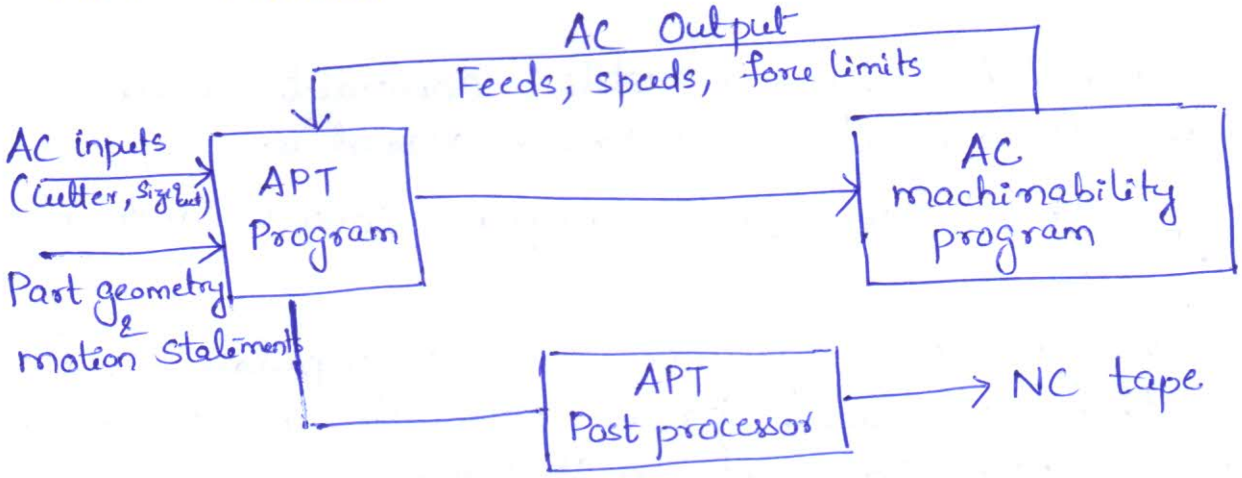
(1) Sensors mounted on the spindle to measure cutter deflection (force).

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

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

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

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



Relationship of AC Software to APT program

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

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

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

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

- In machining, the AC system operates at the force value calculated for the particular cutter & m/c tool spindle.
- Maximum production rates are obtained by running the m/c at the highest feed rate consistent with this force level.
- Since force is dependent on factors such as depth of cut, width of cut, the end result of the control action is to maximize metal removal rates within the limitations imposed by existing cutting conditions.

Benefits of Adaptive Control machining

(1) Increased production rates:-

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

CNC G codes

G00 - Positioning at rapid speed; Mill and Lathe
G01 - Linear interpolation (machining a straight line); Mill and Lathe
G02 - Circular interpolation clockwise (machining arcs); Mill and Lathe
G03 - Circular interpolation, counter clockwise; Mill and Lathe
G04 - Mill and Lathe, Dwell
G09 - Mill and Lathe, Exact stop
G10 - Setting offsets in the program; Mill and Lathe
G12 - Circular pocket milling, clockwise; Mill
G13 - Circular pocket milling, counterclockwise; Mill
G17 - X-Y plane for arc machining; Mill and Lathe with live tooling
G18 - Z-X plane for arc machining; Mill and Lathe with live tooling
G19 - Z-Y plane for arc machining; Mill and Lathe with live tooling
G20 - Inch units; Mill and Lathe
G21 - Metric units; Mill and Lathe
G27 - Reference return check; Mill and Lathe
G28 - Automatic return through reference point; Mill and Lathe
G29 - Move to location through reference point; Mill and Lathe (slightly different for each machine)
G31 - Skip function; Mill and Lathe
G32 - Thread cutting; Lathe
G33 - Thread cutting; Mill
G40 - Cancel diameter offset; Mill. Cancel tool nose offset; Lathe
G41 - Cutter compensation left; Mill. Tool nose radius compensation left; Lathe
G42 - Cutter compensation right; Mill. Tool nose radius compensation right; Lathe
G43 - Tool length compensation; Mill
G44 - Tool length compensation cancel; Mill (sometimes G49)
G50 - Set coordinate system and maximum RPM; Lathe
G52 - Local coordinate system setting; Mill and Lathe
G53 - Machine coordinate system setting; Mill and Lathe

G54~G59 - Workpiece coordinate system settings #1 t0 #6; Mill and Lathe
G61 - Exact stop check; Mill and Lathe
G65 - Custom macro call; Mill and Lathe
G70 - Finish cycle; Lathe
G71 - Rough turning cycle; Lathe
G72 - Rough facing cycle; Lathe
G73 - Irregular rough turning cycle; Lathe
G73 - Chip break drilling cycle; Mill
G74 - Left hand tapping; Mill
G74 - Face grooving or chip break drilling; Lathe
G75 - OD groove pecking; Lathe
G76 - Fine boring cycle; Mill
G76 - Threading cycle; Lathe
G80 - Cancel cycles; Mill and Lathe
G81 - Drill cycle; Mill and Lathe
G82 - Drill cycle with dwell; Mill
G83 - Peck drilling cycle; Mill
G84 - Tapping cycle; Mill and Lathe
G85 - Bore in, bore out; Mill and Lathe
G86 - Bore in, rapid out; Mill and Lathe
G87 - Back boring cycle; Mill
G90 - Absolute programming
G91 - Incremental programming
G92 - Reposition origin point; Mill
G92 - Thread cutting cycle; Lathe
G94 - Per minute feed; Mill
G95 - Per revolution feed; Mill
G96 - Constant surface speed control; Lathe
G97 - Constant surface speed cancel
G98 - Per minute feed; Lathe
G99 - Per revolution feed; Lathe

CNC M Codes

M00 - Program stop; Mill and Lathe
M01 - Optional program stop; Lathe and Mill
M02 - Program end; Lathe and Mill
M03 - Spindle on clockwise; Lathe and Mill
M04 - Spindle on counterclockwise; Lathe and Mill
M05 - Spindle off; Lathe and Mill
M06 - Toolchange; Mill
M08 - Coolant on; Lathe and Mill
M09 - Coolant off; Lathe and Mill
M10 - Chuck or rotary table clamp; Lathe and Mill
M11 - Chuck or rotary table clamp off; Lathe and Mill
M19 - Orient spindle; Lathe and Mill
M30 - Program end, return to start; Lathe and Mill
M97 - Local sub-routine call; Lathe and Mill
M98 - Sub-program call; Lathe and Mill
M99 - End of sub program; Lathe and Mill

Machine Zero and Program Zero

During every machining operation, the CNC machine uses a series of numerical instructions sent by the part program to control movements along the axes. These programs require a starting point that accurately lines up the cutting tool and the workpiece.

Each CNC machine has a built-in location that is called machine zero. This point typically is located at the farthest positive direction along the X-, Y-, and Z-axes, and it cannot be changed by anyone after it leaves the original manufacturer. A cutting tool or a worktable can be moved to the machine zero position for the loading and unloading of parts.

In addition to machine zero, each part program sets a starting location called program zero. Unlike machine zero, the programmer selects the program zero for each workpiece. This location acts as the origin from which all the other dimensions are calculated during the program and it is usually located on the edge of a workpiece. The CNC machine then adjusts its calculations to accurately align the cutting tool with the workpiece.

Work Zero

Machine **zero** is a floating point in space having a measure normally to accommodate length of machine and maximum traverse length to each axes. **Work Zero** normally set at the front face and at center of the **job.** Here it is shown two axis machine and axes termed transverse axis as X-Axis and Longitudinal axis as Z-Axis.

Tool zero

Part **Zero** is the datum corresponding to the 0, 0 coordinate on the CAD drawing that you used for all your CAM work or to generate the g-code for your part program. It's also called "Program **Zero**" since X0Y0Z0 in the g-code program is the location of Part **Zero**.

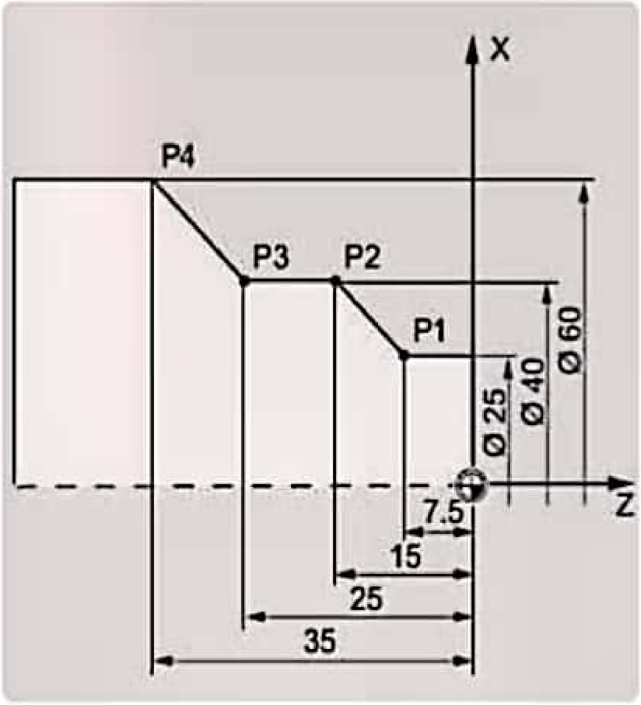
Tool offset

The word 'offset' refers to the allowance made by the CNC machine for the diameter and length of the tool to cut the job. Programming on a CNC machine is always done according to the **centre point** of the cutter. The cutting tool runs along the programmed line. If the offset value of a tool is not set, the tool will move according to this centre point of the cutter rather than according to the tool being used. This means that the tool will be cutting in the wrong part of the work piece.

Since the diameter and length of a tool may vary, an 'offset' value needs to be set so that the tool can be moved to the correct position for the cutting required.

For example, if you were using a 10mm cutter the work piece would be reduced by 5mm on each edge, or 10mm overall. To overcome this, the diameter value of the cutter is entered into the machine.

CNC Lathe Program Example with Code



Simple CNC Programming Example

```
N1 T0101              ; Tool no 1 with offset no 1 FANUC Control
N2 G97 S500 M03       ; Spindle rotation clockwise with 500 RPM
N3 G42 G00 X0 Z0      ; P0 tool nose radius compensation active
N4 G01 X25 G95 F0.3   ;
N5 G01 Z-7.5          ; P1
N6 G01 X40 Z-15       ; P2
N7 G01 Z-25           ; P3
N8 G01 X60 Z-35       ; P4
N9 G40 G00 X200 Z100  ; Tool nose radius compensation cancel
```

Industrial Robotics

Sections:
1.Robot Anatomy and Related Attributes

2.Robot Control Systems

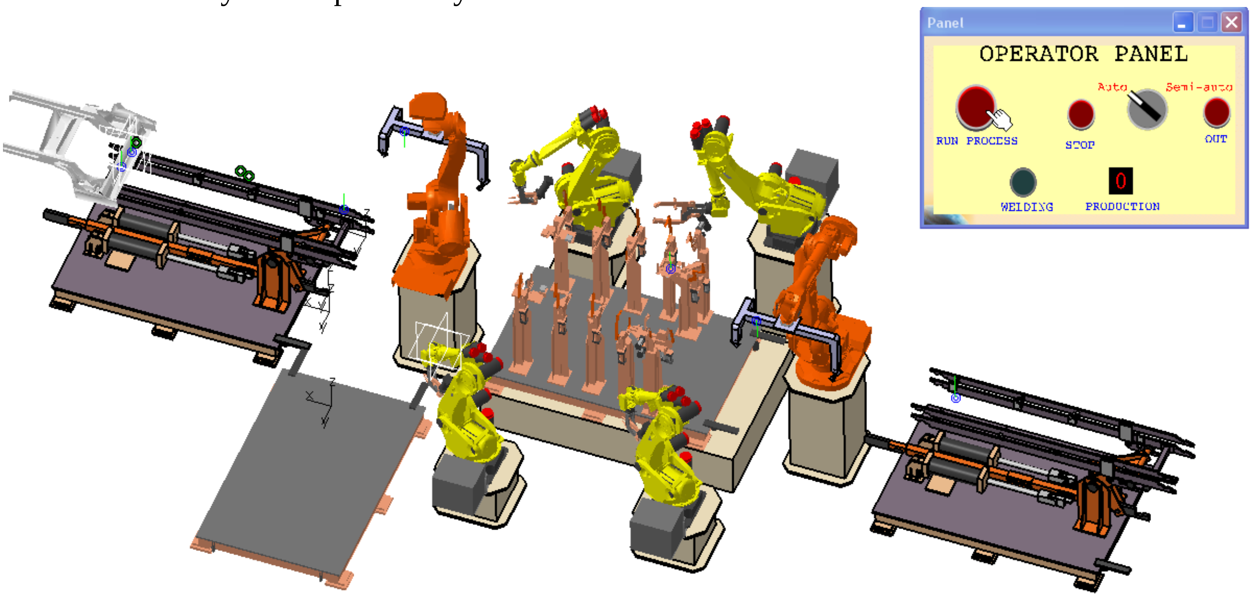
3.End Effectors

4.Sensors in Robotics

5.Industrial Robot Applications

6.Robot Programming

7.Robot Accuracy and Repeatability



Industrial Robot Defined

A general-purpose, programmable machine possessing certain anthropomorphic characteristics

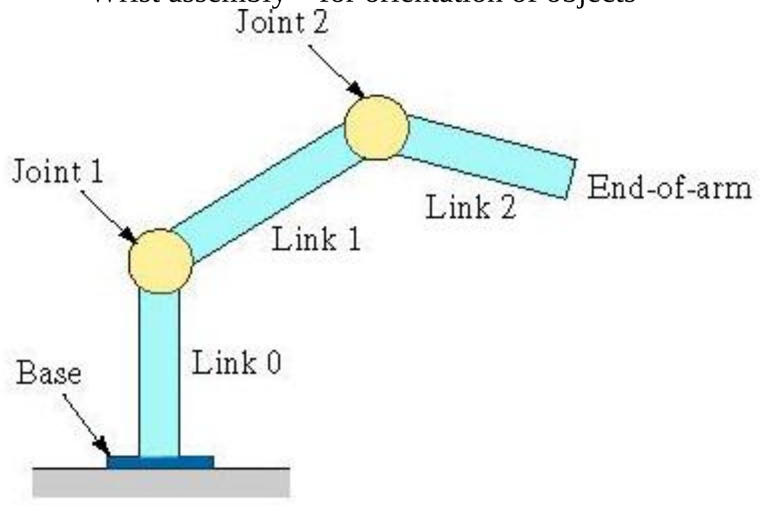
Why industrial robots are important:

- Robots can substitute for humans in hazardous work environments
- Consistency and accuracy not attainable by humans
- Can be reprogrammed
- Most robots are controlled by computers and can therefore be interfaced to other computer systems

Robot Anatomy

Manipulator consists of joints and links

- Joints provide relative motion
- Links are rigid members between joints
- Various joint types: linear and rotary
- Each joint provides a "degree-of-freedom"
- Most robots possess five or six degrees-of-freedom
- Robot manipulator consists of two sections:
- Body-and-arm – for positioning of objects in the robot's work volume
- Wrist assembly – for orientation of objects



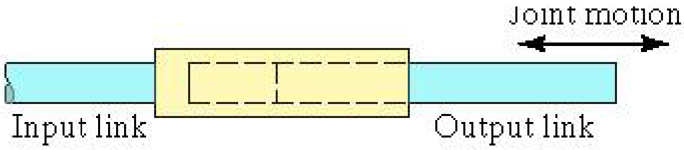
Robot manipulator - a series of joint-link combinations

Types of Manipulator Joints

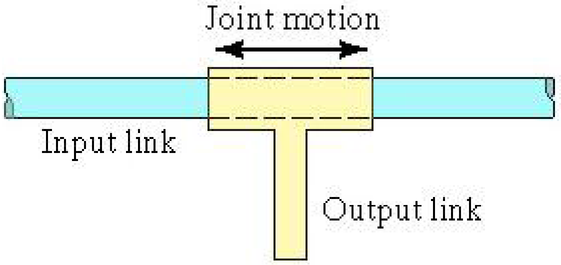
Translational motion

- Linear joint (type L)
- Orthogonal joint (type O)
- Rotary motion
- Rotational joint (type R)
- Twisting joint (type T)
- Revolving joint (type V)

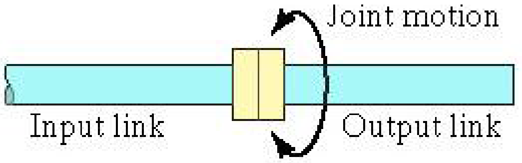
Translational Motion Joints

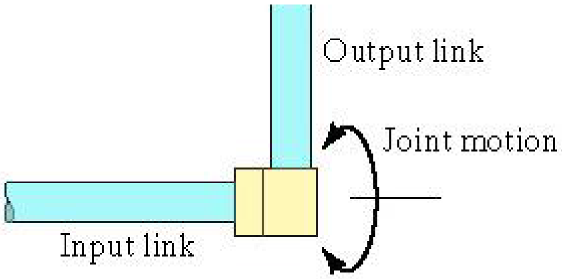


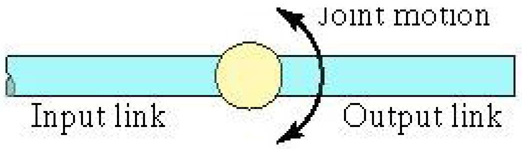
Linear joint (type L)



Orthogonal joint (type O)







Rotational joint (type R)
Twisting joint (type T)
Revolving joint (type V)

Robot Body-and-Arm Configurations

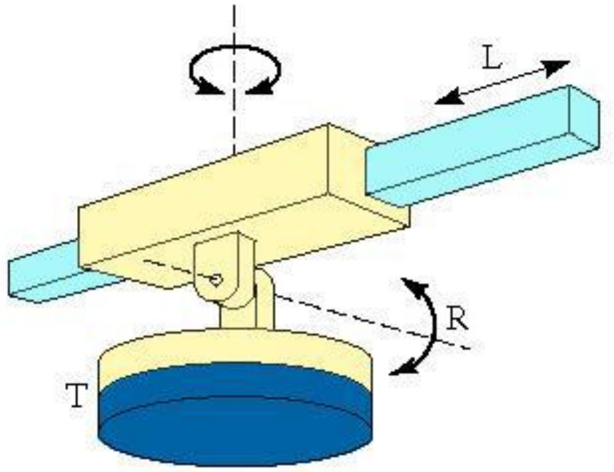
Five common body-and-arm configurations for industrial robots:
1.Polar coordinate body-and-arm assembly

2.Cylindrical body-and-arm assembly

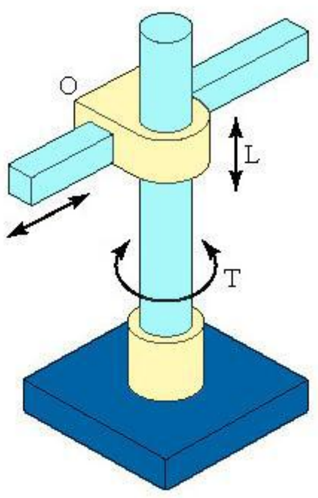
3.Cartesian coordinate body-and-arm assembly

4.Jointed-arm body-and-arm assembly

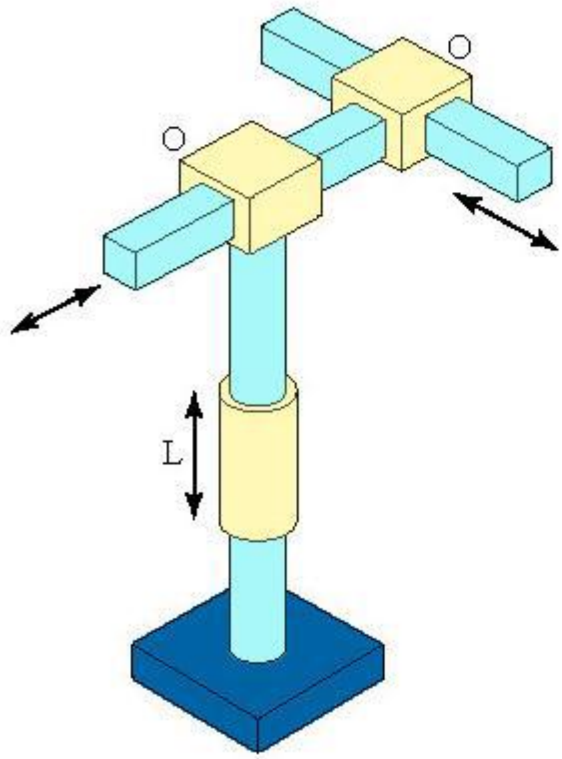
5.Selective Compliance Assembly Robot Arm (SCARA)
Function of body-and-arm assembly is to position an end effector (e.g., gripper, tool) in space
Polar Coordinate Body-and-Arm Assembly



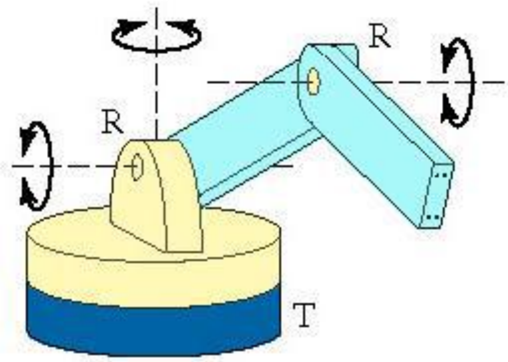
Cylindrical Body-and-Arm Assembly



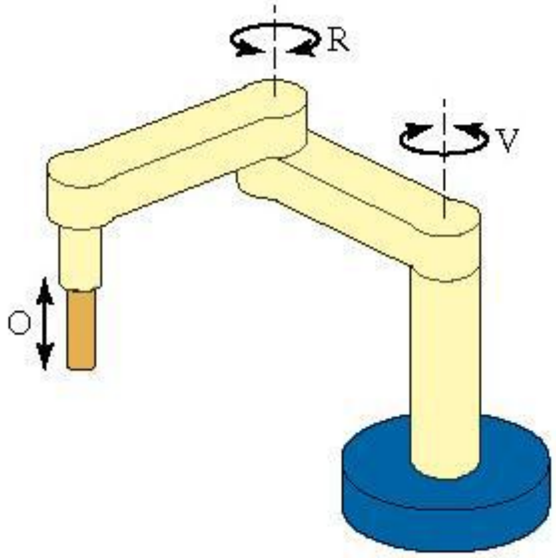
Cartesian Coordinate Body-and-Arm Assembly



Jointed-Arm Robot



SCARA Robot

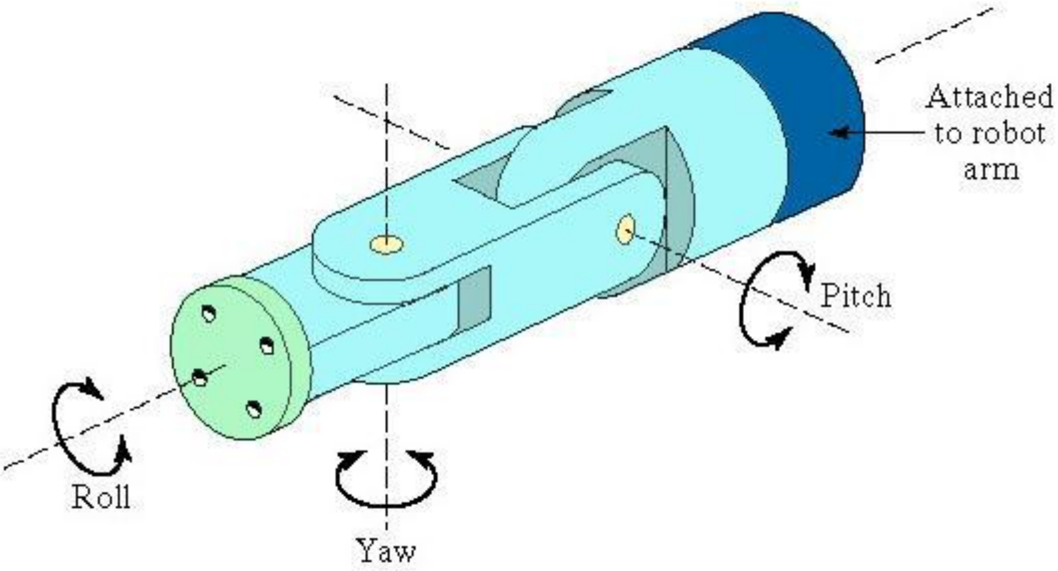


Wrist Configurations

- Wrist assembly is attached to end-of-arm
- End effector is attached to wrist assembly
- Function of wrist assembly is to orient end effector
- Body-and-arm determines global position of end effector

Two or three degrees of freedom:

- Roll
- Pitch
- Yaw
- Wrist Configuration



Industrial Robot Applications

1.Material handling applications

- Material transfer – pick-and-place, palletizing
- Machine loading and/or unloading

2.Processing operations

- Spot welding and continuous arc welding
- Spray coating
- Other – waterjet cutting, laser cutting, grinding

3.Assembly and inspection

Robot Programming

Leadthrough programming - work cycle is taught to robot by moving the manipulator through the required motion cycle and simultaneously entering the program into controller memory for later playback

Robot programming languages - uses textual programming language to enter commands into robot controller

Simulation and off-line programming – program is prepared at a remote computer terminal and downloaded to robot controller for execution without need for leadthrough methods

Leadthrough Programming

Two types:
1.Powered leadthrough
Common for point-to-point robots

Uses teach pendant to move joints to desired position and record that position into memory
2.Manual leadthrough
Convenient for continuous path control robots

Human programmer physical moves manipulator through motion cycle and records cycle into memory

Leadthrough Programming Advantages

Advantages:
Can readily be learned by shop personnel

A logical way to teach a robot

Does not required knowledge of computer programming
Disadvantages:
Downtime - Regular production must be interrupted to program the robot

Limited programming logic capability

Not readily compatible with modern computer-based technologies

Robot Programming Languages

Textural programming languages provide the opportunity to perform the following functions that leadthrough programming cannot readily accomplish:
Enhanced sensor capabilities

Improved output capabilities to control external equipment

Program logic not provided by leadthrough methods

Computations and data processing similar to computer programming languages

Communications with other computer systems
Robot Accuracy and Repeatability

Three terms used to define precision in robotics, similar to numerical control precision:
1.Control resolution - capability of robot's positioning system to divide the motion range of each joint into closely spaced points

2.Accuracy - capability to position the robot's wrist at a desired location in the work space, given the limits of the robot's control resolution

3.Repeatability - capability to position the wrist at a previously taught point in the work space

4. Introduction to FMS

Intense competition in the global market for mechanical parts manufactured on machine tools and other metal working equipment has compelled manufacturers to reduce delivery times and quote competitive prices even for relatively small orders. In many situations, manufacturers have to deliver customized products to the consumers. The batch size is ever-decreasing, and the need to meet specific customer needs calls for considerable flexibility in the working of the manufacturing system. In this situation, the requirements that a modern manufacturing facility has to meet can be detailed as follows:

- High productivity for all batch sizes, large or small
- Shorter throughput times
- Lower storage costs
- Reduced labour if not altogether avoiding labour
- Reduced handling
- Flexible production system to incorporate product changes at short notice to meet customer's specific requirements
- Sensing and taking care of such eventualities like tool breakage.

Conventional high volume production facilities such as automatic equipment and transfer lines do not fulfill these requirements. This provided sufficient reason for manufacturing engineers to turn attention to alternative approaches to manufacturing.

Flexible manufacturing cells and flexible manufacturing systems have been evolved to meet the requirements listed above.

The functions of many manufacturing equipment have already been automated through the use of CNC and PLC. The next stage is to automate the wider manufacturing environment comprising the following activities:

- Management of resources
- Storage, preparation and transport of raw workpieces and finished components
- Acquisition, processing and evaluation of production data
- Inspection of workpieces and continuously monitoring the performance of production equipment
- Testing of products

• Developing software to control all the above operations.

In such a process of integrated automation it is necessary to combine a number of machines, both mechanically and in terms of data processing into a closely linked manufacturing unit. In this way, highly automated manufacturing units (cells) are created which are capable of handling a number of different workpieces without interruptions due to operations like setting up workpieces, tool change, inspection etc.

Monitoring and process correction facilities through appropriate sensors are also part of the system so that operator intervention is kept to a bare minimum. Manufacturing cells normally contain 1 to 4 production machines. In addition to various “service machines” such as measuring machines and washing machines) and transport systems like automated guided vehicles, rail guided vehicles and conveyors for the workpieces and for the tools. The cell computer simultaneously controls the manufacturing operations within the manufacturing cell.

4.1 *Subsystems of FMS*

There are three major subsystems in FMS:

(i) Computer-controlled manufacturing equipment (e.g. numerically controlled machine tools, robots, gantry loaders, palletizing systems, washing stations, tool pre-setters, in-process inspection systems etc.)

(ii) Automated materials storage, retrieval, transport and transfer system

(iii) Manufacturing control system (including both machine tool, tool and logistics control)

Some FMS’s have additional subsystems. For example, in a machining application there may also be systems for presetting tools, storing and retrieving tools, disposing of chips and cutting fluids, washing and inspection workpieces. These subsystems must be linked together to achieve integrated manufacturing operation.

4.2 *Scope of FMS*

Although this was initially developed for machining applications, the concept of FMS has subsequently been used in a variety of other manufacturing applications, such as:

• Assembly of equipments

• Semiconductor component manufacturing

• Plastic injection moulding
• Sheet metal fabrication
• Welding
• Textile machinery manufacture

Such systems have proved to be practical and economical for applications with the following characteristics:

• Families of parts with similar geometric features that require similar types of equipment and processes
• A moderate number of tools and process steps
• Low to medium quantities of parts
• Moderate precision requirements

4.3 *FMS Compared to other types of Manufacturing Approaches*

One-off and low volumes of production are normally carried out by conventional general purpose machine tools. When the number of parts in a production run is more it is called batch production. A batch production shop is best suited for small quantities of many different types of parts. The very nature of production makes the operation of a job shop less efficient than an automated production line.

Since the job shop must be provided the greatest degree of flexibility, most of its operations are manual. They are normally equipped with general purpose CNC machine tools. Hard automation with dedicated equipment is best suited for the production of very large quantities of identical parts. Production of automobile components in a transfer line falls under this category. A large portion of the manufacturing industry involves the intermediate level of batch operations that lend themselves to the FMS approach. In this case volume is less but varieties are more.

FMS thus basically attempts to efficiently automate batch manufacturing operations. They are an alternative that fits in between the manual job shop and hard automation. FMS is best suited for applications that involve an intermediate level of flexibility and low or medium quantities. Fig. 28 shows the different types of production systems and it can be seen from the figure that FMS fits into the intermediate range of production.

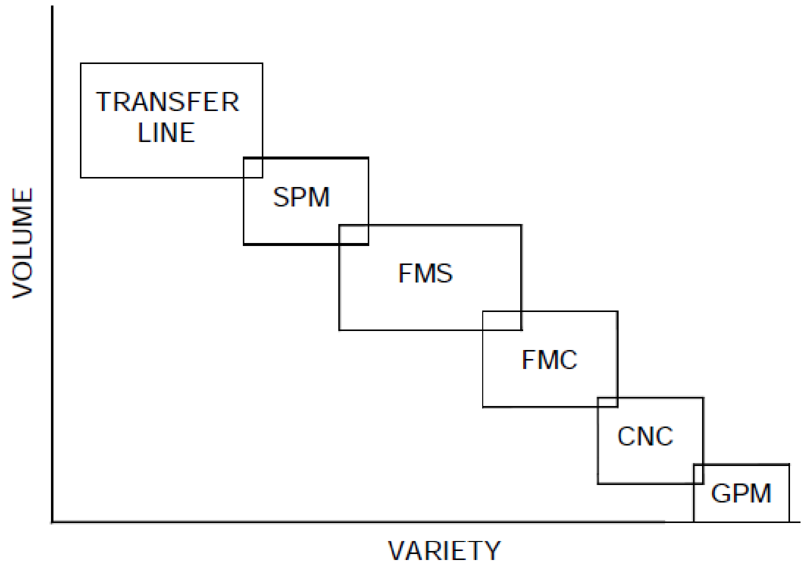


Fig. 28 Types of Production Systems

General purpose machines can accommodate a large variety of parts. They are manually operated and therefore production volumes are low. CNC machines can accommodate variety but the production volume is less as the machines are not optimized for the highest productivity for a specified type of job. It can be seen that FMC and FMS satisfy both variety and volume equally well. If we take special purpose machines, variety is much restricted. Transfer lines are dedicated usually to manufacture a component and hence can be said to have the minimum variety.

4.4 *Types of FMS*

FMS has been classified in several ways. Some of these classifications are still valid but the discussion in this book is restricted to three basic types:

Flexible Manufacturing Cells (FMC)

The simplest, hence most flexible type of FMS is a flexible manufacturing cell. It consists of one or more CNC machine tools, general purpose or of special design interfaced with automated material handling and tool changers. FMC's are capable of automatically machining a wide range of different workpieces. They are usually employed in one off and small batch production as independent machining centres, but are frequently the starting point for FMS.

A turning centre fitted with a gantry loading and unloading system and pallets for storing work pieces and finished parts is a typical flexible turning cell. If the turning centre is incorporated with either in-process or post process metrology equipment like Renishaw probes or inductive measuring equipment for automatic offset correction, the productivity of the system improves and wastage due to rejection is reduced. Automatic tool changers, tool magazines, block tooling, automatic tool offset measurement, and automatic chuck change and chuck jaw change etc. help to make the cell to be more productive.

One or two horizontal machining centres with modular fixturing, multiple pallets, advanced tool management system, automatic tool changer, automatic head changer or automatic magazine changer, robots or other material handling systems to facilitate access of the jobs to the machine also constitute a flexible machining cell.

An FMC can also comprise a turning centre, machining centre and pick and place robots or other materials handling systems. Fig. 29 shows the block diagram of a flexible manufacturing cell. This consists of a CNC lathe, a machining centre, a small automatic storage and retrieval system, two robots for loading and unloading the machines and a small rail guided vehicle to carry the component from one machine tool to another. The system is controlled by a PLC and a couple of personal computer.

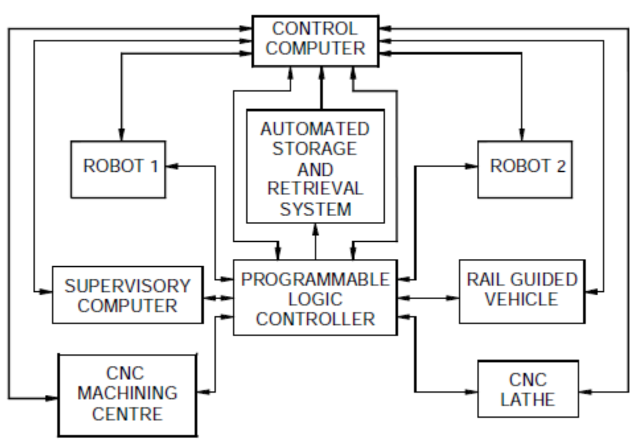


Fig. 29 Flexible Manufacturing Cell

Flexible Turning Cells

One of the most important advantages of CNC machines is their flexibility. The flexibility in this particular context means that these work centres enable the production of components in short batches. The production can be planned to meet immediate requirements because the change over time is short. In order to enable the production set up to change over from one component to another component in the shortest possible time, several technological features have to be added to the turning machines. This section describes some of these important features.

There are several ways to cut down idle time and component change over time and improve the productivity and flexibility of CNC turning centres. Flexible turning cells generally employ turning centres instead of CNC lathes. The availability of C-axis and the live tools in the turret enable the process designer to complete not only turning but also operations like milling, off-centre drilling, tapping, and helical groove cutting etc in one set up. This means that all operations required to completely machine a component can be carried out in one set up itself.

The relatively high cost of CNC machines means that the machine hour rate is several times that of conventional machines. This necessitates not only increasing the utilization by cutting down idle time but also working on all the three shifts of the day as well as during holidays. This calls for a high degree of automation. By using automatic part changer, automatic tool changer and adopting process automation through sensing and feedback devices like tool breakage sensors, automatic tool length offset compensation, in-process or post-process gauging and program correction, automatic chuck changing and chuck jaw changing, it will be possible to achieve fully automatic unmanned machining.

Flexible Transfer Lines (FTL)

Flexible transfer lines are intended for high volume production. A part in a high volume production may have to undergo large number of operations. Each operation is assigned to and performed on only one machine. This results in a fixed route for each part through the system. The material handling system is usually a pallet or carousel or conveyor. In addition to general purpose machines, it can consist of SPM’s, robots and some dedicated equipment. Scheduling to balance the machine loads is easier. Unlike conventional transfer lines, a number of different workpieces can be manufactured on the FTL. The resetting procedure is largely automatic.

Flexible Machining Systems

Flexible Machining Systems consists of several flexible automated machine tools of the universal or special type which are flexibly interlinked by an automatic workpiece flow system so that different workpieces can be machined with the same machine configuration. The characteristic feature is the external interlinkage of the machines, unrestricted by cycle time considerations. Different machining times at the individual stations are compensated for by central or decentralized workpiece buffer stores. Flexibility is applied to machines because of CNC control and flow of products from one machine to another which is possible through flexible transport system. Flexibility is characterized by the system's ability to adapt to changes in the volumes in the product mix and of the machining processes and sequences. This means that a FMS will be able to respond quickly to changing market and customer demands.

4.5 *Benefits of FMS*

FMS's are designed to provide a number of advantages over alternative approaches (Fig. 30). These are listed below:

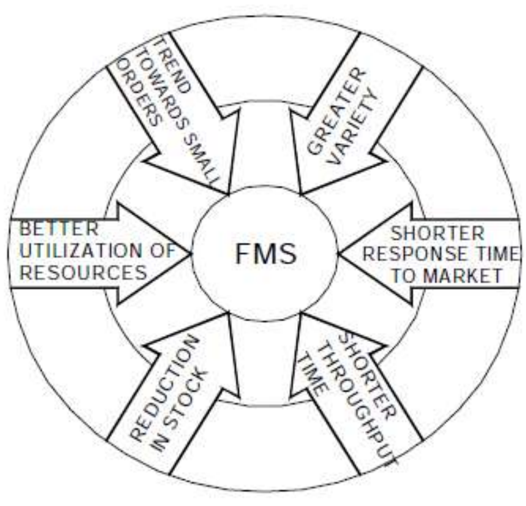


Fig. 30 Benefits of FMS

Reduced cycle times

• Lower work-in-process (WIP) inventory

• Low direct labour costs

• Ability to change over to different parts quickly

• Improved quality of product (due to consistency)

• Higher utilization of equipment and resources (Utilization better than standalone CNC machines)

• Quicker response to market changes

• Reduced space requirements

• Ability to optimize loading and throughput of machines

• Expandability for additional processes or added capacity

• Reduced number of tools and machines required

• Motivation for designers to add variations and features to meet customer requirements.

• Compatible with CIM

Some of these advantages can lead to significant cost savings. Direct labour can be eliminated almost entirely. Cycle time and WIP can be reduced to a fraction of what is normally experienced in a manual operation. An FMS is designed to have the production machines working most of the time rather than standing idle.

This can be explained with the help of Fig. 31. On any manually controlled work centre, the total time available for production per year is 8760 hours. Out of which the company loses 14.3 % of the time on account of Sunday being a weekly holiday. Paid holidays result in production loss of roughly 1.5%. An employee may also be eligible for paid leave (casual leave, earned leave etc.) and this may reduce the available working hours by 8%. The efficiency of production in the third shift is usually less and the production loss due to it is about 14% (assuming only 50% of the normal efficiency in the third shift). In India, a major cause for loss of production is employee absenteeism due to medical or other reasons. A factory employee is eligible to avail unto 90 days leave a year, enjoying the benefits from Employee’s State Insurance. The average absenteeism in many industries varies. If we assume that the loss of production due to absenteeism is approximately 7%, the net available production time is only 55%. Assuming an efficiency of production of 80%, the work centre time utilized comes down to 44%.

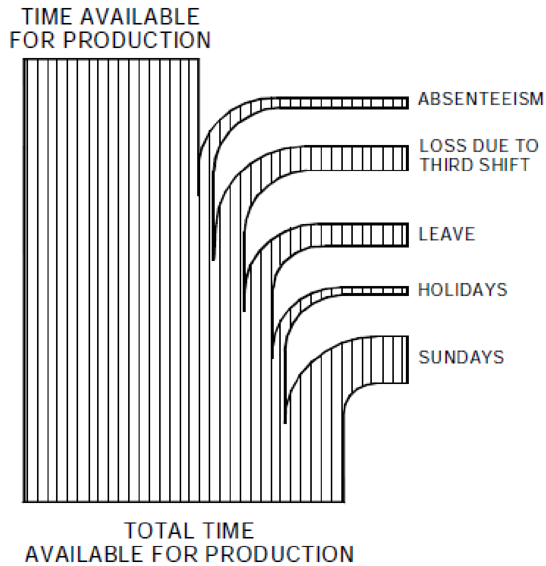


Fig. 31 Loss of Production Time

In the case of conventional manually operated metal cutting machines, the actual time utilized for removal of material is about 30-35% of the working time. The rest of the time is spent on non-productive operations like setting up of work and tools, inspection or procuring tools etc.

In the case of efficient operation of CNC machines this percentage increased to 80 to 85%. In FMS, one can achieve as high as 90-95% efficiency. Another important feature of FMS is that an FMS can produce parts even if the employee is absent or even if it is a holiday. The significance of FMS must be apparent from this fact. An automated material handling system and a computer-based production scheduling system are needed to keep the machines fed with parts. FMS uses computer automation techniques to lower the overall cost of production operations.

4.6 *Major Elements of FMS*

Each of the major subsystems in an FMS performs a number of functions and is dependent on the others to make the entire system work. The functions will vary, depending upon the type of equipment and manufacturing operations involved.

Production Equipment

The production equipment used in FMS depends upon the product manufactured.

(i) FMS for sheet metal work: The work centres used in sheet metal FMS include turret punch presses, laser machining centres, press brakes, guillotines etc. A typical FMC consists of sheet stacking system, sheet unloading device, sorting conveyor, turret punch press, right angle shear, loading device and automatic storage.

(ii) FMS for machining: This type of FMS typically has a number of machining centres and/or turning centres to provide general purpose machining capabilities. Machining centers offer the greatest flexibility, since they can perform many different machining operations. (e.g. milling, drilling, and boring). This is made possible by a toolchanging system that is either built into or supports the machining centre. A part can therefore undergo multiple machining processes at a single workstation. Special purpose machines may also be included in the FMS to perform operations which are unique or require more efficiency (e.g. turning, grinding). Washing machines and inspection machines also form the equipment of FMS. The family of parts which the FMS is designed to produce will determine the capabilities required from the machine tools (e.g. accuracy, size, power etc).

Support Systems

Automated machine tools typically require several systems to support their operation.

The tools required to perform the multiple processes of a machining centre or a turning centre may be stored in magazines at each machine or in central tool storage. Local magazines provide fast access as well as backup capability but in a large FMS a central tool facility may be more efficient. Centralization not only permits the total number of tools to be minimized; it also provides the opportunity to perform additional functions automatically, such as:

(i) Measurement of tool wear

(ii) Tool pre-setting

(iii) Tool regrinding, repair and maintenance

(iv) Replacement of broken or worn tools

Many automated machine tools have built-in systems to monitor tool wear and detect tool breakage. They may use probes or non-contact techniques such as acoustic emission for this purpose. When a tool needs replacement, the machine can signal the tool room for the delivery of a replacement. This may be performed by an AGV or gantry set up or RGV. Elaborate tool management support is an integral part of FMS software. With this software, operating personnel can have effective centralized control of a large tool inventory. Automated machining operations also need to have the chips cleaned off the workstation and the workpiece. This may be performed by robots or special washing stations. Cleaning may involve turning the workpiece over, vacuuming and washing.

Materials Handling System

• A FMS typically needs several materials handling systems to service the machines.

• A transport system to move workpieces into and out of the FMS (e.g. overhead conveyors, gantry systems, AGV's, RGV's)

• A buffer storage system for queues of workpieces at the machines (e.g., pallets)

• A transfer system to load and unload the machines (e.g. robots, transfer fixtures)

For these systems to work effectively, they must be synchronized with the machine operations. The location and movement of workpieces must be tracked automatically. This is done by using sensors on the materials handling system and workstations.
They may be either contact devices (e.g. switches) or non-contact devices (e.g. optical, tags or proximity devices).

Automatic Guided Vehicles (AGV)

AGV is one of the widely used types of material handling device in an FMS. These are battery-powered vehicles that can move and transfer materials by following prescribed paths around the shop floor. They are neither physically tied to the production line nor driven by an operator like forklift. Such vehicles have on-board controllers that can be programmed for complicated and varying routes as well as load and unload operations. The computer for the materials handling system or the central computer provides overall control functions, such as dispatching, routing and traffic control and collision avoidance. AGV's usually complementing an automated production line consisting of conveyor or transfer systems by providing the flexibility of complex and programmable movement around the manufacturing shop.

Advantages of using AGV systems in FMS

(i) Flexibility: The route of the AGV's can be easily altered, expanded and modified, simply by changing the guide path of the vehicles. This is more cost effective than modifying fixed conveyor lines or rail guided vehicles. It provides direct access materials handling system for loading and unloading FMS cells and accessing the automated storage and retrieval system.

(ii) Real time monitoring and control: Because of computer control, AGV's can be monitored in real time. If the FMS control system decides to change the schedule, the vehicles can be re-routed and urgent requests can be served. AGV's are usually controlled through wires implanted on the factory floor. The control is effected using a variable frequency approach. Radio control, an alternative to in-floor mounted communication lines, permits two way communications between the on-board computer and a remote computer, independent of where the vehicle is i.e. whether it is in the parking place or whether it is in motion. To issue a command to a vehicle, the central computer sends a bit stream via its transmitter using frequency shift keying methods to address a specific vehicle. The signal transmitted from the base station is, therefore, read by the appropriate vehicle only. The vehicle is also capable of sending signals back to the remote controller, to report the status of the vehicle, vehicle malfunction, battery status, and so on.

(iii) Safety: AGV's can travel at a slow speed but typically operate in the range 10 to 70 m/min. They have on-board microprocessor control to communicate with local zone controllers which direct the traffic and prevent collisions between vehicles as well as the vehicle and other objects. A bumper is attached to some designs of AGV's to prevent collision. AGV's may also incorporate warning lights, fire safety interlocks and controls for safety in shops. During design, the use of simulation can help detect whether there are enough vehicles to perform the necessary load, unload and transportation tasks and thus optimize the utilization of the AGV system. Because these vehicles have to work in a tandem with highly organized FMS cells as well as with automated warehouses under computer control, their level of performance will affect the entire efficiency of the FMS.

Automated Storage and Retrieval Systems

A key part of any materials handling system is storage. Major advances have been made in recent years to automate the storage and retrieval of product and materials by employing sophisticated materials handling machines, high-density storage techniques and computer control. Such systems come in a variety of forms and sizes depending on the materials handling and storage job that has to be done. They often take the form of automated warehouses which use automatic storage and retrieval systems, conveyors and computers to control the materials handling machines and to track and control the inventory. The characteristics of such warehouses include:

(i) High density storage (in some cases, large, high-rise rack structures)

(ii) Automated handling systems (such as elevators, storage and retrieval carousels and conveyors).

(iii) Materials tracking systems (using optical or magnetic sensors)

In such a storage system, the computer can keep track of a large number of different parts, products and materials and can assign bin locations to optimize the use of storage space. When such a system is tied into the production control system, parts and materials can be replenished as they are consumed on the factory floor, keeping the work in process (WIP) to a minimum.

Categories of AS/RS

The automatic storage and retrieval system can be classified into several types. Some of them are:

- Unit load AS/RS
- Mini load AS/RS
- Man-on-board AS/RS

• Automated item retrieval system

• Deep lane AS/RS

Basic Components of AS/RS

An AS/RS normally consists of:

• Storage structure

• Storage and retrieval machine

• Storage modules

• Pick-up and deposit stations

Special Features of AS/RS

Some of the special features of AS/RS are:

• Aisle transfer cars

• Full/empty bin detectors

• Sizing stations

• Load identification stations

Buffer Storing of Parts

In an FMS, parts move from one work cell to another where the various processing tasks are performed. Because of the almost random production facilities of FMS, the destination cell might not always ready to accept the incoming part and the part has to wait in a buffer store. These and other bottlenecks in the materials handling problems can be successfully detected by simulation. Buffer stores for parts will always be desirable. Figure 19.8 shows a typical FMC cell layout where buffer stores are used as an integral part of the cell as well as the overall materials handling system.

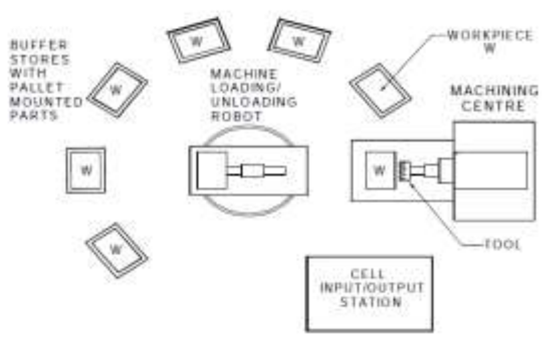


Fig. 32 Typical FMC Layout

In the case of turning centres, the machining time may be of the order of a few minutes. A gantry robot is used for loading and unloading the component. It is better to present the raw workpieces in a pallet to the gantry. Finished workpieces can be deposited in another pallet. The empty raw material pallet and the filled finished part pallet will be transported by the AGV. Buffer store is also recommended for sheet metal items. Machining centres with multiple pallets (2, 4, 8 or more) incorporate adequate buffer capacity to last several hours.

Chip Removal and Washing Stations

Workpiece cleaning is important, especially before the part goes to the inspection station or assembly station, because un-removed swarf can cause problems during the inspection cycles or assembly. The swarf removal is done at the washing station of the FMS. The pallet with fixture part is loaded on to the washing station, where it is located as if it was a table of any other machining station. It is tilted, by a hydraulic mechanism, while being rinsed under high pressure coolant or pressurized air supply. Then, while reverting to its load/unload position, the pallet is blown clean with compressed air. Once the part is clean, it can be taken away by a robot or AGV together with its pallet.

Computer Control System

The computer control system of an FMS integrates several sub-systems including:

CNC systems

Support system controllers

Materials handling system controller

Monitoring and sensing devices

Data communication system

Data collection system

Programmable logic controllers

Supervisory computer

This control system must also integrate other computer systems if existing in the factory. The FMS system must also communicate with the following systems:

• The CAD/CAM system which generates the CNC programs for the machine tools

COMPUTER AIDED DESIGN AND MANUFACTURING

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

- It is concerned with the application of computers to the manufacture of engg. components, from the drawing phase to the production phase (to the m/c and assembly shops), to the quality control dept & to the warehouses.

- The technology of CAD/CAM represents an efficient, accurate and consistent method to design and manufacture high quality products.

The Role of Computers in manufacturing :-

It is classified into two groups :-

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

- In the 1st category, computer is directly interfaced with the manufacturing process for monitoring & control functions.
  Ex:- In a chemical processing industry, a number of process parameters may be monitored.

- In the 2nd category, all support functions are included for the successful completion of manufacturing operations.
  Ex:- CAD :- Use of computers method to develop the geometric model of the product in 3D form.
  CAE (Engg) :- .... to support basic error checking, analysis, optimization, manufacturability.

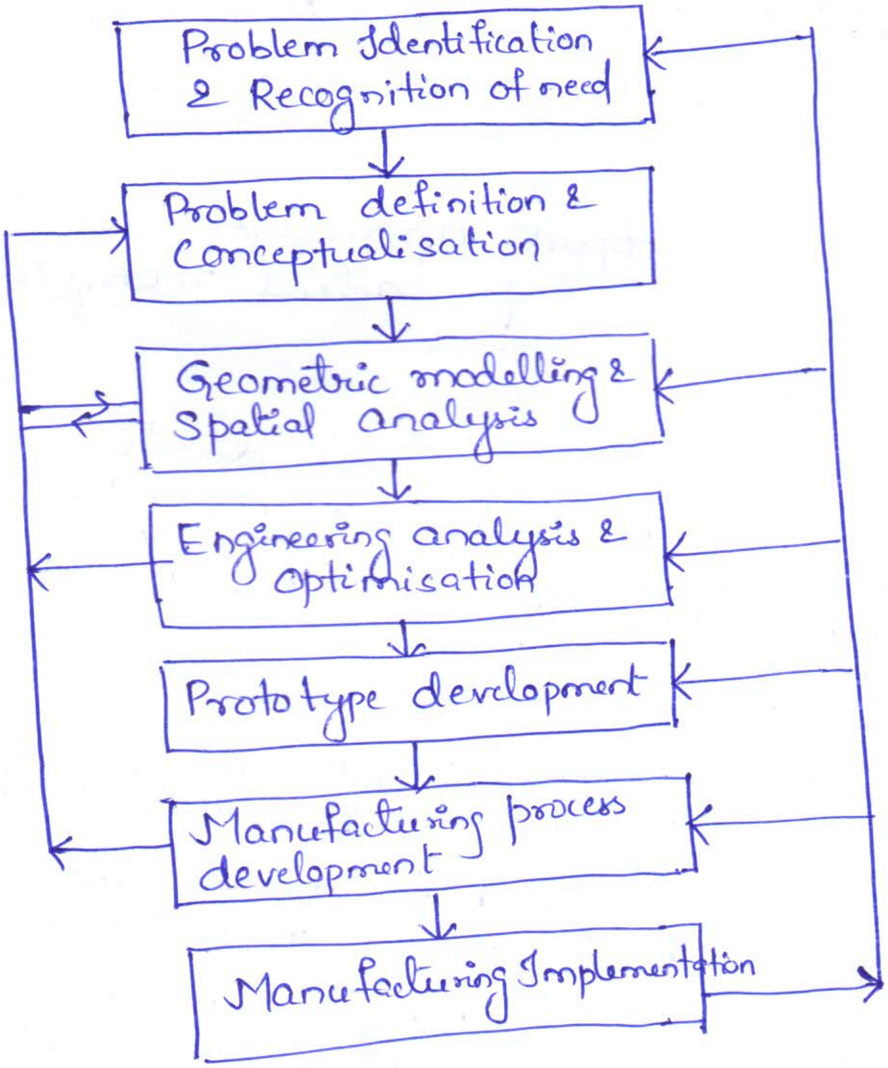
- CAM:- Use of computers to generate software to develop the Computer Numerical Control post programs for machining & other processing applications.

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

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

DESIGN PROCESS

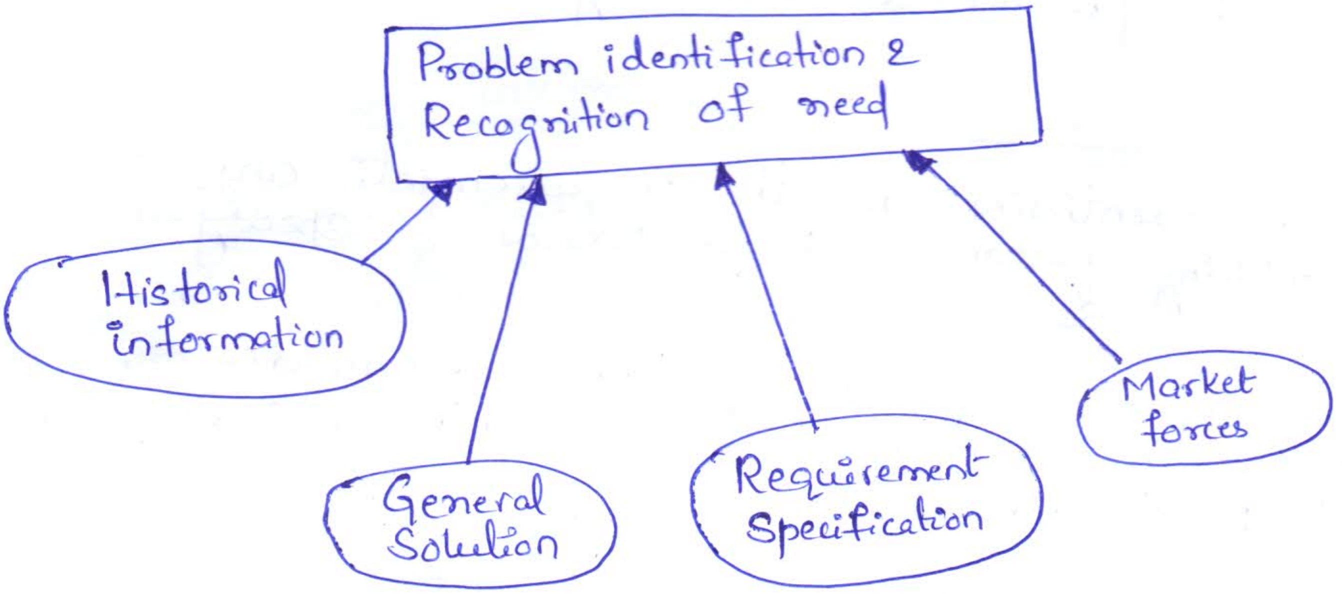
Stages in Design process



STAGES IN DESIGN PROCESS

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

PROBLEM IDENTIFICATION



Processes involved in the problem-identification stage

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

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

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

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

(3) Market forces

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

(4) General Solutions

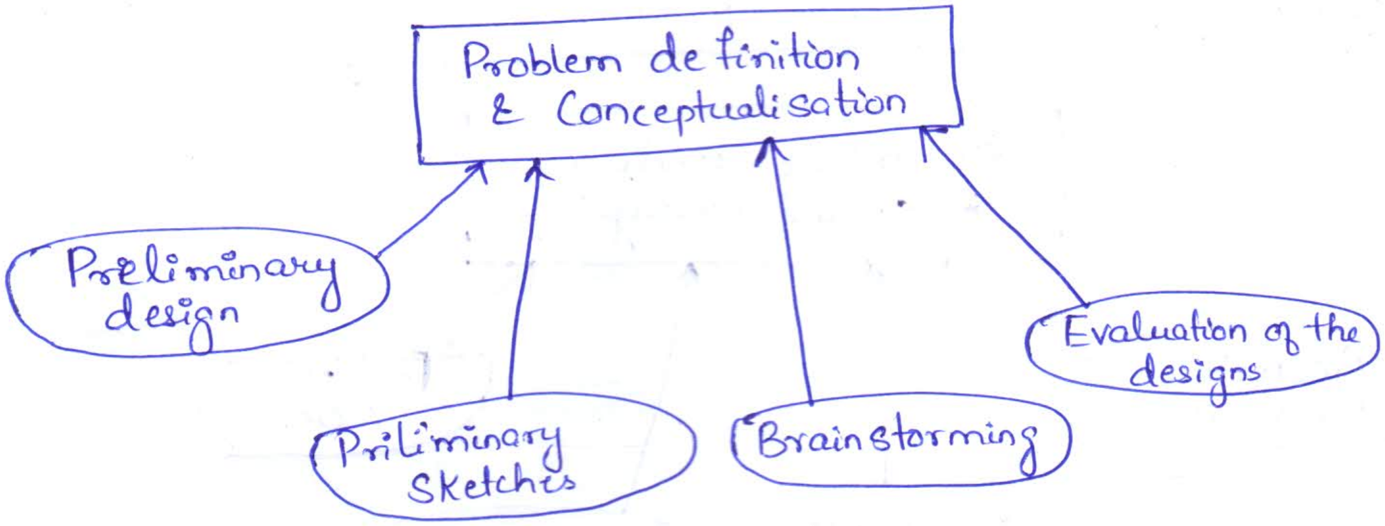
- Having identified all the requirements and controlling factors, it is possible to specify a general solution.
- This can be done by resorting to past designs, engineering standards, technical reports, catalogues, hand books, patents, etc.

II Stage :- Problem Definition

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

(1) Preliminary Design :-

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



Processes involved in the problem-definition stage

(2) Preliminary Sketches :-

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

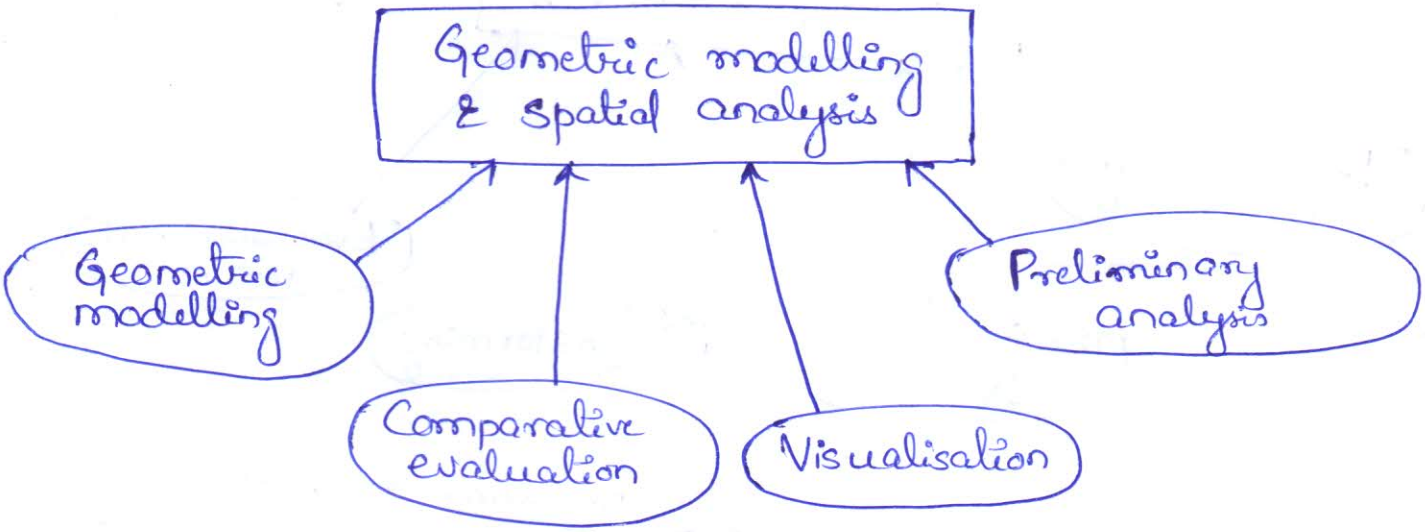
(3) Brain storming :-

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

(4) Evaluation of the designs :-

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

STAGE- III :- GEOMETRIC MODELLING



Geometric-modelling stage in the design process

(1) Geometric Modelling :-

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

(2) Visualisation :-

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

(3) Preliminary Analysis :-

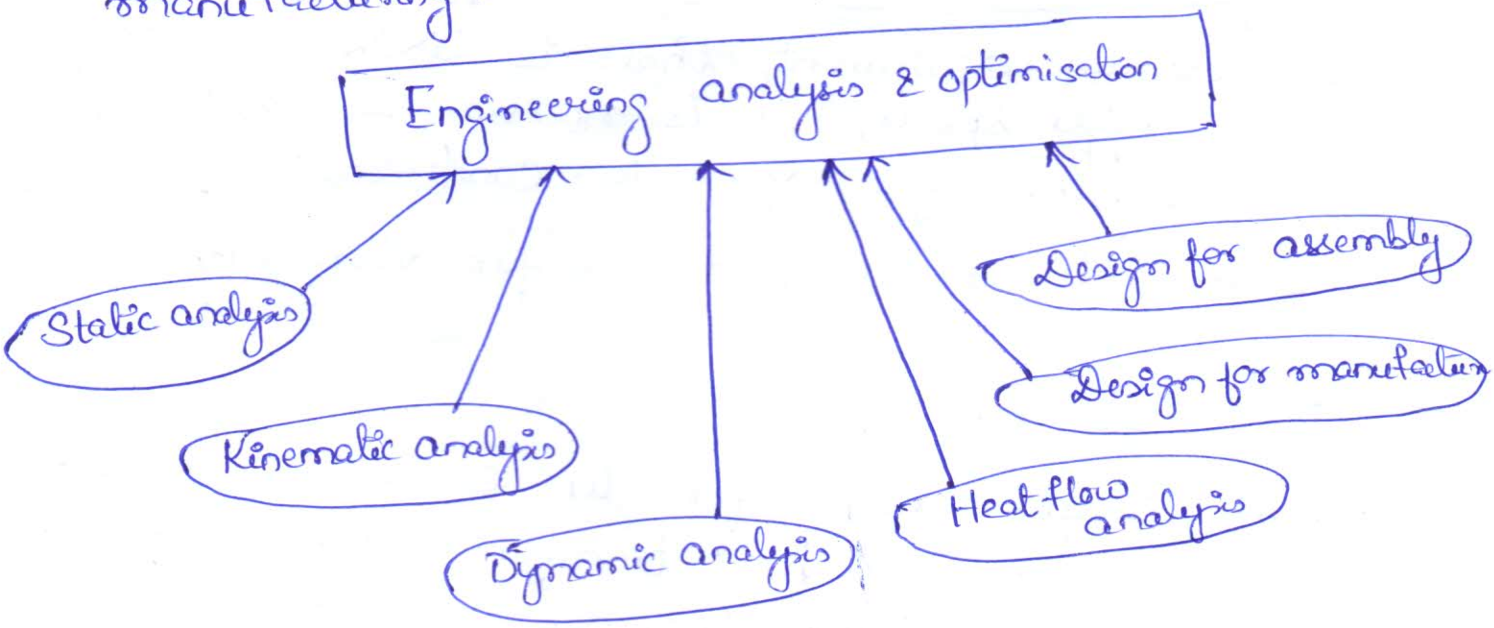
- This allows for simple analysis techniques such as volumes & masses, inertia, spatial analysis, etc.
- Also, ergonomics & human factors requirements can be analysed at this stage.

(4) Comparative evaluation :-

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

STEP IV ENGINEERING ANALYSIS

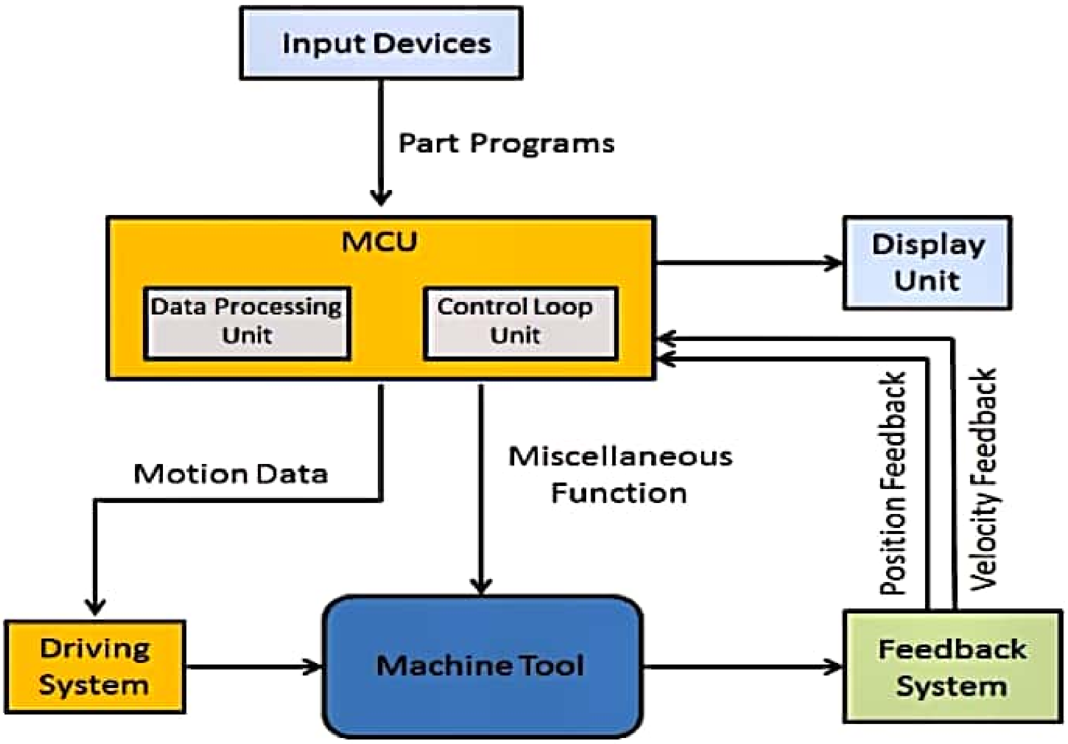
- In this stage of design process, a thorough analysis of the product is carried out to get as much information as possible before committing to final manufacturing.



Analysis stage in the design process

(1) Static analysis :-

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



Benefits of CAD. CAD software and hardware

CAD (Computer Aided Design) is used to design components in virtual environment. So you create 3D models and 2D drawings instead of hand drawn technical drawings. Examples of CAD software: Autodesk AutoCAD, Autodesk Inventor, Autodesk Fusion, SolidWorks, CATIA, Solid Edge, NX CAD, Creo (formerly ProEngineer).

CAM (Computer Aided Manufacturing) is used to prepare manufacturing process for previously created virtual model (the one from CAD software). Usually that process is some kind of machining (milling or turning). Preparations in CAM consist of setting paths for tool and watching animations of the process. Examples of CAM software: NX CAM, Edge CAM, CAMWorks, MasterCAM. Also most of the CAD software have CAM module too.

Differentiate between CAD and CAM

	CAD	CAM
Purpose	making 2D technical drawings and 3D models	using 3D models to design machining process
Procedure	sketching with 2D primitives and in case of 3D adding 3rd dimension to tchem (extruding, revolving)	automatic and manual path planning for machining tools
Software examples	Autodesk AutoCAD and Inventor, SolidWorks, Solid Edge, CATIA, Creo	EdgeCAM, NX CAM, MasterCAM
Advantages	much easierm more accurate and faster drafting, making 3D models impossible without computers	automatization of machining process
Disadvantages	requires expensive software and knowledge how to use it, sometimes you can loose your data easily if you don't save it	expensive software, requires knowledge how to use it, it depends on CAD model accuracy, glitches can occur

COMPUTER INTEGRATED MANUFACTURING

1. INTRODUCTION:

Computer Integrated Manufacturing (CIM) encompasses the entire range of product development and manufacturing activities with all the functions being carried out with the help of dedicated software packages. The data required for various functions are passed from one application software to another in a seamless manner. For example, the product data is created during design. This data has to be transferred from the modeling software to manufacturing software without any loss of data. CIM uses a common database wherever feasible and communication technologies to integrate design, manufacturing and associated business functions that combine the automated segments of a factory or a manufacturing facility. CIM reduces the human component of manufacturing and thereby relieves the process of its slow, expensive and error-prone component. CIM stands for a holistic and methodological approach to the activities of the manufacturing enterprise in order to achieve vast improvement in its performance.

Manufacturing engineers are required to achieve the following objectives to be competitive in a global context.

- Reduction in inventory
- Lower the cost of the product
- Reduce waste
- Improve quality
- Increase flexibility in manufacturing to achieve immediate and rapid response to:
    - Product changes
    - Production changes
    - Process change
    - Equipment change
    - Change of personnel

CIM technology is an enabling technology to meet the above challenges to the manufacturing environment.

2. EVOLUTION OF CIM:

Computer Integrated Manufacturing (CIM) is considered a natural evolution of the technology of CAD/CAM which by itself evolved by the integration of CAD and CAM. Massachusetts Institute of Technology (MIT, USA) is credited with pioneering the development in both CAD and CAM.

If we review the manufacturing scenario during 80's we will find that the manufacturing is characterized by a few islands of automation. In the case of design, the task is well automated. In the case of manufacture, CNC machines, DNC systems, FMC, FMS etc provide tightly controlled automation systems. Similarly computer control has been implemented in several areas like manufacturing resource planning, accounting, sales, marketing and purchase. Yet the full potential of computerization could not be obtained unless all the segments of manufacturing are integrated, permitting the transfer of data across various functional modules. This realization led to the concept of computer integrated manufacturing. Thus the implementation of CIM required the development of whole lot of computer technologies related to hardware and software.

3. DEFINITION OF CIM:

CIM is defined differently by different users, and can be implemented in varying an increasing degree of complexity. For many companies, improving shop-floor communications is the primary goal. Others extend the degree of integration to encompass communication between engineering and manufacturing functions. The ultimate benefit of CIM is the improvement of communication and control of information flow to all aspects of an enterprise.

The computer and automated systems association of the society of Manufacturing Engineers (CASA/SEM) defines CIM is the integration of total manufacturing enterprise by using integrated systems and data communication coupled with new managerial philosophies that improve organizational and personnel efficiency.

CIM is recognized as Islands of Automation. They are

1. CAD/CAM/CAE/GT
2. Manufacturing Planning and Control.
3. Factory Automation
4. General Business Management

CASA/SME's CIM Wheel is as shown in figure 1

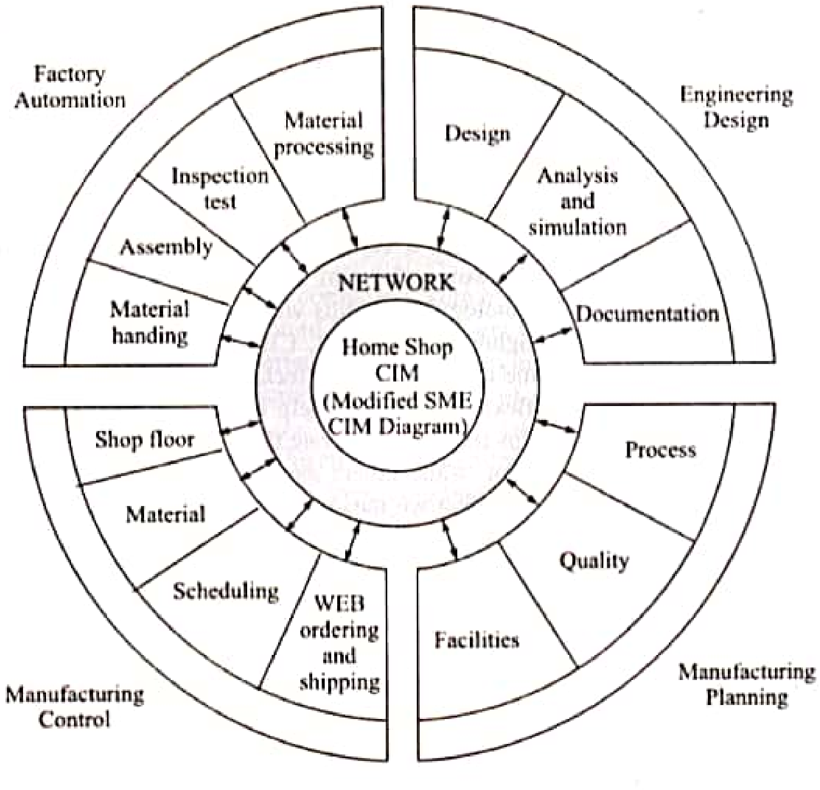


Figure 1 CASA/SME's CIM Wheel

4. CIM HARDWARE AND CIM SOFTWARE:

CIM Hardware comprises the following:

I. Manufacturing equipment such as CNC machines or computerized work centers, 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, RFID tags, printers, plotters and other peripheral devices, modems, cables, connectors etc.,

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

- Management Information System
- Sales
- Marketing
- Finance
- Database Management
- Modeling and Design
- Analysis
- Simulation
- Communications
- Job Tracking
- Inventory Control
- Shop Floor Data Collection
- Order Entry
- Materials Handling
- Device Drivers
- Process Planning
- Manufacturing Facilities Planning
- Work Flow Automation

5. ROLE OF THE ELEMENTS OF CIM SYSTEM:

Nine major elements of a CIM system are in Figure 2 they are,

- Marketing
- Product Design
- Planning
- Purchase
- Manufacturing Engineering
- Factory Automation Hardware
- Warehousing
- Logistics and Supply Chain Management
- Finance
- Information Management

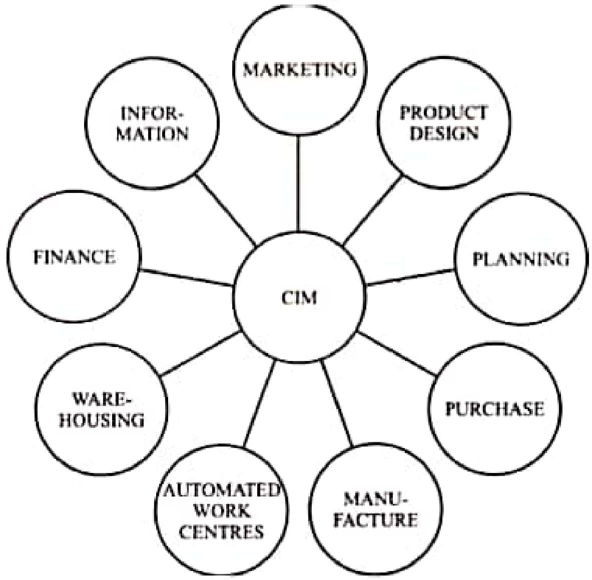


Figure 2 Major elements of CIM systems

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 modeling 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 andassembly.

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.