LECTURE NOTES

ON

Advance Manufacturing & CAD/CAM

Subject Code- MET-603

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By

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SYLLABUS

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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.

Course Contents:

Module-1:

Non-Conventional Machining Process: Electro chemical machining process, Electro discharge machining process, Plasma arc machining process, Laser beam machining process, Abrasive jet machining process, Electron beam machining process.

Module-2:

Automation: Define Automation, List types of Automation, Explain need for Automation.

Module-3:

Numerical Control: Define Numerical Control, Explain the NC system with block diagram.

Describe the types of NC co-ordinate: Point – to – point, Straight Cut, and Contouring.

NC part programming: G code and M-code, Reference Point (Machine Zero, Work zero, Tool zero & Tool offset), Simple part program for lathe.

Explain the Extension of NC with the block diagram:

i. DNC (Direct numerical Control)
ii. CNC (Computer numerical Control)
iii. Adaptive Control

Module-4:

Robot Technology: Defining a robot (ISO), Fields of application of robots, Explain Robot anatomy, Describe Robot Configuration.

Module-5:

Flexible Manufacturing System(FMS): Need for FMS.

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

Module-6:

CAD/CAM & CIM: Define CAD, CAM and CIM, Explain the benefits of CAD, CAD software and hardware.

Explain the benefits of CAM, differentiate between CAD and CAM.

Explain the concept, background. Software and hardware of CIM.

Module-1

ELCTRO CHEMICAL MACHINING PROCESS(ECM):

- Electrochemical machining (ECM) is a machining process in which electrochemical process is used to remove materials from the work piece.
- In the process, work piece is taken as anode and tool is taken as cathode. The two electrodes work piece and tool is immersed in an electrolyte (such as NaCl).
- When the voltage is applied across the two electrodes, the material removal from the work piece starts. The work piece and tool is placed very close to each other without touching.
- In ECM the material removal takes place at atomic level so it produces a mirror finish surface.

Working Principle:

- ECM working is opposite to the electrochemical or galvanic coating or deposition process.
- During electrochemical machining process, the reactions take place at the electrodes i.e. at the anode (work piece) and cathode (tool) and within the electrolyte.
- Let's take an example of machining low carbon steel which is mainly composed of ferrous alloys (Fe). We generally use neutral salt solution of sodium chloride (NaCl) as the electrolyte to machine ferrous alloys. The ionic dissociation of NaCl and water takes place in the electrolyte as shown below.

$$NaCl \rightarrow Na^+ + Cl^-$$

$$H_2O \rightarrow H^+ + OH^-$$

- As the potential difference is applied across the electrode, the movement of ions starts in between the tool and w/p. The positive ions move towards the tool (cathode) and negative ions move towards the work piece.
- At cathode the hydrogen ions take electrons and gets converted into hydrogen gas.

$$2H^+ + 2e^- \rightarrow H_2 \uparrow$$

- In the same way the iron atoms come out from the anode (w/p) as Fe++ ions.

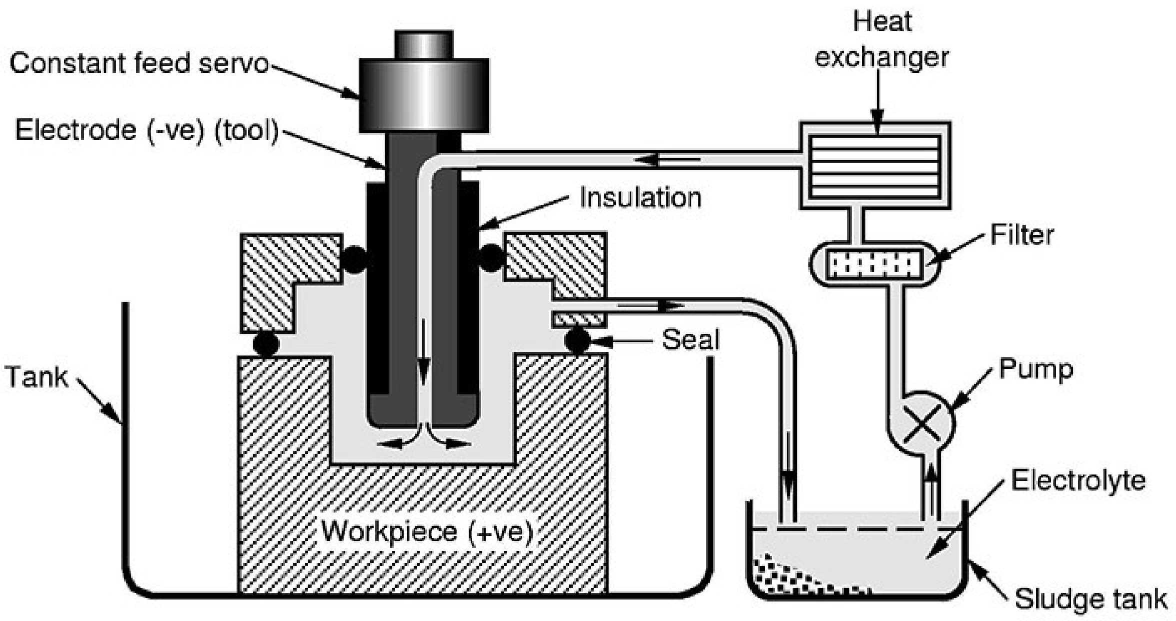
$$Fe \rightarrow Fe^{++} + 2e^-$$

- Within the Electrolyte, the sodium ions combine with Hydroxyl ions and form sodium hydroxide and ferrous ion combine with Chloride ions and forms ferrous chloride. Also iron ions combine with hydroxyl ions and form Iron hydroxide.

$$Na^+ + OH^- \rightarrow NaOH$$

$$Fe^{2+} + 2Cl^- \rightarrow FeCl_2 \downarrow$$

- In the electrolyte the FeCl2 and Fe(OH)2 produced and gets precipitated in the form of sludge and settle down. In this way material is removed from the work piece as sludge.



Schematic of the Electrochemical Machining process (ECM)

Main Equipment of ECM:

The ECM system has the following modules:

1. Power Supply
2. Electrolyte filtration and delivery system
3. Tool Feed system
4. Working Tank

Working Process:

- First, the work piece is assembled in the fixture and the tool is brought close to the work piece. The tool and work piece is immersed in a suitable electrolyte.
- After that, a potential difference is applied across the w/p (anode) and tool (cathode). The removal of material starts. The material is removed in the same manner as we have discussed above in the working principle.
- Tool feed system advances the tool towards the w/p and always keeps a required gap in between them. The material from the w/p comes out as positive ions and combine with the ions present in the electrolyte and precipitates as sludge. Hydrogen gas is liberated at the cathode during the machining process.
- Since the dissociation of the material from the w/p takes place at atomic level, so it gives excellent surface finish.
- The sludge from the tank is taken out and separated from the electrolyte. The electrolyte after filtration again transported to the tank for the ECM process.

Application:

- The ECM process is used for die sinking operation, profiling and contouring, drilling, grinding, trepanning and micro machining.
- It is used for machining steam turbine blades within closed limits.

Advantages:

- Negligible tool wear.
- Complex and concave curvature parts can be produced easily by the use of convex and concave tools.
- No forces and residual stress are produced, because there is no direct contact between tool and work piece.
- An excellent surface finish is produced.
- Less heat is generated.

Disadvantages:

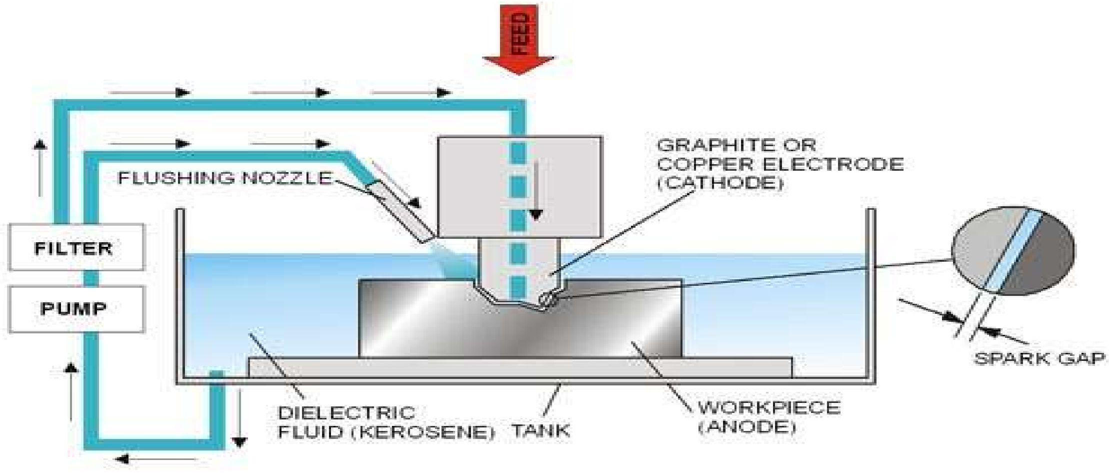
- The risk of corrosion for tool, w/p and equipment increases in the case of saline and acidic electrolyte.
- Electrochemical machining is capable of machining electrically conductive materials only.
- High power consumption.
- High initial investment cost.

ELECTRO DISCHARGE MACHINING PROCESS(EDM):

- Electrical Discharge Machining (EDM) is a non-traditional machining and electro thermal process in which material from the work piece is removed by using electrical discharges (sparks).
- It was first observed in 1770 by Joseph Priestley. He was an English physicist.
- In EDM machine the material is removed by rapidly recurring (repeating) discharges of current in between the electrodes. The electrodes are separated by dielectric liquid and a high voltage is applied across it.
- It is used to machine those materials which are difficult to machine and have high strength temperature resistance.
- EDM can be used to machine only electrically conductive materials. Otherwise it cannot be used.
- One of the electrodes is called as tool and other is called as work piece. Here the tool is connected with the negative terminal of the power supply and the work piece is connected with the positive terminal.

Working principle:

- In Electrical discharge machining; a potential difference is applied across the tool and w/p in pulse form.
- The tool and work piece must be electrically conductive and a small gap is maintained in between them. The tool and work piece is immersed in a dielectric medium (kerosene or deionized water).
- As the potential difference is applied, electrons from the tool start to move towards the work piece. Here the tool is negative and w/p is positive. The electrons moving from the tool to the w/p collide with the molecules of dielectric medium. Due to the collision of electrons with the molecule, it gets converted into ions.
- This increases the concentration of electrons and ions in the gap between the tool and w/p. The electron moves towards the w/p and ions towards the tool. An electric current is set up in between the tool and w/p and called as plasma.
- As the electrons and ions strikes the w/p and tool, its kinetic energy changes to heat energy. The temperature of the heat produced is about 10000 degrees Celsius. This heat vaporizes and melts the material from the work piece.
- As voltage is break down, the current stops to flow between the tool and w/p. And the molten material in the w/p is flushed by circulating dielectric medium leaving behind a crater.
- The spark generation is not continuous because constant voltage is not applied across the electrodes. The voltage is applied in pulse form.



Equipment:

- The various equipment used in Electrical Discharge Machining are:

1. Dielectric Reservoir, Pump and Circulating system

Pump is used to circulate the dielectric medium between the two electrodes (tool and work piece). Kerosene or deionized water is used as dielectric medium.

2. Power Generator and Control Unit

Generator is used to apply potential difference. The voltage used in this machining process is not constant but it is applied in pulse form. A control unit is used to control the different operation during machining process.

3. Working Tank with Work Holding Devices

It has working tank with a work holding device. The work piece is hold in the work holding devices. The tank contains dielectric medium.

4. Tool Holder

It is used to hold the tool.

5. Servo System to Move the Tool

A servo system is used to control the tool. It maintains the necessary gap between the electrodes (tool and work piece).

Working:

- In EDM, first the tool and w/p is clamped to the machine. After that with the help of a servo mechanism a small gap (of human hair) is maintain in between the tool and work piece.
- The tool and work piece is immersed in dielectric medium (kerosene of deionized water).
- A potential difference is applied across the Electrode. An electric spark is generated in between the tool and work piece. This spark generates a heat of about 10000 degrees Celsius. And due to this heat the material from the work piece starts to vaporize and melts.
- The spark generation in electrical discharge machining is not continuous. As the voltage breaks, the dielectric fluid flushes away the molten materials leaving behind a crater.
- This process keeps continue and machined the work piece.

Advantages:

- It can be used to machine any material that is electrically conductive.
- It can easily machine thin fragile sections such as webs or fins without deforming the part.
- Complex dies sections and molds are produced accurately, faster and at lower price.
- It is burr-free process.
- It does not involve contact between the tool and work piece. So delicate sections and work material can be machined easily without any distortion.
- It can have machined complex shapes which is not manufactured by the conventional machine tools.
- It can produce tapered holes.

Disadvantages:

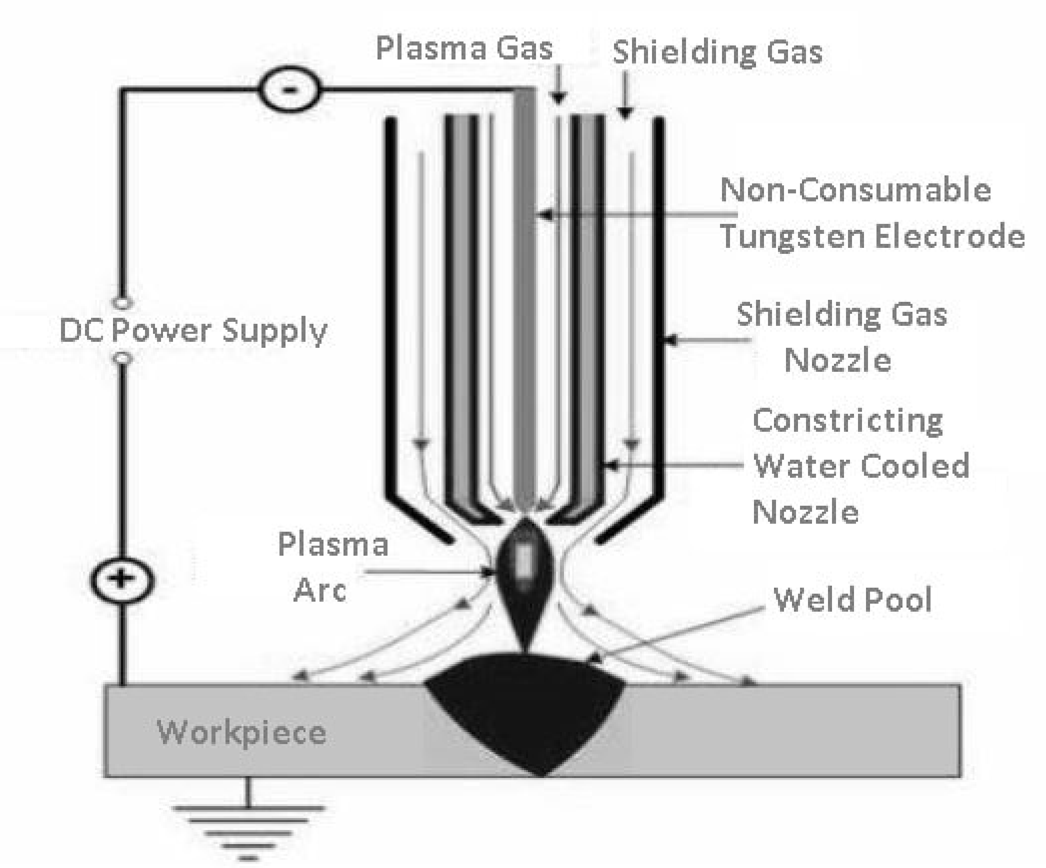
- It can machine only electrically conductive materials.
- Low rate of metal removal.
- More tool wear during machining.
- Takes extra cost and time for the preparing electrodes for ram/sinker EDM.
- High power consumption.
- Overcut is formed in EDM.

Application:

- It is mostly used by mold making and dies industries.
- It is used in prototype manufacturing in aerospace, automobile and electronic industries.
- It is used for coinage die making.
- It is used to create small holes in variety of application.
- It is used to disintegrate parts which cannot be disintegrate easily such as broken tools (studs, bolts drill bit and taps) form the work piece.

PLASMA ARC MACHINING PROCESS(PAM):

- When a gas or air heated at high temperatures, the number of collisions between atoms increases. When you heat the gas above 5500ºC, it partially ionizes into positive ions, negative ions and neutral ions.
- When you further heat the gas above 11000ºC then, it completely ionizes. Such a completely ionized gas is called Plasma. Plasma State lies in between temperatures 11,000ºC to 28,000ºC.
- Basically, Plasma Arc Machining (PAM) is a metal cutting process where metals are cut with plasma arc, tungsten-inert-gas arc or a torch. It is mostly used for the metals that cannot be cut by an oxyacetylene torch.
- In PAM, different gases are used according to different material. Different material means a work piece. Work piece may be made up of aluminum, iron or steel. For example, for aluminum nitrogen is used, for argon hydrogen is used. In most of the cases, nitrogen and hydrogen are used.
- Plasma Arc Welding employs a high-velocity jet of high-temperature gas to melt and displace material in its path.



Construction:

- Plasma arc machining consists of a Plasma gun. Plasma gun has an electrode made up of tungsten situated in the chamber.
- Here, this tungsten electrode is connected to the negative terminal of DC power supply. Thus, the tungsten acts as a cathode.
- While the positive terminal of DC power supply is connected to the nozzle. Thus, the nozzle of the plasma gun acts as an anode.

Working:

- As we give the power supply to the system, an electric arc develops between the cathode tungsten electrode and an anodic nozzle.
- As the gas comes in contact with the plasma, there is a collision between the atoms of gas and electrons of an electric arc and as a result, we get an ionized gas. That, means we get the plasma state that we wanted for Plasma Arc machining.
- Now, this plasma is targeted towards the work piece with a high velocity and the machining process starts. One thing to note down is that a high potential difference is applied in order to get the plasma state.
- In the whole process, high temperature conditions are required. As hot gases come out of nozzle there are chances of overheating. In order to prevent this overheating, a water jacket is used.

Following are some of the parameters involved in PAM that you must consider are:

- Current: Up to 500A
- Voltage: 30-250V
- Cutting speed: 0.1-7.5 m/min.
- Plate thickness: Up to 200mm
- Power require: 2 to 200 KW
- Material removal rate: 150 cm3/min
- Velocity of Plasma: 500m/sec
- Material of work piece: As previously stated, you can use any metal as material of work piece. For instance, aluminum and stainless steel are highly recommended for this process.

Advantages:

- In Plasma Arc Machining, hard as well as brittle metals can be easily machined.
- It can be applied to almost all types of metals.
- The best part of this process is that we get high cutting rate.
- We get a better dimensional accuracy in case of machining small cavities.
- It is a simple process to carry out and a very efficient process.
- It takes a big part in automatic repair of jet engine blades.

Disadvantages:

- PAM involves various equipment but the cost of this equipment is very high.
- This entire machining process consumes a high amount of inert gases.
- Production of narrower surfaces takes place which is unnecessary.
- The most harmful part of PAM is that metallurgical changes takes place on the surface.
- The operator or person handling the whole process must take proper precautions. This process can affect human eyes so a proper googles or helmet must be worn by an operator.

Application:

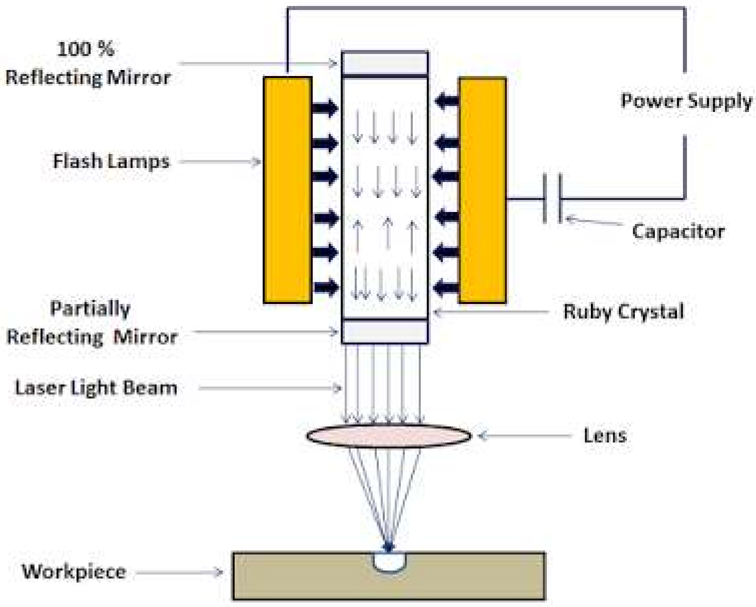
- It is mostly used for cryogenic, high temperature corrosion resistant alloys.
- It is also used in case of titanium plate up to 8mm thickness.
- PAM is used in nuclear submarine pipe system and for welding steel rocket motor case.
- PAM is prominent for the applications related to stainless tube and tube mills.

LASER BEAM MACHINING PROCESS(LBM):

- **Laser Beam Machining (LBM)** is a form of machining process in which laser beam is used for the machining of metallic and non-metallic materials.
- In this process, a laser beam of high energy is made to strike on the work piece, the thermal energy of the laser gets transferred to the surface of the w/p (work piece). The heat so produced at the surface heats, melts and vaporizes the materials from the w/p.
- Light amplification by stimulated emission of radiation is called **LASER**.

Working principle:

- It works on the principle that when a high energy laser beam strikes the surface of the work piece. The heat energy contained by the laser beam gets transferred to the surface of the w/p.
- This heat energy absorbed by the surface heat melts and vaporizes the material from the w/p. In this way the machining of material takes place by the use of laser beam.



Main parts:

- The various main parts used in the laser beam machining are:

1. **A pumping Medium**:
   A medium is needed that contains a large number of atoms. The atoms of the media are used to produce lasers.
2. **Flash Tube/Flash Lamp:**
   The flash tube or flash lamp is used to provide the necessary energy to the atoms to excite their electrons.
3. **Power Supply:**
   A high voltage power source is used to produce light in flashing tube.
4. **Capacitor**
   Capacitor is used to operate the laser beam machine at pulse mode.

5. **Reflecting Mirror:**

Two types of mirror are used, first one is 100 % reflecting and other is partially reflecting. 100 % reflecting mirror is kept at one end and partially reflecting mirror is at the other end. The laser beams come out from that side where partially reflecting mirror is kept.

Production of laser:

- A high voltage power supply is applied across the flash tube. A capacitor is used to operate the flash tube at pulse mode.
- As the flash is produced by the flash tube, it emits light photons that contain energy.
- These light photons emitted by the flash tube is absorbed by the ruby crystal. The photons absorbed by the atoms of the ruby crystals excite the electrons to the high energy level and population inversion (situation when the number of exited electrons is greater than the ground state electrons) is attained.
- After short duration, these excited electrons jump back to its ground state and emits a light photon. This emission of photon is called spontaneous emission,
- The emitted photon stimulates the excited electrons and they start to return to the ground state by emitting two photons. In this way two light photons are produced by utilizing a single photon. Here the amplification (increase) of light takes place by stimulated emission of radiation.
- Concentration of the light photon increases and it forms a laser beam.
- 100 % reflecting mirror bounces back the photons into the crystal. Partially reflecting mirror reflects some of the photons back to the crystal and some of it escapes out and forms a highly concentrated laser beam. A lens is used to focus the laser beam to a desired location.

Working of LBM:

- A very high energy laser beam is produced by the laser machines. This laser beam produced is focused on the work piece to be machined.
- When the laser beam strikes the surface of the w/p, the thermal energy of the laser beam is transferred to the surface of the w/p. this heats, melts, vaporizes and finally removes the material form the work piece. In this way laser beam machining works.

Advantages:

- It can be focused to a very small diameter.
- It produces a very high amount of energy, about 100 MW per square mm of area.
- It is capable of producing very accurately placed holes.
- Laser beam machining has the ability to cut or engrave almost all types of materials, when traditional machining process fails to cut or engrave any material.
- Since there is no physical contact between the tool and work piece. The wear and tear in this machining process is very low and hence it requires low maintenance cost
- This machining process produces object of very high precision. And most of the object does not require additional finishing
- It can be paired with gases that help to make cutting process more efficient. It helps to minimize the oxidation of w/p surface and keep it free from melted of vaporized materials. Produces a very high energy of about 100 MW per square mm of area.
- It has the ability to engrave or cut almost all types of materials. But it is best suited for the brittle materials with low conductivity.

Disadvantages:

- High initial cost. This is because it requires many accessories which are important for the machining process by laser.
- Highly trained worker is required to operate laser beam machining machine.
- Low production rate since it is not designed for the mass production.
- It requires a lot of energy for machining process.
- It is not easy to produce deep cuts with the w/p that has high melting points and usually cause a taper.
- High maintenance cost.

Application:

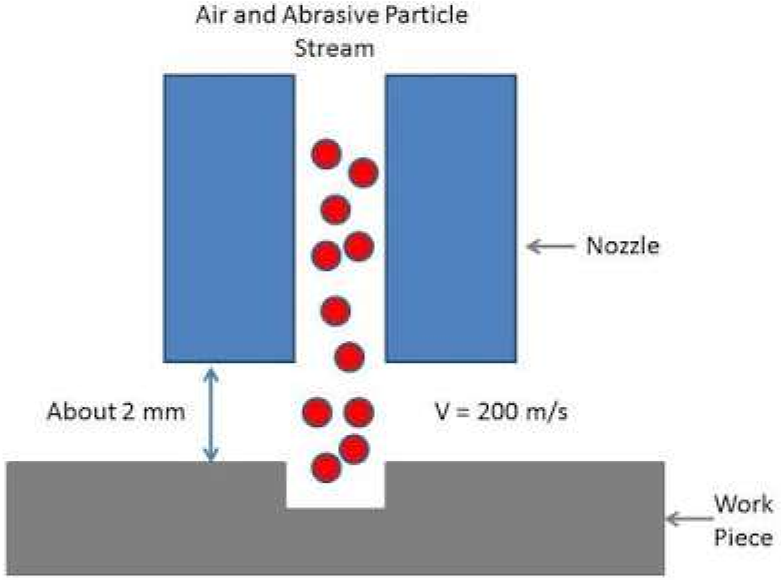
- The laser beam machining is mostly used in automobile, aerospace, shipbuilding, electronics, steel and medical industries for machining complex parts with precision.
- In heavy manufacturing industries, it is used or drilling and cladding, seam and spot welding among others.
- In light manufacturing industries, it is used for engraving and drilling other metals.
- In the electronic industry, it is used for skiving (to join two ends) of circuits and wire stripping.
- In medical industry, it is used for hair removal and cosmetic surgery.

ABRASIVE JET MACHINING PROCESS(AJM):

- Abrasive jet machining is a non-traditional machining process which is mostly used in machining of hardened metals.
- In this machining process a focus stream of abrasive particles are forces to impinge on work piece at high velocity. These high velocity abrasive particles remove metal by brittle fracture or erosion from work piece.

Principle:

- This machining process works on the basic principle of abrasive erosion.
- If a high velocity abrasive particles strike on a hard or brittle work piece, it removes some metal at the striking surface. This metal removal process takes place due to brittle fracture of metal and also due to micro cutting by abrasive particle.
- This is principle process of abrasive jet machining.



Abrasive Jet Machining

Major equipment:

1. **Gas Propulsion System:**

The main purpose of gas propulsion system is to provide clean and dry, high velocity air or gas for machining. Mostly air, carbon dioxide, Nitrogen etc. are used as gas in gas propulsion system. This system consists, compressor, air filter and drier. The gas used in this system should easily available. First gas is compressed into a compressor. This compressed gas sends to filler and drier where all dust and unwanted particle along with moisture remove from it. Now these clean air send to mixing chamber.

2. **Abrasive feeder:**

As the name implies, abrasive feeder is used to provide abrasive particles in mixing chamber. It is fed through a sieve which vibrates at 50-60 Hz and mixing ratio is control by the vibration of the sieve and its amplitude.

3. Abrasive:

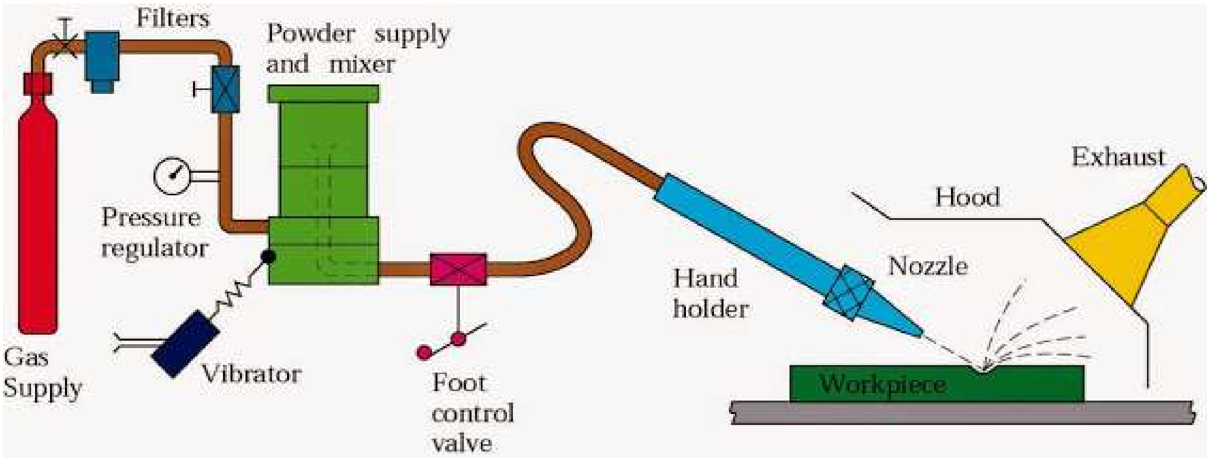
These are the main particles which take part in machining process. These particles should have high metal removal rate and accuracy. The most common abrasive particles used are aluminum oxide, silicon carbide, boron carbide etc. The selection of abrasive particle is depending upon material of work piece, speed of machining, and machining environment.

4. Cutting Nozzle:

To direct the abrasive particle on work piece cutting nozzles are used. They are usually made by tungsten carbide. They are available in both circular and square cross section. Its life is usually low about 30 hours for tungsten carbide.

5. Machining Chamber:

It is fully closed air tight chamber witch control the concentration of abrasive particle around work piece. This is equipped with a vacuum dust collector which collect used abrasive particle and removed material from mixing chamber.



Working principle:

The basic concept of abrasive jet machining is abrasive erosion or metal cutting by high velocity abrasive particle. Its working process can be easily summarized into following point.

- First gas or air is compressed into gas compressor. There the density and pressure of gas increases.
- Now this compressed gas sends to filtration unit, where dust and other suspended particle removed from it.
- This clean gas sends to drier, which absorb moisture from it. It is used to avoid water or oil contamination of abrasive power.
- Now this clean and dry gas sends to mixing chamber where abrasive feeder feed abrasive particle in it. The abrasive particle is about 50 micro meter grit size.
- This high pressuring abrasive carried gas send to nozzle where its pressure energy converted into kinetic energy. The velocity of abrasive particle leaving the nozzle is about 200m/s.
- The standoff distance between work piece and nozzle is about 2mm.

- Now these high velocity abrasive particles impinge on work piece. These high velocity abrasive particles remove the material by micro cutting action as well as brittle fracture of the work material.

Advantages:

- High surface finish.
- It can machine heat sensitive material.
- It is free from vibration
- Initialization cost is low compare to other non-traditional processes.
- Thin section can be machined easily.

Disadvantages:

- Low metal removal rate.
- Abrasive particle can have embedded into work piece mostly in soft metals.
- Nozzle life is limited so it needs frequently replacement.
- Abrasive particle cannot be reuse in this process.
- It cannot use for machine soft and ductile material.

Application:

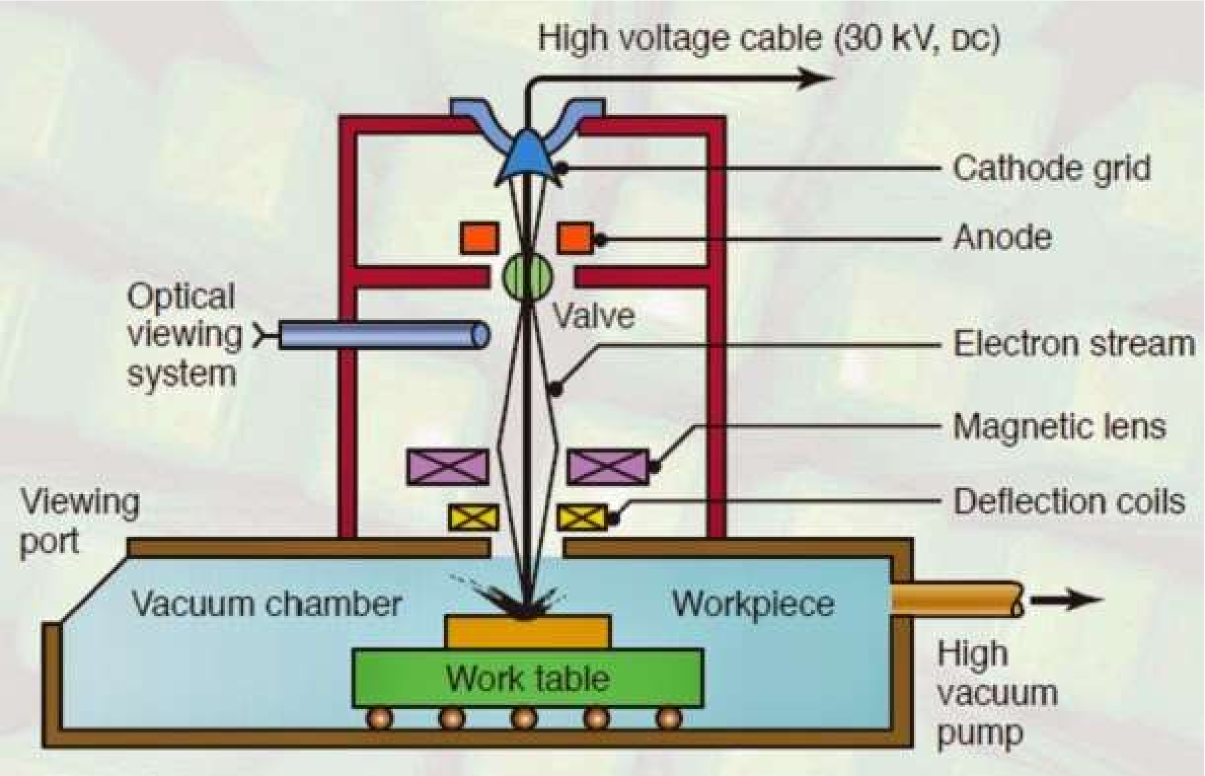
- It is used in drilling and cutting of hardened metals.
- It is used for machining brittle and heat sensitive material like glass, quartz, sapphire, mica, ceramic etc.
- It is Use to manufacture electronic devices.
- It is used in deburring small holes and some critical zones in machine parts.

ELECTRON BEAM MACHINING PROCESS(EBM):

- It is a non-traditional machining process in which no physical tool is used.
- Electron beam machining is same as laser beam machining process in which except laser, high speed electron beam impinges on work piece.
- This will generate high heat energy and melts and vaporize metal from work piece. This whole process takes place in vacuum chamber. It is mostly used to drill holes in any shape.

Principle:

- This machining process works on basic principle of conversion of kinetic energy of electron into heat energy.
- When a high speed electron impinges on a work piece, they convert its kinetic energy into heat energy.
- This heat energy used to vaporize material at contact surface. This process is carried out in vacuum otherwise the electron will collide with air particle and loses its energy before impinging on work material. This is basic principle of EBM machining.



Major equipment:

1. **Electron Gun:**

It is called heart of electron beam machining. It is used to generate electron. It is simply a cathode ray tube which generates electron, accelerate them to sufficient velocity and focus them at small spot size. In this gun cathode is made by tungsten or tantalum. This cathode filament heated up to 2500 degree centigrade which accelerate to electron emission by thermionic reaction. There is very low vacuum in the chamber.

2. Annular Bias Grid:

It is next element of EBM. It is just after the electron gun. It is an anode which is connected by the negative bias so the electron generated by the cathode do not diverge from its path and approach to the next element. When the electrons leave this section, the velocity of electron is almost half the velocity of light.

3. Magnetic Lenses:

After the anode, magnetic lenses are provided which shape the beam and does not allow to diverge electron or reduce the divergence of beam. These lenses allow to pass only convergent electron; thus a high focused beam is obtained. They also capture low energy electron, thus increase the quality of beam.

4. Electromagnetic lens and deflection coil:

Electromagnetic lens is used to focus the electron beam at a spot. They use to focus beam at a spot on work piece so a high intense beam reaches at work surface, which produces more heat and improve machining. The defecting coil does not allow to beam deflect and take care of all electrons moves in series thus form a high intense beam.

5. Work piece and work holding device:

It can machine both metallic and non-metallic material. The work piece is hold by suitable fixture which is mounted on a CNC table. This table can be move in all three directions which control the shape of machining.

Working principle:

- First electron gun produces high velocity electron particles. These electron particles move towards anode which is placed after cathode tube.
- Now this high intense electron beam passes through magnetic lenses. There are a series of lenses which take care of only convergent electron passes through it. It absorbs all divergent electron and low energy electron. It provides a high quality electron beam.
- This electron beam now passes through electromagnetic lens and deflecting coil. It focuses the electron beam at a spot.
- The high intense electron beam impinges on the work piece where kinetic energy of electrons converts into thermal energy.
- The material is removed from contact surface by melting and vaporization due to this high heat generated by conversion of kinetic energy into thermal energy. This whole process take place in a vacuum chamber otherwise these electrons collide with air particle between path and loses its kinetic energy.

Advantages:

- It can be used for produce very small size hole in any shape.
- It can machine any material irrespective its hardness and other mechanical properties.
- It provides good surface finish. No any surface finishing process is requiring after EBM.
- Highly reacting material can be machine easily because machining is done under vacuum.

Disadvantages:

- High capital cost.
- High skill operator required.
- Low material removal rate.
- Regular maintenance is required
- Material removal rate is very low compare to other conventional process.
- It is difficult to produce perfect vacuum.

Application:

- It is used to produce very small size hole about 100 micro meters to 2 millimeters.
- It is used to produce holes in diesel injection nozzle.
- Used in aerospace industries for producing turbine blade for supersonic engines and in nuclear reactors.

Module-2

AUTOMATION:

- The word 'Automation' is derived from Greek words "Auto" (self) and "Matos" (moving). Automation therefore is the mechanism for systems that "move by itself'. However, apart from this original sense of the word, automated systems also achieve significantly superior performance than what is possible with manual systems, in terms of power, precision and speed of operation.

Definition:

- Automation is a set of technologies that results in operation of machines and systems without significant human intervention and achieves performance superior to manual operation.
- Automation of production systems can be classified into three basic types:
    - Fixed automation (Hard Automation)
    - Programmable automation
    - Flexible automation (Soft Automation)

1. Fixed automation (Hard automation):

Fixed automation refers to the use of special purpose equipment to automate a fixed sequence of processing or assembly operations. Each of the operation in the sequence is usually simple, involving perhaps a plain linear or rotational motion or an uncomplicated combination of two. For example, feeding of a rotating spindle. It is relatively difficult to accommodate changes in the product design. This is also called hard automation.

Advantages:

- Low unit cost
- Automated material handling
- High production rate

Disadvantages:

- High initial Investment
- Relatively inflexible in accommodating product changes

2. Programmable automation:

In programmable automation, the production equipment is designed with the capability to change the sequence of operations to accommodate different product configurations. The operation sequence is controlled by a program, which is a set of instructions coded. So that they can be read and interpreted by the system. New programs can be prepared and entered into the equipment to produce new products. Examples of programmable automation include numerically controlled (NC) machine tools, industrial robots, and programmable logic controllers.

Advantages:

- Flexible to deal with design variation
- Suitable for batch production.

Disadvantages:

- High investment in general purpose equipment
- Lower production rate than fixed automation

3. Fixed automation (Soft automation):

Flexible automation is an extension of programmable automation. A flexible automation system is capable of producing a variety of parts with virtually no time lost for changeovers from one-part style to the next. There is no lost production time while reprogramming the system and altering the physical set up. Examples of flexible automation are the flexible manufacturing systems for performing machining operations.

Advantages:

- Continuous production of variable mixtures of product
- Flexible to deal with product design variation.

Disadvantages:

- Medium production rate
- High investment
- High 'unit cost relative to fixed automation.

Need of Automation:

- **To increase labor productivity:** Automating a manufacturing operation usually increases production rate and labor productivity. This means greater output per hour of labor input.
- **To reduce labor cost:** Higher investment in automation has become economically justifiable to replace manual operations. Machines are increasingly being substituted for human labor to reduce unit product cost.
- **To improve worker safety:** By automating a given operation and transferring the worker from active participation in the process to a supervisory role, the work is made safer. The safety and physical well-being of the worker has become a national objective which has achieved through automation.
- **To improve product quality:** Automation not only results in higher production rates than manual operations, it also performs manufacturing process with great uniformity and conformity to quality specification.
- **To reduce manufacturing lead lime:** Automation helps to reduce the elapsed time between customer order and product delivery, providing a competitive advantage to the manufacturer for future orders. By reducing manufacturing lead time, the manufacturer also reduces work-in-process inventory

Module-3

NUMERICAL CONTROL(NC):

- Numerical control of machine tool may be defined as methods of programmable automation in which various function of the machine tool are controlled by letters, numbers and symbols. Basically an NC machine runs on a program fed to it. The program consists of instruction about the method of what tool are to be used, at what speed, at what feed and to move from which point to point in which path etc. Since program is the controlling point for product manufacturing, the machine becomes versatile and can be used for any part. All the function of an NC machine tool is therefore controlled electronically, hydraulically and pneumatically.
- In NC machines tool one or more of the following functions may be automatic:

  a) Starting and stopping of machine-tool spindle

  b) Controlling the spindle speed

  c) Positioning the tool at desired locations

  d) Controlling the rate of movement of the tool tip (i.e. feed rate)

  e) Changing of tool in spindle

- Numerical control can be applied to a wide variety of processes. The application is generally divided into two categories

  a) Machining tool application such as drilling, milling, turning, grinding etc.

  b) Non machine tool application such as assembly, drafting and inspection.

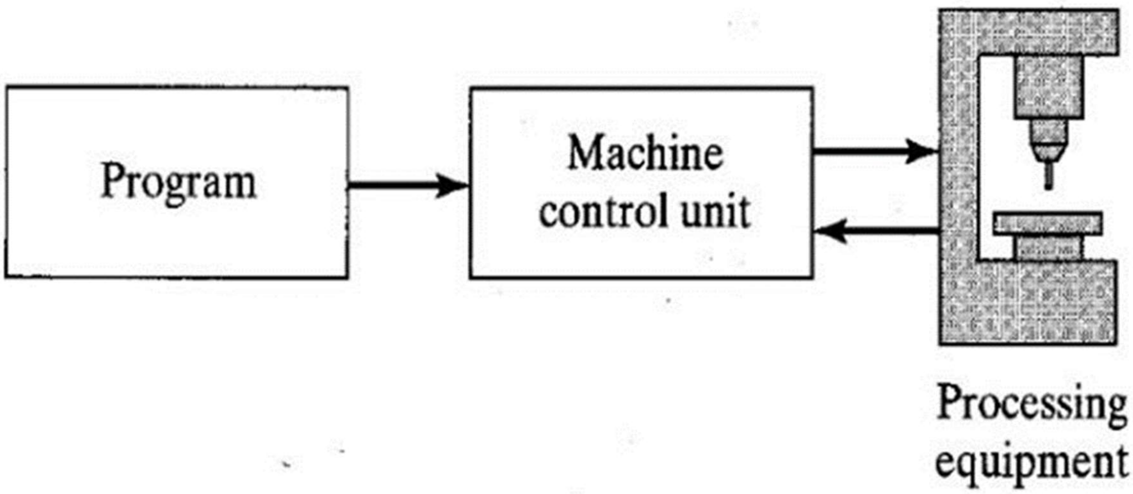
Basic component of an NC system:

- An NC system consists of three basic components

  I. A program of instruction

  II. Machine control unit (MCU)

  III. Processing Equipment or Machine tool



I. **Program of instruction:**

- The program of instruction is the detailed step by step commands that direct the processing equipment. In machine tool applications, the program of instruction is called a part program and the person who prepares the program is called a part programmer. The program is coded in numerical or symbolic form on some type of input medium that can be interpreted by the controller unit. For many years, the common input medium was 1-inch wide punch tape. Today punch tape has been replaced by newer storage technologies in modern machine shops. These technologies include magnetic tape, diskettes and electronic transfer of part programs from a computer.

II. **Machine control unit (MCU):**

- It is the second basic component of NC system. The machine control unit (MCU) consists of a microcomputer and related control hardware that store the program of instruction and executes it by converting each command into mechanical actions of the processing equipment one command at a time. The related hardware of the MCU includes components to interface with the processing equipment and feedback control element. The typical element of MCU includes the tape reader, a data buffer, signal output channel and feedback channel.
- The tape reader is an electro mechanical device for winding and reading the punched tape containing the program of instruction. The data contained on the tape are reads into the data buffer. The signal output channels are connected to the servo motors and other controls in the processing equipment. Through these channels, the instructions are sending to the processing equipment from the machine tool unit.

III. **Processing equipment:**

- The third basic component of an NC system is the processing equipment that performs useful work. Its operation is directed by MCU, which in turn is driven by instruction contained in the part program. In the common example of NC machining the processing equipment consists of work table and spindle as well as the motors and controllers to drive them. Varity of machining operation means that a verity of cutting tool is required. The tool is kept in a tool drum or other holding devices, when the tape called a particular tool the drum rotates to position the tool for inserting into the spindle chuck. The machining table or worktable can orient the job so that it can be machined o several surface as per requirement.

Different steps used in NC manufacturing or The NC procedure:

1. **Process planning:**

   It is concerned with the preparation of a route sheet. The route sheet is a listing of the sequence of operation which must be performed on the work piece. It is called a rout sheet because it also lists the machine through which the part must be routed in order to accomplish the sequence of operation.

2. **Part programming:**

   A part programmer plans the process for the portion of the job to be accomplished by NC. Part programming is the sequence of machining steps to be performed by NC. There are two ways to program for NC.

   I. Manual part programming
   II. Computer assisted part programming

3. **Tape Preparation:**

   A punch tape is prepared from the part programmers NC process plan. In manual part programming, punch tape is prepared directly from the part program manuscript or a typewriter like device equipped with tape punching capabilities. In computer assisted part programming the computer interprets the list of part programming instruction performs the necessary calculation to convert into a detail set of machine tool motion commands.

4. **Tape verification:**

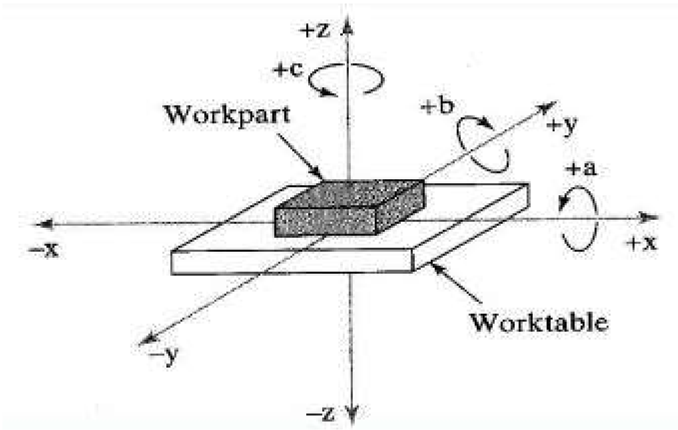
   After punch tape has been prepared, a method is usually provided for checking the accuracy of tape. Sometimes the tape is checked by running it through a computer program which plots the various tool movements on paper.

5. **Production:**

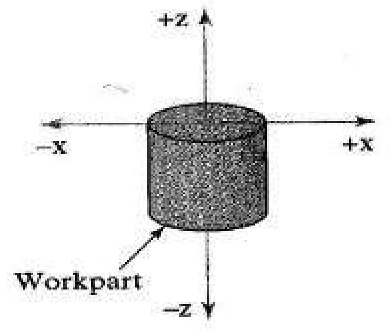
   The final step in NC procedure is to use NC tape in production. The machine tool operator's function during production is to load raw work piece in machine. The NC system then takes over and machined the part according to the instruction on tape. When the part is completed the operator removes it from the machine and loads the next part.

NC coordinate system:

- To program NC processing equipment, a standard axes system must be defined by which the position of the cutting tool related to the work piece can be specified. There are two axis system used in NC.
  I. For flat and prismatic work part
  II. For rotational parts
- Both axis systems are based on Cartesian coordinate system. Axes system for flat and prismatic parts consists of three linear axes (x, y, z) and three rotational axes (a, b, c) as shown in fig. below,



- The coordinate axes for a rotational NC system are illustrated in the figure below,



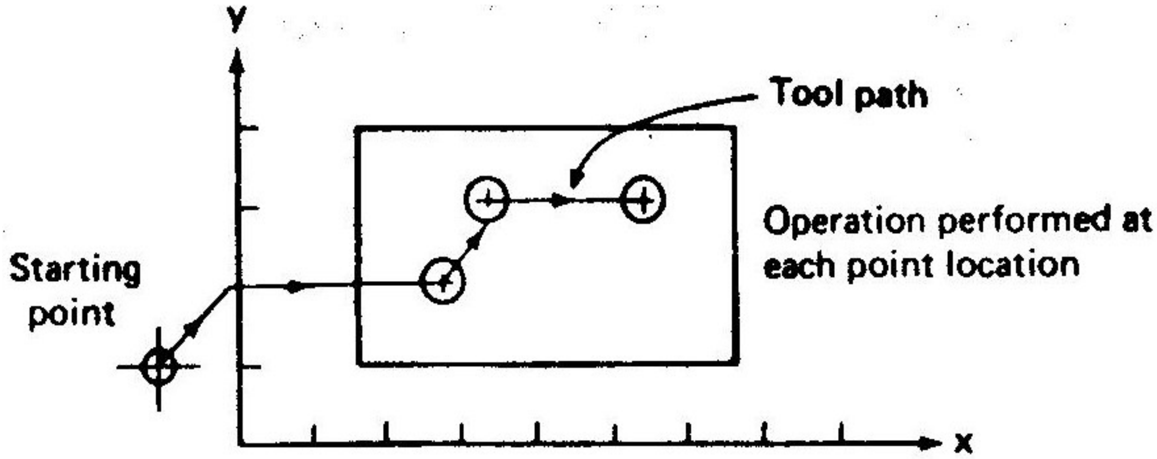
- These systems are associated with NC lathes and turning centers. Although the work rotates, this is not one of the controlled axes on most of these turning machines. Consequently, the y- axis is not used. The path of the cutting tool relative to the rotating work piece is defined in the x-z plane, where the x-axis is the radial location of the tool, and the z-axis is parallel to the axis of rotation of the part.

NC motion control system:

- In order to accomplish machining process, cutting tool and work piece must be moved relative to each other. In NC there are three basic types of motion control system:
  I. Point-to-Point(PTP)
  II. Straight cut
  III. Contouring
- Point-to-point systems represent the lowest level of motion control between the tool and work piece. Contouring represents the highest level of control.

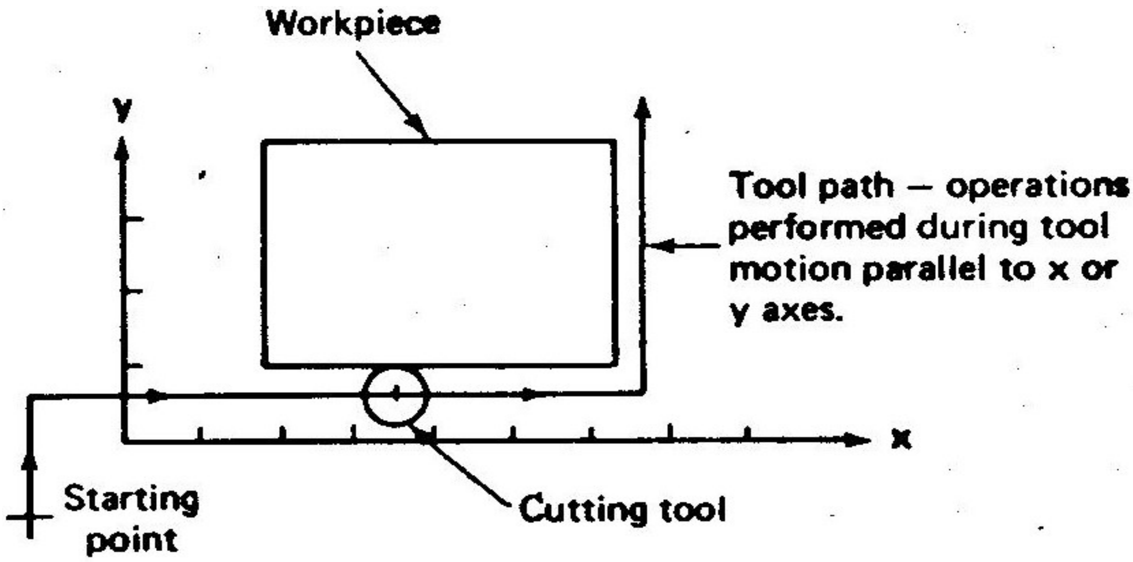
I. **Point-to-point control:**

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. Each tool axis is controlled independently, therefore; the programmed motion always in rapid traverse. Once the tool reaches the desired location, the machining operation is performed at that position. NC drill presses are a good example of PTP systems. The spindle must first be positioned at a particular location on the work piece. This is done under PTP control.



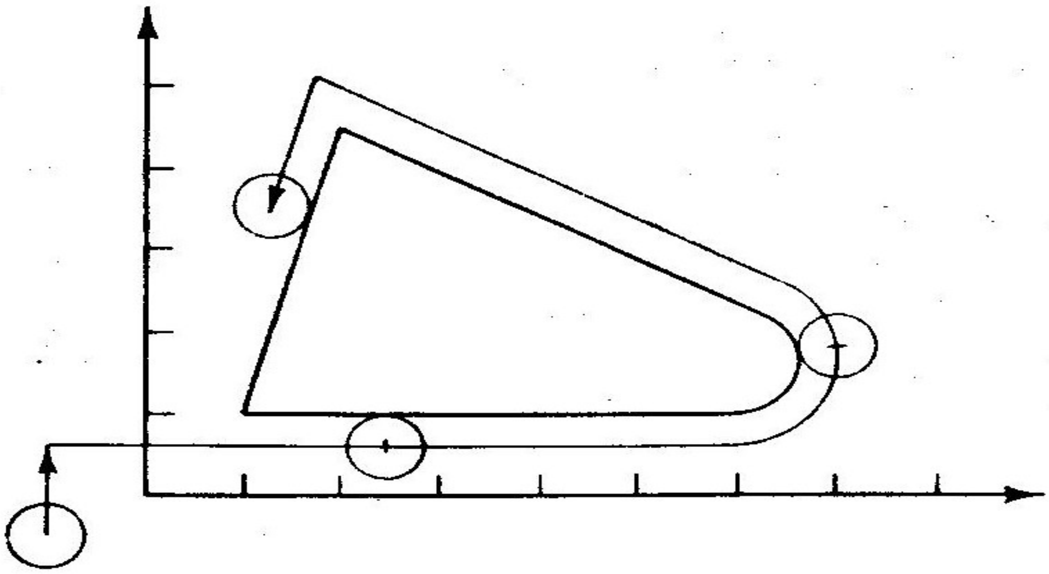
II. **Straight cut:**

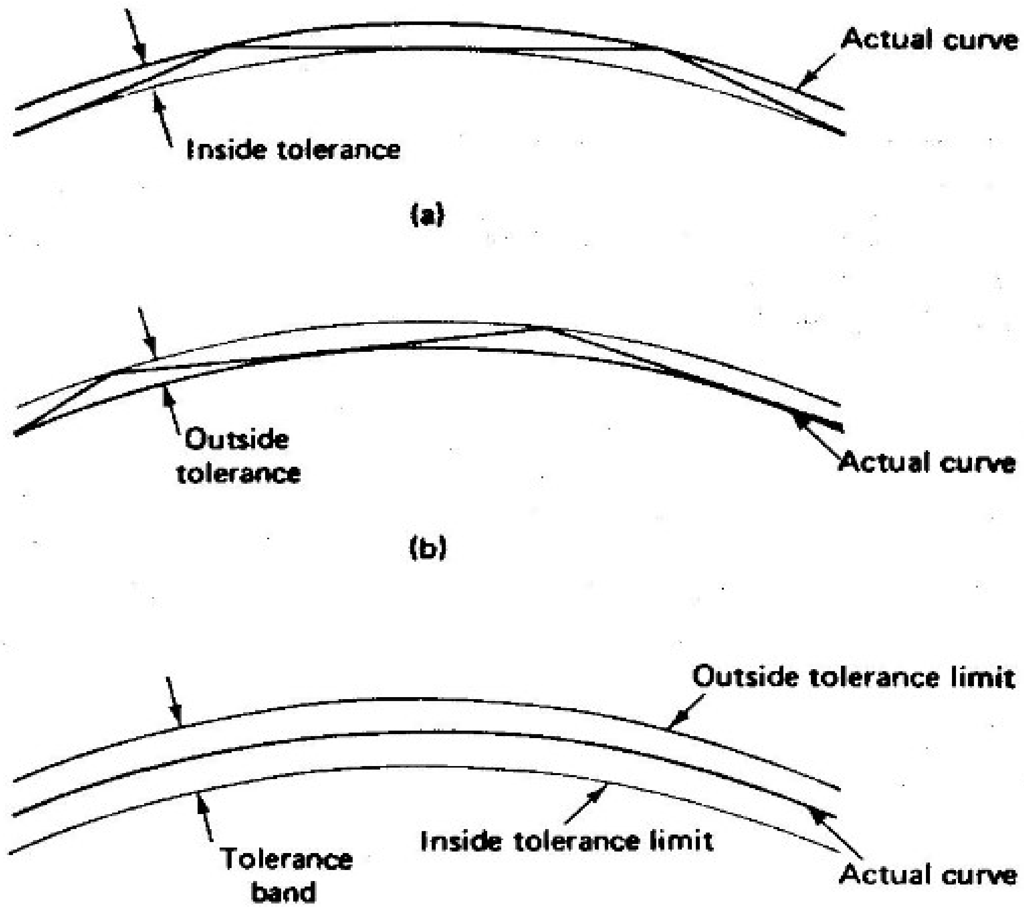
Positioning systems are the simplest machine tool control systems and are therefore the least expensive of the three types. However, for certain processes, such as drilling operations, tapping, riveting and spot welding, PTP is perfectly suitable. Straight-cut control systems are capable of moving the 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 work piece of rectangular configurations. An example of a straight cut operation is shown in the figure below. An NC machine capable of straight cut movements is also capable of PTP movements.



III. Contouring:

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 work piece. For this reason, contouring systems are also called continuous-path NC systems. Straight or plane surfaces at any orientation, circular paths, conical shapes, or most any other mathematically definable form are possible under contouring control. Figure illustrates the versatility of continuous-path NC. Milling and turning operations are common examples of the use of contouring control.





Advantages of NC system:

- **Reduce non productive time:** It reduce nonproductive time in NC machine tools in the following ways:
  - By reducing set up time
  - By reducing work piece handling time
  - By reducing tool changing time

  Due to reduction in nonproductive time the production of machine increases.
- **Greater accuracy and repeatability:** Compared with manual production methods, NC reduces or eliminates variations that are due to operator skill differences, fatigue, and other factors attributed to inherent human variability. Parts are made closer to nominal dimensions, and there is less dimensional variation among parts.
- **Inspection requirement are reduced:** Less inspection is needed when NC is used because parts produced from the same NC part program are virtually identical. Once the program has been verified, there is no need for the high level of sampling inspection.
- **More-complex part geometries are possible:** NC technology has extended the range of possible part geometries beyond with manual machining methods. This is an advantage in product design in several ways: (I) More functional features can he designed into a single part, thus reducing the total number of parts in the product and the associated cost of assembly (2) mathematically defined surfaces can be fabricated with high precision and (3) the space is expanded within which the designer's imagination can wander to create new part and product geometries.

- **Reduce Fixturing:** NC requires fixture which are simpler and less costly to fabricate because the positioning is done by the NC tapes rather than by jigs and fixture.
- **Reduce manufacturing lead time:** As the job can be set up more quickly with NC and few steps are generally required with NC. The lead time to deliver a job to the customer is reduced.
- **Reduced floor space requirements:** Since one NC machine center can often accomplish the production of several conventional machines, the amount of floor space required in an NC shop is usually less than a conventional shop

Disadvantages of NC system:

- **Higher initial investment:** The cost of NC machine tool is much higher compared to conventional machining tool. The cost is often 5 to 10 times and also the cost of tool is high so there is very high initial investment. All these make the machine hourly rate high. As a result, it is necessary to utilize the machine tool for a large percentage of time.
- **Higher maintenance cost:** As NC is a complex and sophisticated technology it requires higher investment foe maintenance in terms of wages of highly skilled personnel and expensive spares.
- **Part programming:** NC equipment must be programmed. To be fair it should be mentioned that process planning must be accomplished for any part whether or not it is produced on NC equipment. However, NC part programming is a special preparation step in batch production that is absent in conventional machine shop operations.
- **Higher utilization of NC equipment:** To maximize the economic benefits of an NC machine tool, it usually must he operated multiple shifts. This might mean adding one or two extra shifts to the plants normal operations, with the requirement for supervision and other staff support.

Application of NC system:

- Parts with complicated contours.
- Parts requiring close tolerance and/or good repeatability,
- Its parts requiring expensive jigs and fixtures if produced on conventional machines.
- Parts can undergo many engineering changes, such as during the development phase of a prototype.
- In cases where human errors could be extremely costly Parts that are needed in a hurry.
- Small batch lots or short production runs.

NC PART PROGRAMMING:

- The part program is a sequence of instructions, which describe the work, which has to be done on a part, in the form required by a computer under the control of a numerical control computer program.
- It is the task of preparing a program sheet from a drawing sheet. All data is fed into the numerical control system using a standardized format.
- Programming is where all the machining data are compiled and where the data are translated into a language which can be understood by the control system of the machine tool.
- The machining data is as follows:
    - Machining sequence classification of process, tool start up point, cutting depth, tool path, etc.
    - Cutting conditions, spindle speed, feed rate, coolant, etc.
    - Selection of cutting tools.

- While preparing a part program, need to perform the following steps:
  - Determine the startup procedure, which includes the extraction of dimensional data from part drawings and data regarding surface quality requirements on the machined component.
  - Select the tool and determine the tool offset.
  - Set up the zero position for the work piece.
  - Select the speed and rotation of the spindle.
  - Set up the tool motions according to the profile required.
  - Return the cutting tool to the reference point after completion of work.
  - End the program by stopping the spindle and coolant.
- The part programming contains the list of coordinate values along the X, Y and Z directions of the entire tool path to finish the component.
- The program should also contain information, such as feed and speed. Each of the necessary instructions for a particular operation given in the part program is known as an NC word.
- A group of such NC words constitutes a complete NC instruction, known as block. The commonly used words are N, G, F, S, T, and M.
- Hence the methods of part programming can be of two types depending upon the two techniques as below:
  - Manual part programming, and
  - Computer aided part programming.

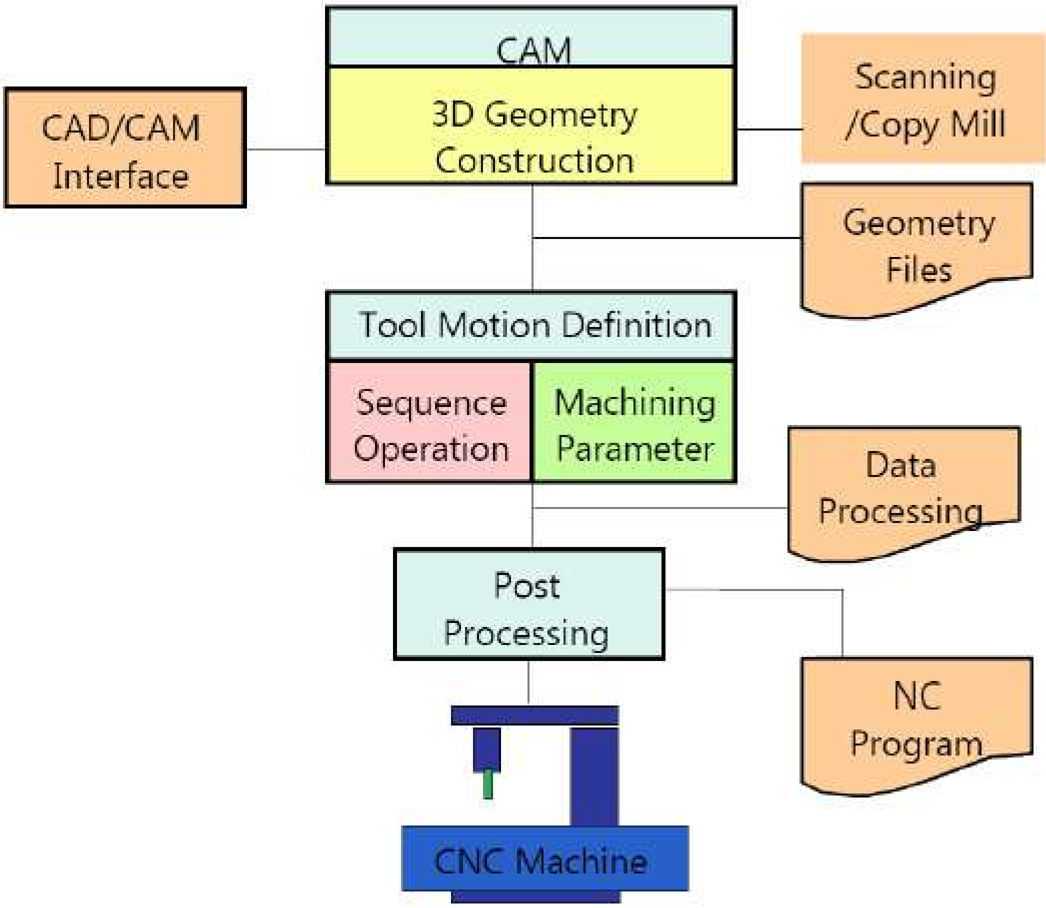
Manual part programming:

- The programmer first prepares the program manuscript in a standard format. Manuscripts are typed with a device known as flexo writer, which is also used to type the program instructions.
- After the program is typed, the punched tape is prepared on the flexo writer. Complex shaped components require tedious calculations.
- This type of programming is carried out for simple machining parts produced on point-to-point machine tool.
- To be able to create a part program manually, need the following information:
  - Knowledge about various manufacturing processes and machines.
  - Sequence of operations to be performed for a given component.
  - Knowledge of the selection of cutting parameters.
  - Editing the part program according to the design changes.
  - Knowledge about the codes and functions used in part programs.

Computer aided part programming:

- If the complex-shaped component requires calculations to produce the component are done by the programming software contained in the computer.
- The programmer communicates with this system through the system language, which is based on words.
- There are various programming languages developed in the recent past, such as APT (Automatically Programmed Tools), ADAPT, AUTOSPOT, COMPAT-II, 2CL, ROMANCE, SPLIT is used for writing a computer program, which has English like statements.
- A translator known as compiler program is used to translate it in a form acceptable to MCU.

- The programmer has to do only following things:
  - Define the work part geometry.
  - Defining the repetition work.
  - Specifying the operation sequence.

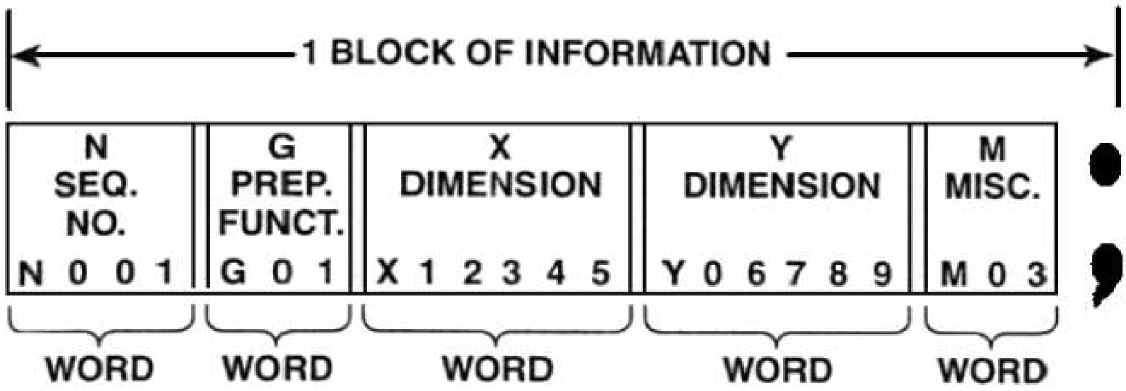


NC words:

- The NC word is a unit of information, such as a dimension or feed rate and so on.
- A block is a collection of complete group of NC words representing a single NC instruction. An end of block symbol is used to separate the blocks.
- NC word is where all the machining data are compiled and where the data are translated in to a language, which can be understood, by the control system of the machine tool.

Block of information:

- NC information is generally programmed in blocks of words.
- Each word conforms to the EIA standards and they are written on a horizontal line.
- If five complete words are not included in each block, the machine control unit (MCU) will not recognize the information; therefore, the control unit will not be activated. It consists of a character N followed by a three-digit number raising from 0 to 999.



- Using the example shown in Figure, the words are as follows:
  - N001 – represents the sequence number of the operation.
  - G01 – represents linear interpolation.
  - X12345 – will move the table in a positive direction along the X-axis.
  - Y06789 – will move the table along the Y-axis.
  - M03 – Spindle on CW and
  - ; – End of block.

<u>Standard G codes & M codes:</u>

- The most common codes used when programming NC machines tools are G-codes (preparatory functions), and M codes (miscellaneous functions).
- Other codes such as F, S, D, and T are used for machine functions such as feed, speed, cutter diameter offset, tool number, etc.
- G-codes are sometimes called cycle codes because they refer to some action occurring on the X, Y, and/or Z-axis of a machine tool.

<u>G-Codes (Preparatory Functions):</u>

- The total numbers of these codes are 100, out of which some of important codes are given as under with their functions:

Code	Function
G00	Rapid positioning
G01	Linear interpolation
G02	Circular interpolation clockwise (CW)
G03	Circular interpolation counterclockwise (CCW)
G20	Inch input (in.)
G21	Metric input (mm)
G24	Radius programming
G28	Return to reference point
G29	Return from reference point

G32	Thread cutting
G40	Cutter compensation cancel
G41	Cutter compensation left
G42	Cutter compensation right
G43	Tool length compensation positive (+) direction
G44	Tool length compensation minus (-) direction
G49	Tool length compensation cancels
G 53	Zero offset or M/c reference
G54	Settable zero offset
G84	Canned turn cycle
G90	Absolute programming
G91	Incremental programming

*Note: On some machines and controls, some may differ.

M-Codes (Miscellaneous Functions):

- M or miscellaneous codes are used to either turn ON or OFF different functions, which control certain machine tool operations.
- M-codes are not grouped into categories, although several codes may control the same type of operations such as M03, M04, and M05, which control the machine tool spindle. Some of important codes are given as under with their function s:

Code	Function
M00	Program stop
M02	End of program
M03	Spindle start (forward CW)
M04	Spindle start (reverse CCW)
M05	Spindle stop
M06	Tool change
M08	Coolant on
M09	Coolant off
M10	Chuck - clamping
M11	Chuck - unclamping
M12	Tailstock spindle out
M13	Tailstock spindle in

M17	Tool post rotation normal
M18	Tool post rotation reverse
M30	End of tape and rewind or main program end
M98	Transfer to subprogram
M99	End of subprogram

*Note: On some machines and controls, some may differ.

Tape Programming Format:

- Both EIA and ISO use three types of formats for compiling of NC data into suitable blocks of information with slight difference.

Word Address Format:

- This type of tape format uses alphabets called address, identifying the function of numerical data followed. This format is used by most of the NC machines, also called variable block format. A typical instruction block will be as below:

N20 G00 X1.200 Y.100 F325 S1000 T03 M09 <EOB>

or

N20 G00 X1.200 Y.100 F325 S1000 T03 M09;

- The MCU uses this alphabet for addressing a memory location in it.

Tab Sequential Format:

- Here the alphabets are replaced by a Tab code, which is inserted between two words. The MCU reads the first Tab and stores the data in the first location then the second word is recognized by reading the record Tab. A typical Tab sequential instruction block will be as below:

>20 >00 >1.200 >.100 >325 >1000 >03 >09

Fixed Block Format:

- In fixed block format no letter address of Tab code are used and none of words can be omitted. The main advantage of this format is that the whole instruction block can be read at the same instant, instead of reading character by character. This format can only be used for positioning work only. A typical fixed block instruction block will be as below:

20 00 1.200 .100 325 1000 03 09 <EOB>

Machine Tool Zero Point Setting:

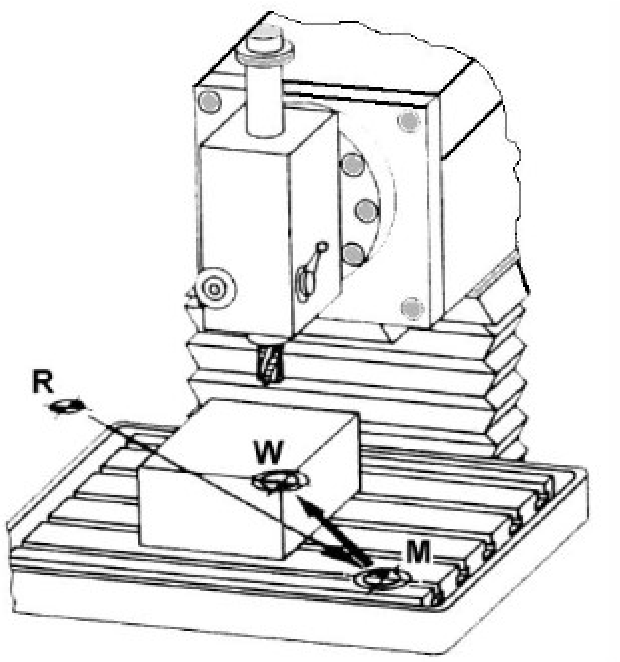
- The machine zero point can be set by two methods by the operator, manually by a programmed absolute zero shift, or by work coordinates, to suit the holding fixture or the part to be machined.

Manual Setting:

- The operator can use the MCU controls to locate the spindle over the desired part zero and then set the X and Y coordinate registers on the console to zero.

Absolute Zero Shift:

- The absolute zero shift can change the position of the coordinate system by a command in the CNC program. The programmer first sends the machine spindle to home zero position by a command in the program. Then another command tells the MCU how far from the home zero location, the coordinate system origin is to be positioned.



(Machine tool zero-point setting)

R = Reference point (maximum travel of machine)

W = Part zero-point work piece coordinate system

M = Machine zero point (X0, Y0, Z0) of machine coordinate system

The sample commands may be as follows:

N1 G28 X0 Y0 Z0 (sends spindle to home zero position or Return to reference point).

N2 G92 X3.000 Y4.000 Z5.000 (the position the machine will reference as part zero or Programmed zero shift).

Coordinate Word:

- A co-ordinate word specifies the target point of the tool movement or the distance to be moved. The word is composed of the address of the axis to be moved and the value and direction of the movement.

Example:

X150 Y-250 represents the movement to (150, -250). Whether the dimensions are absolute or incremental will have to be defined previously using G-Codes.

Parameter for Circular Interpolation:

- These parameters specify the distance measured from the start point of the arc to the center. Numerals following, ***I, J*** and ***K*** are the ***X***, ***Y*** and ***Z*** components of the distance respectively.

Spindle Function:

- The spindle speed is commanded under an S address and is always in revolution per minute. It can be calculated by the following formula:

$$Spindle\ speed = \frac{Surface\ cutting\ speed\ in\ m/min\ \times\ 1000}{\pi\ \times\ Cutter\ Diameter\ in\ mm}$$

  Example: S1000 represents a spindle speed of 1000 rpm.

Feed Function:

- The feed is programmed under an *F* address except for rapid traverse. The unit may be in mm per minute or in mm per revolution. The unit of the federate has to be defined at the beginning of the program. The feed rate can be calculated by the following formula:

$$Feed\ rate = \frac{Chip\ load}{Tooth \times no.of\ tooth \times spindle\ speed}$$

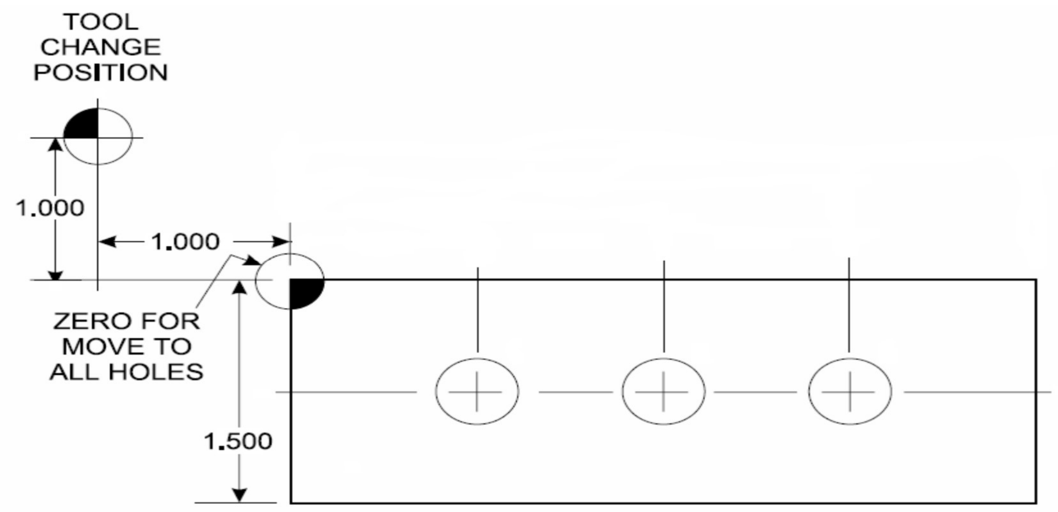
  Example: F100 represents a feed rate of 100 mm/min.

Tool Function:

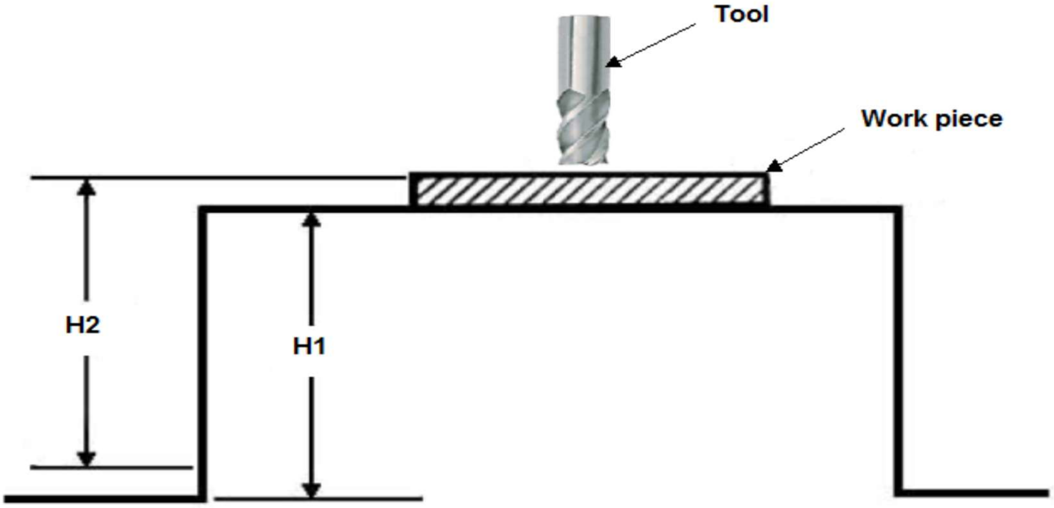
- The selection of tool is commanded under a *T* address. T04 represents tool number 4.

Work settings & offsets:

- All NC machine tools require some form of work setting, tool setting, and offsets to place the cutter and work in the proper relationship.
- Compensation allows the programmer to make adjustments for unexpected tooling and setup conditions.
- A retraction point in the *Z*-axis to which the end of the cutter retracts above the work surface to allow safe table movement in the *X*-*Y* axes. It is often called the rapid-traverse distance, retract or work plane.
- When setting up cutting tools, the operator generally places a tool on top of the highest surface of the work piece.
- Each tool is lowered until it just touches the work piece surface and then its length is recorded on the tool list. Once the work piece has been set, it is not generally necessary to add any future depth dimensions since most MCU do this automatically.



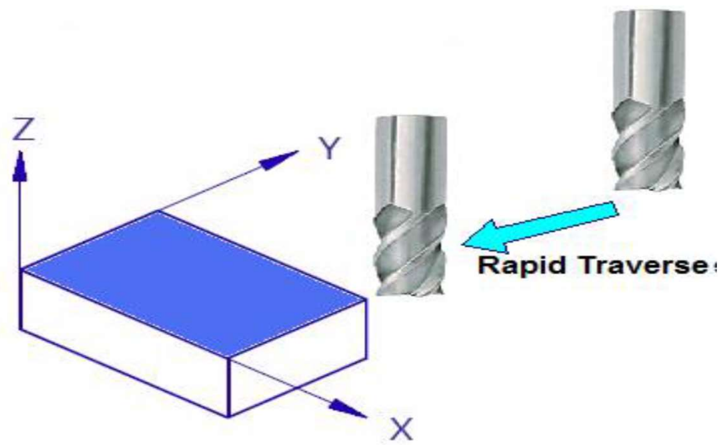
(Work setting)



(Offsets)

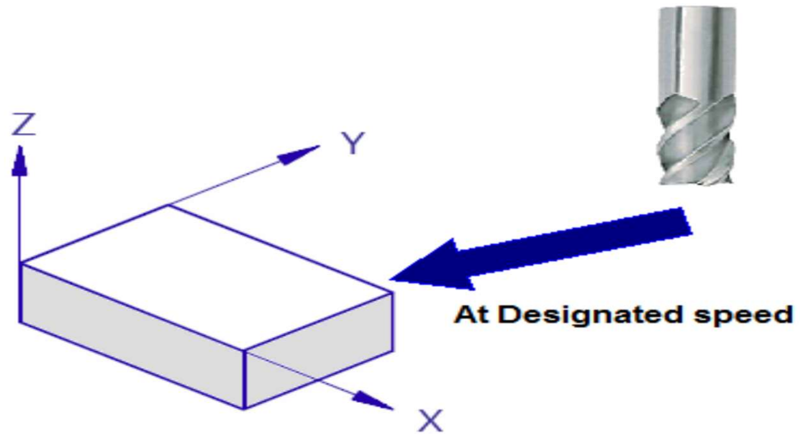
Rapid Positioning:

- This is to command the cutter to move from the existing point to the target point at the fastest speed of the machine.



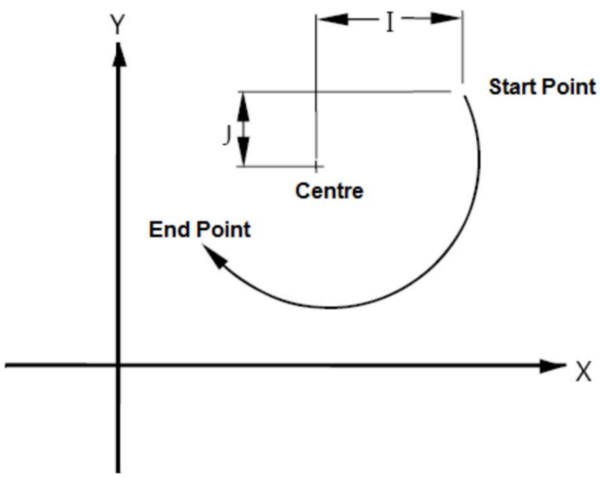
Linear Interpolation:

- This is to command the cutter to move from the existing point to the target point along a straight line at the speed designated by the *F* address.

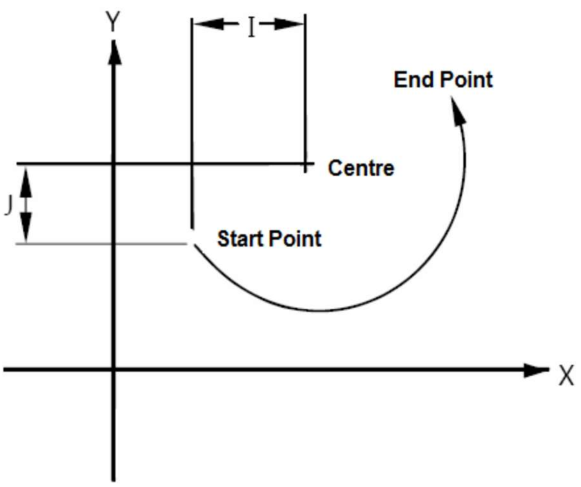


Circular Interpolation:

- This is to command the cutter to move from the existing point to the target point along a circular arc in clockwise direction or counter clockwise direction. The parameters of the center of the circular arc is designated by *I*, *J* and *K* addresses. I is the distance along the *X*-axis, *J* along the *Y*, and *K* along the *Z*. This parameter is defined as the vector from the starting point to the center of the arc.



(Circular interpolation CW)



(Circular interpolation CCW)

Symbols used:

% – Main Program (1 to 9999)
L – Sub program (1 to 999)/Home position
N – Sequence of block number
Lf – Block end (EOB) means "; or *"
T – Tool number or Tool station number
D – Tool offset
S – Spindle speed
F – Feed
M – Switching function
G – Transverse commands

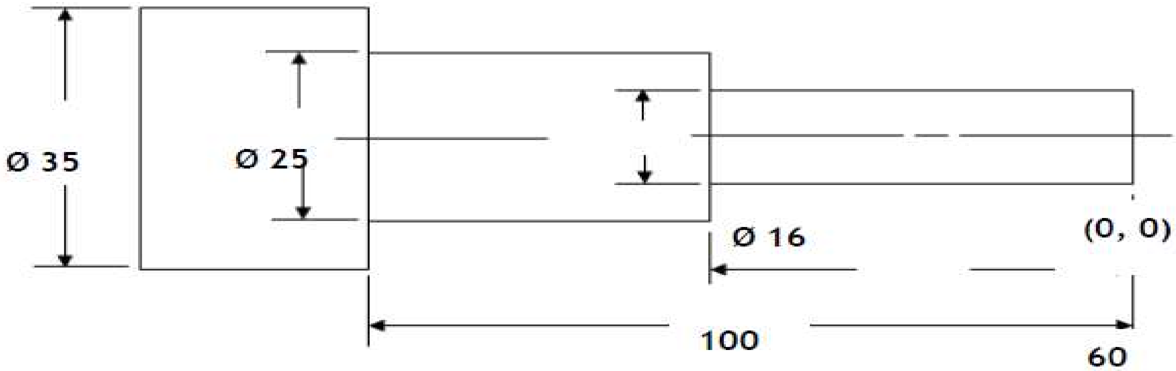
R – Parameters
I, J, K – Circle parameters
B/U/R – Radius
X/Y/Z – Axis coordinates
P – Passes

Simple part program for lathe:

- The CNC lathe operation such as simple facing, turning, taper turning, thread, boring, parting off etc. The X-axis and Z-axis are taken as the direction of transverse motion of the tool post and the axis of the spindle respectively. To prepare part programs using G-codes and M-codes. The following examples illustrated the part program for different components.

Example:

01 (All dimensions are in mm).



(Turning operation)

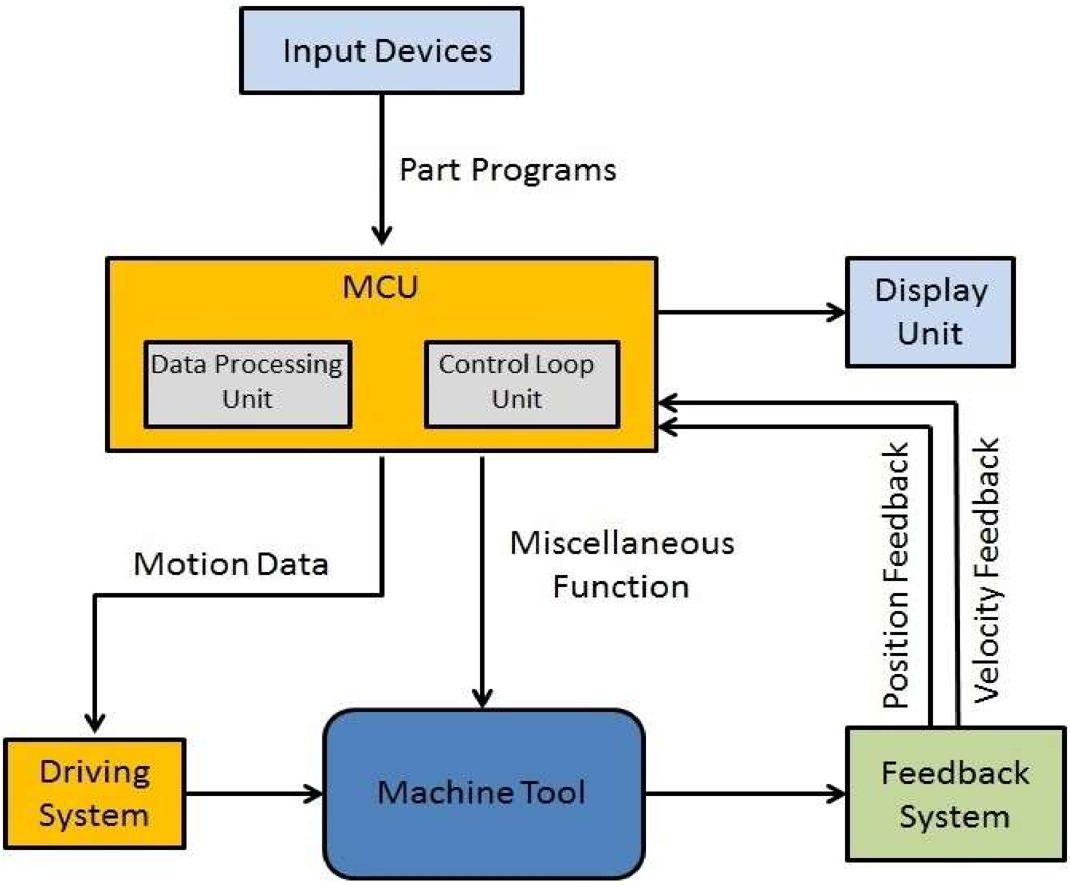
% 1000;	(Main program)
N01 G54 G90 G71 G94 M03 S800;	(Parameters Setting)
N05 G01 X-12.5 Z0 F2;	(Facing the job)
N10 G00 Z1;	(Retrieval of tool)
N15 G00 X00;	(Tool clearance)
N20 G01 Z-100;	(Starting cut)
N25 G00 X1 Z1;	(Clearance position)
N30 G00 X-2;	(Position of cut)
N35 G01 Z-60;	(Cutting length)
N40 G00 X-1 Z1;	(Retrieval of tool)
N45 G00 X-3;	(Position of cut)
N50 G01 Z-60;	(Cutting length)
N55 G00 X-2 Z1;	(Retrieval of tool)
N60 G00 X-4;	(Position of cut)
N65 G01 Z-60;	(Cutting length)
N70 G00 X-3 Z1;	(Retrieval of tool)
N75 G00 X-4.5;	(Position of cut)
N80 G01 Z-60;	(Cutting length)
N85 G00 X5 Z5;	(Final position of tool)
N90 M02;	(End of program)

COMPUTER NUMERICAL CONTROL(CNC):

- Computer Numerical Control (CNC) is one in which the functions and motions of a machine tool are controlled by means of a prepared program containing coded alphanumeric data.
- CNC can control the motions of the work piece or tool, the input parameters such as feed, depth of cut, speed, and the functions such as turning spindle on/off, turning coolant on/off.

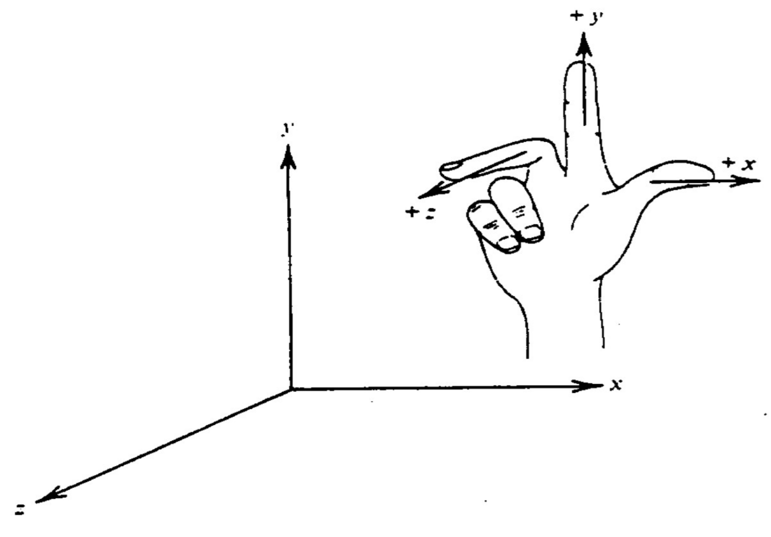
Elements of CNC:

- A CNC system consists of three basic components which are as follows:
  1. Part program
  2. Machine Control Unit(MCU)
  3. Machine tool



1. **Part program:**
   - The part program is a detailed set of commands to be followed by the machine tool.
   - Each command specifies a position in the Cartesian coordinate system (x, y, z) or motion (work piece travel or cutting tool travel), machining parameters and on/off function.
   - Part programmers should be well versed with machine tools, machining processes, effects of process variables, and limitations of CNC controls.
   - The part program is written manually or by using computer assisted language such as APT (Automated Programming Tool).

2. **Machine Control Unit(MCU):**
   - The machine control unit (MCU) is a microcomputer that stores the program and executes the commands into actions by the machine tool.
   - The MCU consists of two main units:
     i. Data processing unit (DPU)
     ii. Control loops unit (CLU)
   - The DPU software includes control system software, calculation algorithms, translation software that converts the part program into a usable format for the MCU, interpolation algorithm to achieve smooth motion of the cutter, editing of part program (in case of errors and changes).
   - The DPU processes the data from the part program and provides it to the CLU which operates the drives attached to the machine leadscrews and receives feedback signals on the actual position and velocity of each one of the axes.
   - A driver (dc motor) and a feedback device are attached to the leadscrew.
   - The CLU consists of the circuits for position and velocity control loops, deceleration and backlash take up, function controls such as spindle on/off.
3. **Machine tool:**
   - The machine tool could be one of the following: lathe, milling machine, laser, plasma, Co-ordinate measuring machine etc.
   - The figure shows that a right-hand coordinate system is used to describe the motions of a machine tool.
   - There are three linear axes (x, y, z), three rotational axes (i, j, k), and other axes such as tilt (θ) are possible. For example, a 5-axis machine implies any combination of x, y, z, i, j, k, and θ.



Incremental & absolute system:

- CNC systems are further divided into incremental and absolute systems.
- In incremental mode, the distance is measured from one point to the next.
- An absolute system is one in which all the moving commands are referred from a reference point (zero point or origin).

- The absolute system has two significant advantages over the incremental system:
    i. Interruptions caused by, for example, tool breakage (or tool change, or checking the parts), would not affect the position at the interruption.
    ii. Easy change of dimensional data.
- The incremental mode has two advantages over the absolute mode:
    i. Inspection of the program is easier because the sum of position commands for each axis must be zero.
    ii. Mirror image programming (for example, symmetrical geometry of the parts) is simple by changing the signs of the position commands.

Open loop control system:

- The open-loop control means that there is no feedback and uses stepping motors for driving the leadscrew.
- A stepping motor is a device whose output shaft rotates through a fixed angle in response to an input pulse.
- The accuracy of the system depends on the motor's ability to step through the exact number.
- The frequency of the stepping motor depends on the load torque.
- The higher the load torque, lower would be the frequency.
- Excessive load torque may occur in motors due to the cutting forces in machine tools. Hence this system is more suitable for cases where the tool force does not exist (Example: laser cutting).

Close loop control system:

- Closed-loop NC systems are appropriate when there is a force resisting the movement of the tool/work piece. Milling and turning are typical examples.
- In these systems the DC servomotors and feedback devices are used to ensure that the desired position is achieved.
- The encoder consists of a light source, a photodetector, and a disk containing a series of slots. The encoder is connected to the leadscrew.
- As the screw turns, the slots cause the light to be seen by the photodetector as a series of flashes which are converted into an equivalent series of electrical pulses which are then used to characterize the position and the speed.
- The equations remain essentially the same as open-loop except that the angle between the slots in the disk is the step angle.

Advantages:

- The benefits of CNC system are,
    - High accuracy in manufacturing
    - Short production time
    - Greater manufacturing flexibility
    - Simpler fixturing
    - Contour machining (2 to 5 axis machining)
    - Reduced human error

Disadvantages:

- The limitations of the CNC system are,
    - High cost
    - Maintenance
    - Requirement of high skilled part programmer

Application:

- The applications of CNC include both for machine tool as well as non-machine tool areas.
- In the machine tool category, CNC is widely used for lathe, drill press, milling machine, grinding unit, laser, sheet-metal press working machine, tube bending machine etc.
- Highly automated machine tools such as turning center and machining center which change the cutting tools automatically under CNC control have been developed.
- In the non-machine tool category, CNC applications include welding machines (arc and resistance), coordinate measuring machine, electronic assembly, tape laying and filament winding machines for composites etc.

DIRECT NUMERICAL CONTROL(DNC):

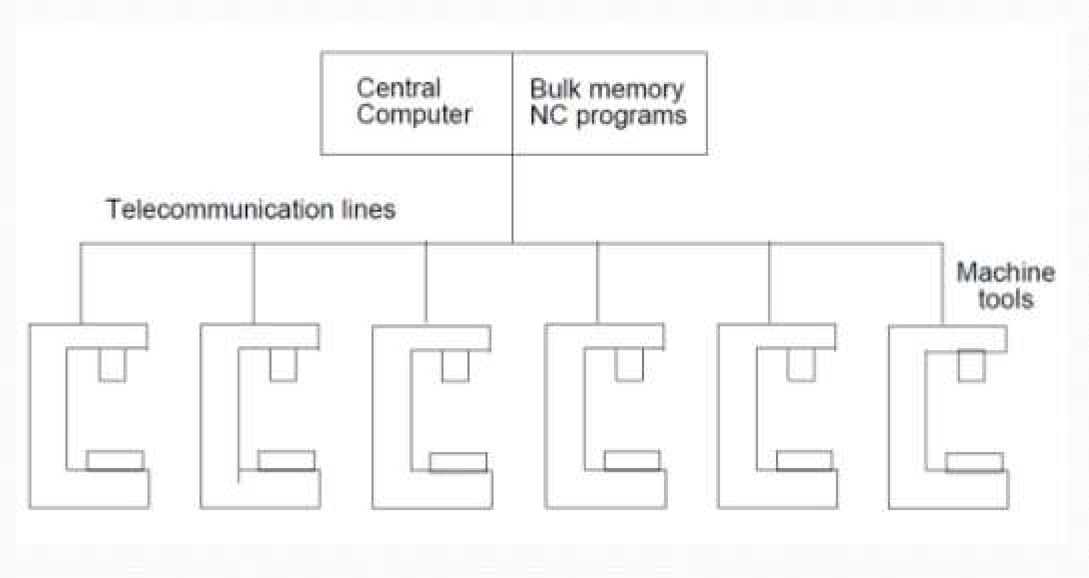
- Early NC machines used a tape reader for storing and inputting the program into the memory of the NC machine tool. Because of the unreliability of the tape reader as well as the low speed of operation NC engineers were searching for a suitable alternative.
- DNC is a manufacturing system in which a number of machines are controlled by a computer through direct- connection and in real time.
- Also, defined by EIA as: DNC is a system connecting a set of NC machines to a common memory for part program or machine program storage with provision for on- demand distribution of data to machines.
- The tape reader is omitted.
- Involves data connection and processing from the machine tool back to the computer.

Components of DNC:

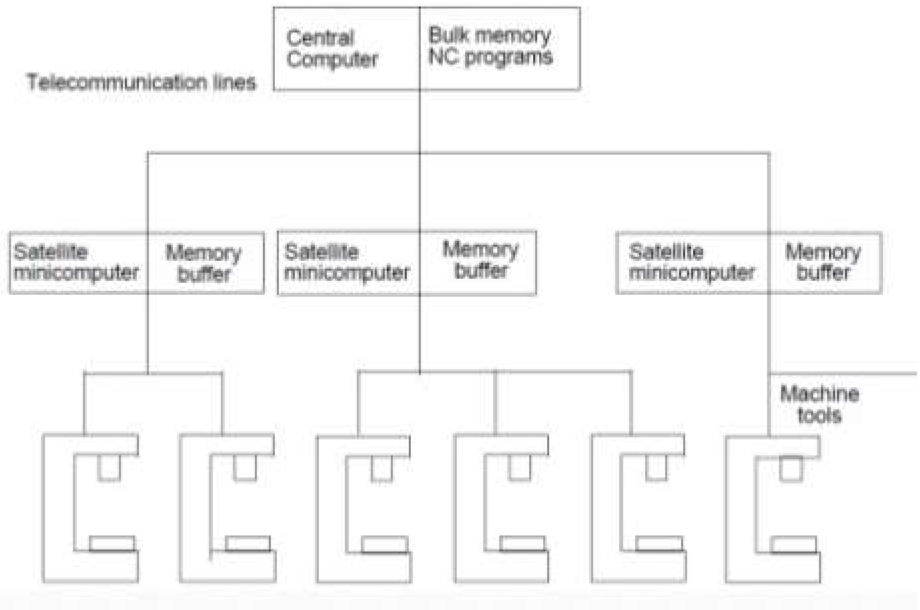
1. Central computer
2. Bulk memory which stores NC part program
3. Telecommunication lines
4. Machine tools

- In DNC system,
    i. A number of NC machines can be connected to a single computer. In many cases a single computer can manage all the machines on a shop floor.
    ii. Programs in full or in segments can be transferred to the NC machines in a multiplexing mode.
    iii. The computer can be conveniently used for program editing.
    iv. Since the computer has large memories there is no limitation on the number or size of programs stored.
    v. The computer can be used for other tasks like program creation using computer aided part program generation software as well as for operation management tasks like production planning, scheduling etc.
- With the development of CNC, DNC concept was extended to CNC machines also mainly for part program management.

- The DNC computer (sometimes referred to as host computer) could serve a number of CNC machines in shop floor.
- The figure shows a typical DNC network. The DNC computer stores all the part programs and transfers the part programs to the CNC machines in response to the requests of the operators.



- The configuration of the DNC system can be divided into:
  1. DNC system without satellite computer.
  2. DNC system with satellite computer.
- Satellite computers are minicomputers and they serve to take some of the burden off central computer. Each satellites controls several machine tools.



Types of DNC:

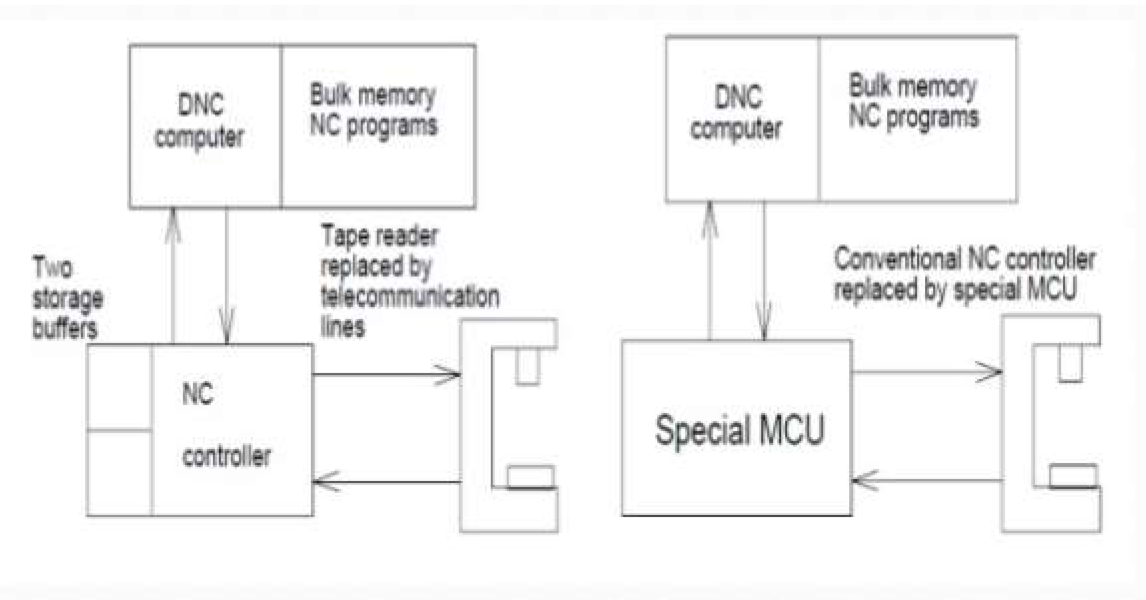
- There are two types of DNC systems are there, which are as follows,
    1. Behind the Tape Reader (BTR) system
    2. Special Machine Control Unit

Behind the Tape Reader (BTR) system:

- The computer is linked directly to the regular NC controller unit.
- Except for the source of the command instructions, the operation of the system is very similar to conventional NC.
- The controller unit uses two temporary storage buffers to receive blocks of instructions from the DNC computer and convert them into machine actions.
- One buffer is receiving a block of data, the other is providing control instructions to machine tool.
- This system's cost is very less.

Special Machine Control Unit:

- It replaces the regular controller unit with a special machine control unit.
- The special control unit is designed to facilitate communication between the machine tool and the computer.
- The special MCU configuration achieve a superior balance between accuracy of the interpolation and fast metal removal rates than is generally possible with the BTR system.



Functions of a DNC system:

- The functions of a DNC system can be summarized as below:
    i. **Part Program management:** Part program stored in the hard disc can be routed to appropriate machines in the network depending upon the schedule.
    ii. **Shop floor editing:** Program can be edited or modified to take into account design changes, tool changes or machine changes.
    iii. **Shop floor graphics:** The tool path simulation can be carried out on the shop floor.

iv. **Data collection:** The DNC computer can be used for shop floor data collection for scheduling and monitoring.

v. **Shop scheduling:** Since NC program dispatch is interlinked with the schedule, the DNC computer can be used for scheduling.

vi. **Statistical Process Control (SPC):** The SPC function can be integrated into the working of the DNC computer as it can be interfaced with the shop floor data collection function.

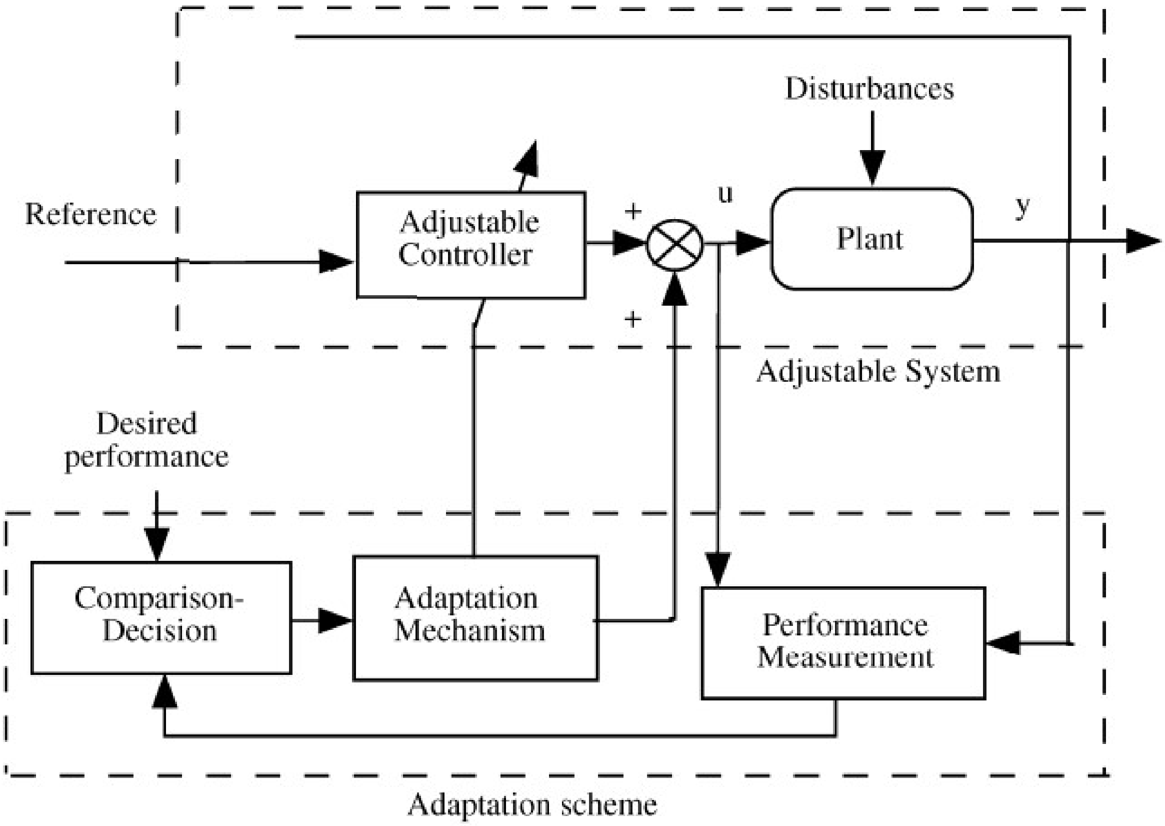
vii. **Tool offset management:** Tool offset data is sent to appropriate machine by this function.

Advantages:

- There are various advantages provided by DNC system.
- These are as follows:
    1. Easy and Effective programming using DNC Software.
    2. Higher level of decision making.
    3. Real time control of various machine tools.
    4. First step which gives hands on experience for future expansion.
    5. Elimination of Punched Tape and Tape Reader.
    6. CLFILE- A Convent and more general way of program storage.
    7. Elimination of hardwired controller unit on some system.
    8. Greater Productivity.
    9. Convenient Storage of NC Part Program.
    10. Greater Computational ability.
    11. Location of central computer in remote and clean environment.
    12. Effective support to management information system.
    13. Effective data collection and reporting.
    14. Enhanced manufacturing flexibility by real time rescheduling.

ADAPTIVE CONTROL:

- Adaptive Control covers a set of techniques which provide a systematic approach for automatic adjustment of the controllers in real time, in order to achieve or to maintain a desired level of performance of the control system when the parameters of the plant dynamic model are unknown and/or change in time.
- An adaptive control system measures a certain performance index (IP) of the control system using the inputs, the states, the outputs and the known disturbances. From the comparison of the measured performance index and a set of given ones, the adaptation mechanism modifies the parameters of the adjustable controller and/or generates an auxiliary control in order to maintain the performance index of the control system close to the set of given ones (i.e., within the set of acceptable ones).



(Basic configuration for an adaptive control system)

Functions of Adaptive Control:

- The three functions of adaptive control are:
  i. Identification function
  ii. Decision function
  iii. Modification function
- The main idea of AC is the improvement of the cutting process by automatic on line determination of speed and/or cutting.

- The AC is basically a feedback system in which cutting speed and feed automatically adapt themselves to the actual condition of the process and are varied accordingly to the changes in the work conditions as work progresses.

  Identification functions:

  - This involves determining the current performance of the process or system.
  - The identification function is concerned with determining the current value of this performance measure by making use of the feedback data from the process.

  Decision function:

  - Once the system performance is determined, the next function is to decide how the control mechanism should be adjusted to improve process performance.
  - The decision procedure is carried out by means of a pre-programmed logic provided by the designer.

  Modification function:

  - The third AC function is to implement the decision.
  - While the decision function is a logic function, modification is concerned with a physical or mechanical change in the system.
  - The modification involves changing the system parameters or variables so as to drive the process towards a more optimal state.

Classification of AC systems:

- In practice the AC system of machine tools can be classified into three types:
  1. AC with optimization (ACO)
  2. AC with constrains (ACC)
  3. Geometric Adaptive Control (GAC)

1) AC with optimization (ACO):
   - The ACO Systems for N/C machine tools is a control system that optimizes performance index subjects to various constraints.
   - It is basically a sophisticated closed loop control system, which automatically works in optimum conditions, even in the presences of work piece and tools materials variations.
2) AC with constraints (ACC):
   - ACC are systems in which machining conditions such as spindle speed or feed rate are maximized within the prescribed limits of machines and tool constrains such as maximum torque, force or horse power.
   - In AC system the correct feed and speed are automatically found and it is not necessary to spend efforts on calculations of optimum feeds and speeds.
   - ACC systems do not utilize a performance index and are based on maximizing a machining variable (e.g., feed rate) subject to process and machine constraints (e.g., allowable cutting force on the tool, or maximum power of the machine).
   - The objective of most ACC types of systems is to increase the MRR during rough cutting operations.
3) Geometric Adaptive Control(GAC):
   - GAC are typically used in finish machining operations.
   - In GACs the part quality is maintained in real time by compensating for the deflection and wear of cutting tools.

- The objective of GAC is to achieve:
  i. The required dimensional accuracy.
  ii. A consistency of surface finish of machined parts despite tool wear or tool deflection.

Advantages:

- Increased production rates.
- Increased tool life.
- Greater part protection.
- Less operator intervention.

Disadvantages:

- A major drawback is the unavailability of suitable sensors that have a reliable operation in a manufacturing environment (Tool wear sensor).
- Another problem is the interface of an AC system with CNC units.

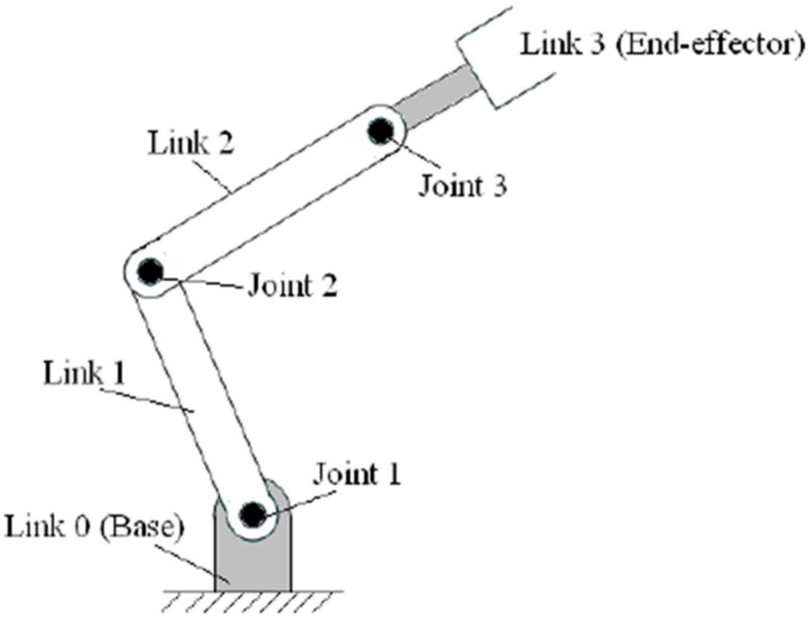
Module-4

Definition:

Manipulating industrial robot as defined in ISO 8373 is an automatically controlled, reprogrammable, multipurpose, manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications.

Anatomy of robots:

There are several classes of robots: robotic aircraft, robotic ships, mobile robots and others. An important application of robots is in industry – for machine tending, welding, painting, assembly and etc. These "industrial robots" can be viewed as consisting of a mechanical portion "the manipulator" controlled by a microprocessor.



Base: The stable platform to which an industrial robotic arm is attached.

Link: The **links** are the rigid members connecting the joints.

Joint: The **joints** (also called axes) are the movable components of the robot that cause relative motion between adjacent links.

End effector: In robotics, an **end effector** is a device or tool that's connected to the end of a robot arm where the hand would be. The end effector is the part of the robot that interacts with the environment.

Subsystems of industrial robots include:

1. Actuators
2. Transmission systems
3. Power supplies & power storage system
4. Sensors
5. Microprocessors & controllers
6. Algorithms & software (higher level & lower level)

Actuators:

Actuators are basically prime movers providing both force and motion. Pneumatic cylinders, hydraulics, permanent magnet motors, stepper motors, linear motors are some conventional actuators. More advanced ones are based on hi-tech polymers, shape memory alloys, piezo patches, and pneumatic muscles. Brushless servo motors also exist for low noise levels, and printed armature motors are used for quick response.

Transmission systems:

The transmission system used in robot to transmit power and motion consists of chains, timing belts, metal belts, cables and pulleys and linkages. Gear boxes and harmonic drives serve to provide speed reduction. Ball screws are used with suitable mechanisms to convert rotary motion to linear motion and if needed back to oscillatory motion. Drive stiffness is an important consideration in robotics and so also is backlash.

Power supplies:

Hydraulic and Pneumatic power packs: These consist of a motor driving a positive displacement pump or compressor to generate the high pressure fluid flow. In using hydraulic system, the necessity of having an oil tank increases the weight of the system, additionally the issue of ensuring that the oil is free of contaminants is to be handled. In pneumatics power pack dry air is desired. Electric motors use what ate known as PWM (pulse width modulation) amplifiers. These are electronic devices, consisting of transistors used as switches to rapidly switch on and off the supply in a controlled manner to control motor speeds. Such drives have higher efficiency.

Sensors and other electronics:

The sensors for feedback in robots consists of tachometers and encoders and potentiometers to sense motor motions, simple switches, force sensors, acceleration sensors, optical systems, special cameras and vision systems.

Electronics:

There are a host of electronic circuits, motor controllers, analog to digital converters and digital to analogue converters, frame grabbers and so on utilized to handle sensors and vision systems and convert the inputs from them into a form usable by the processor for control of the entire system in conjunction with the algorithms and software developed specifically for the purpose.

Software:

The software used consists of several levels. Motor control software consists of algorithms which help the servo to move smoothly utilizing the data from feed-back units. At the next level there is software to plan the trajectory of the end effector and translate the same into commands to individual motor controllers. The output of sensors is also to be interpreted and decisions made. At the highest level there is software which accepts commands from the user of the robot and translates it into appropriate actions at the lower level.

Robot Arm Configurations:

• Cartesian (3P)

• Cylindrical (R2P)

• Spherical (Polar) (2 RP)

• Articulated (3R)

• SCARA (2R in horizontal + 1P in vertical plane)

Cartesian (3P):

• Due to their rigid structure they can manipulate high loads so they are commonly used for pick-and-place operations, machine tool loading, in fact any application that uses a lot of moves in the X, Y, Z planes.

• These robots occupy a large space, giving a low ratio of robot size to operating volume. They may require some form of protective covering.

Cylindrical (R2P):

• They have a rigid structure, giving them the capability to lift heavy loads through a large working envelope, but they are restricted to area close to the vertical base or the floor.

• This type of robot is relatively easy to program for loading and unloading of palletized stock, where only the minimum number of moves is required to be programmed.

Spherical (Polar) (2 RP):

• These robots can generate a large working envelope.

• The robots can allow large loads to be lifted.

• The semi-spherical operating volume leaves a considerable space near to the base that cannot be reached.

• This design is used where a small number of vertical actions is adequate: the loading and unloading of a punch press is a typical application.

Articulated Arm (3R):

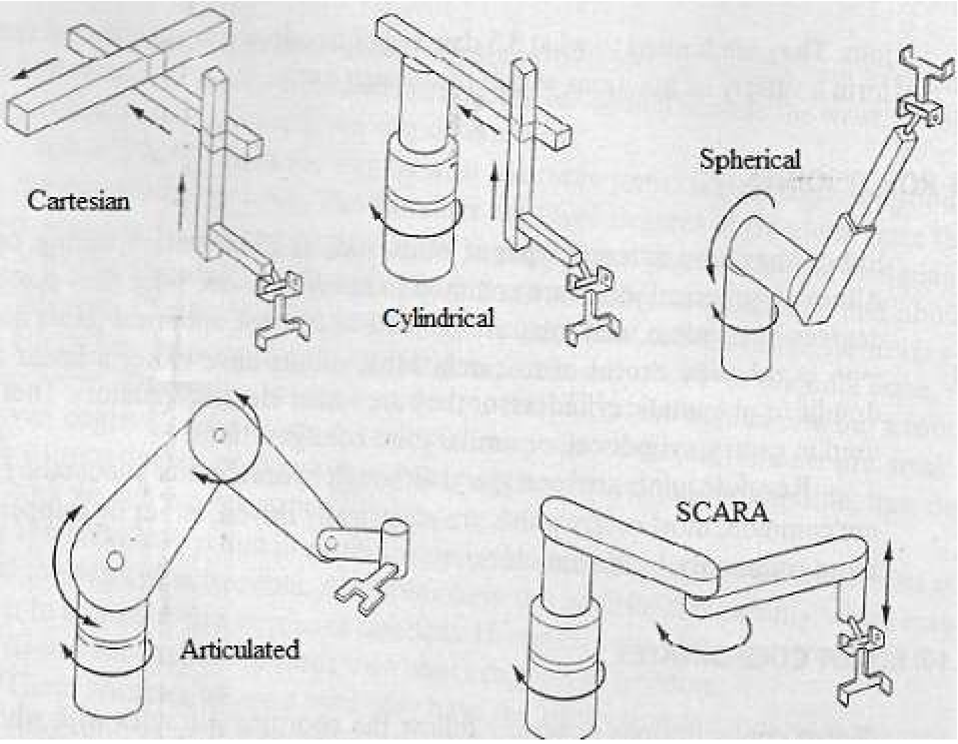
• This is the most widely used arm configuration because of its flexibility in reaching any part of the working envelope.

• This configuration flexibility allows such complex applications as spray painting and welding to be implemented successfully.

SCARA:

• Although originally designed specifically for assembly work, these robots are now being used for welding, drilling and soldering operations because of their repeatability and compactness.

• They are intended for light to medium loads and the working volume tends to be restricted as there is limited vertical movement.



Robot Applications:

The common industrial applications of robots in manufacturing involve loading and unloading of parts.

1. The robot unloading parts from die-casing machines

2. The robot loading a raw hot billet into a die, holding it during forging, and unloading it form the forging die.

3. The robot loading sheet blanks into automatic pressed, with the parts falling out of the back of the machine automatically after the press operation is performed.

4. The robot unloading molded parts formed in injection molding machines.

5. The robot loading raw balks into NC machine tools and unloading the finished parts from the machines.

6. Welding

7. Spray painting

8. Assembly

Module-5

FLEXIBLE MANUFACTURING SYSTEM(FMS):

- A flexible manufacturing system (FMS) is a highly automated group technology machine cell, consisting of a group of processing workstations (usually CNC machine tools), interconnected by an automated material handling and storage system, and controlled by a distributed computer system.

  Or

- FMS may be defined as a manufacturing system dealing with group of machining stations (NC, CNC machine tools) and automated material handling system using computer controlled machines.
- The reason the FMS is called flexible is that it is capable of processing a variety of different part styles simultaneously at the various workstations, and the mix of part styles and quantities of production can be adjusted in response to changing demand patterns.
- The FMS is most suited for the mid-variety, mid-volume production range.

Need for FMS:

- Flexibility is an important feature of modern manufacturing. FMS use technology in such a way that it helps to achieve the optimum balance between flexibility and production runs. So FMS should be implemented in manufacturing to avail the benefits as follows:

Increased machine utilization:

- FMS achieve a higher average utilization than machines in a conventional batch production machine shop. Reasons for this include:
  - 24 Hr./day operation.
  - Automatic tool changing at machine tools.
  - Automatic pallet changing at workstations.
  - Queues of parts at stations.
  - Dynamic scheduling of production that takes into account irregularities from normal operations.

Fewer machines required:

- Because of higher machine utilization, fewer machines are required.

Reduction in factory floor space required:

- FMS generally requires less floor area.

Greater responsiveness to change:

- An FMS improves response capability to part design changes, introduction of new part s, changes in production schedule and product mix, machine breakdowns, and cutting tool failures.

Reduced inventory requirements:

- Reduced inventory, due to the planning and programming precision.

Lower manufacturing lead times:

- This means faster customer deliveries

Reduced direct labor requirements and higher labor productivity:

- Higher production rates and lower reliance on direct labor translate to greater productivity per labor hour with an FMS

Opportunity for unattended production:

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

Components of FMS:

- The basic components of an FMS are: processing stations/workstations, material handling and storage systems, computer control system, and the personnel that manage and operate the system.

1. Processing stations/ work stations:

- The processing or assembly equipment used in an FMS depends on the type of work accomplished by the system. So the types of workstations that may be utilized in FMSs include: load/unload stations, machining stations, other industry-specific processing stations (such as sheet metal fabrication and forging), assembly stations, and supporting stations.

Load/Unload Stations:

- The load/unload station is the physical interface between the FMS and the rest of the factory. Raw work-parts enter the system at this point, and finished parts exit the system from here.
- Loading and unloading can be accomplished either manually or by automated handling systems. Manual loading and unloading is prevalent in most FMSs today.
- It should be designed to permit the safe movement of parts, and may be supported by various mechanical devices (e.g. cranes, forklifts).
- The station should include a data entry unit and monitor for communication between the operator and computer system, regarding parts to enter the system, and parts to exit the system. In some FMSs, various pallet fixtures to accommodate different pallet sizes may have to be put in place at load/unload stations.

Machining Stations:

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

Other Processing Stations:

- The FMS concept has been applied to other processing operations in addition to machining.
- One such application is sheet metal fabrication processes. The processing workstations consist of press-working operations, such as punching, shearing, and certain bending and forming processes. Also, flexible systems are being developed to automate the forging process, which may be broken into specific workstations in the system consist principally of a heating furnace, a forging press, and a trimming station.

Assembly:

- Some FMSs are designed to perform assembly operations.
- Flexible automated assembly systems are being developed to replace manual labor in the assembly of products typically made in batches.
- The assembly operation usually consists of a number of workstations with industrial robots that sequentially assemble components to the base part to create the overall assembly.
- They can be programmed to perform tasks with variations in sequence and motion pattern to accommodate the different product styles assembled in the system.

Other Stations and Equipment:

- It may consider inspection which can be incorporated into an FMS, either by including, an inspection operation at a processing workstation or by including a station specifically designed for inspection. Inspection is important in flexible assembly systems to ensure that components have been properly added at the workstations.
- In addition to the above, other operations and functions are often accomplished on an FMS. These include stations for cleaning parts and/or pallet fixtures, central coolant delivery systems for the entire FMS, and centralized chip removal systems often installed below floor level

2. Material Handling and Storage System:

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

Functions of the Handling System:

- The material handling and storage system in an FMS performs the fol1owing functions:

  Allow Random, independent movement of work-parts between stations:

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

  Enables handling a variety of work-part configurations:

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

Provides Temporary storage:

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

Provides convenient access for loading and unloading work-parts:

- The handling system must include locations for load/unload stations.

Creates compatibility with computer control:

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

Material Handling Equipment:

- The types of material handling systems used to transfer parts between stations in a FMS include a variety of conventional material transport equipment, inline transfer mechanisms, and industrial robots.
- The material handling function in an FMS is often shared between two systems:
  - A primary handling system
  - A secondary handling system.

The primary handling system:

- It establishes the basic layout of the FMS and is responsible for moving work-parts between stations in the system.

The secondary handling system:

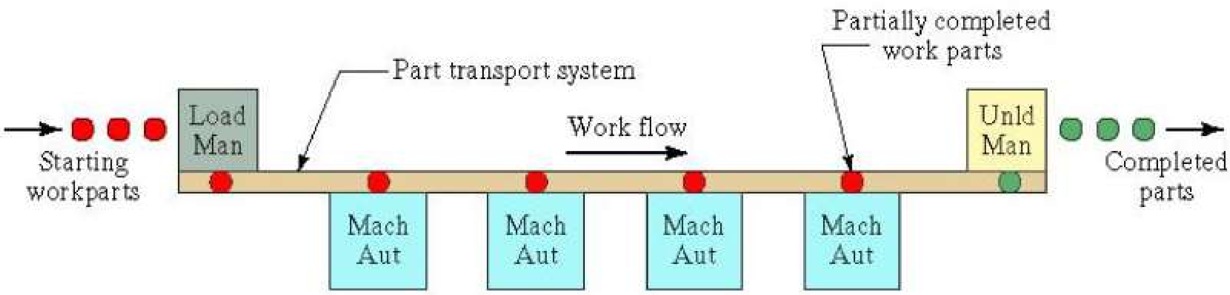
- It consists of transfer devices, automatic pallet changers and similar mechanisms located at the workstations in the FMS.
- The function of the secondary handling system is to transfer work from the primary system to the machine tool or other processing station and to position the parts with sufficient accuracy and repeatability to perform the processing or assembly operation.
- Other purposes served by the secondary handling system include:
  - Reorientation of the work-part if necessary to present the surface that is to be processed
  - Buffer storage of parts to minimize work change time and maximize station utilization.

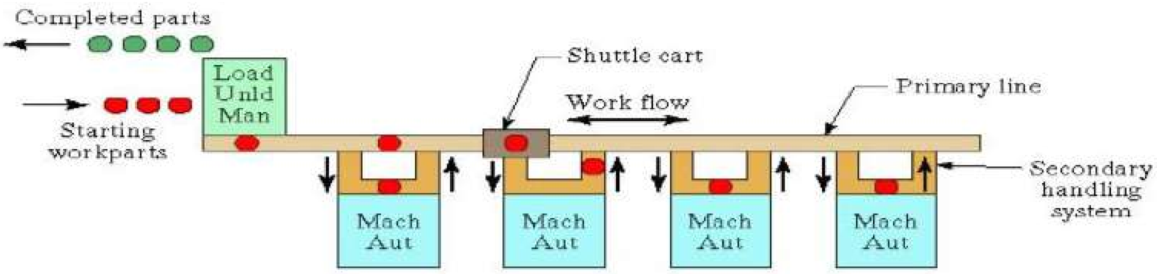
FMS Layout Configurations:

- The material handling system establishes the FMS layout. Most layout configurations FMSs can be divided into five categories:
  - Inline layout
  - Loop layout
  - Ladder layout
  - Open field layout
  - Robot-centered cell

Inline Layout:

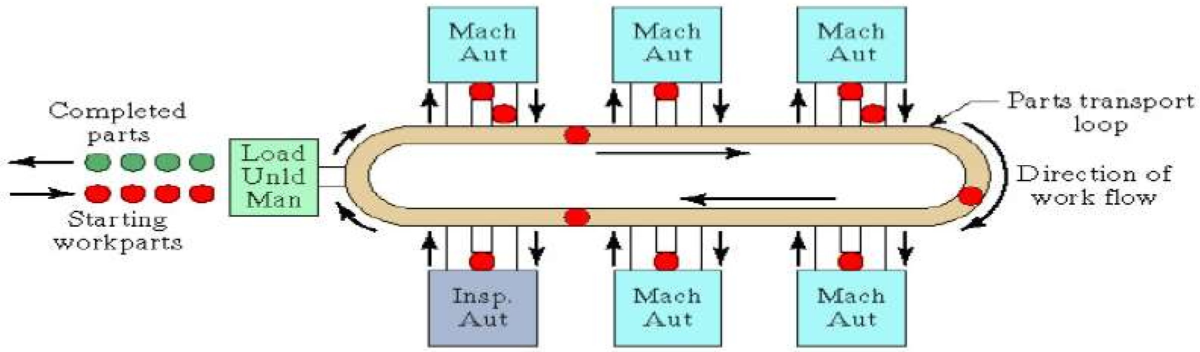
- The machines and handling system are arranged in a straight line. In the first figure parts progress from one workstation to the next in a well-defined sequence with work always moving in one direction and with no back-flow.
- Routing flexibility can be increased by installing a linear transfer system with bidirectional flow, as shown in the second figure.
- Here a secondary handling system is provided at each workstation to separate most of the parts from the primary line.
- Material handling equipment used: in-line transfer system; conveyor system; or rail-guided vehicle system.

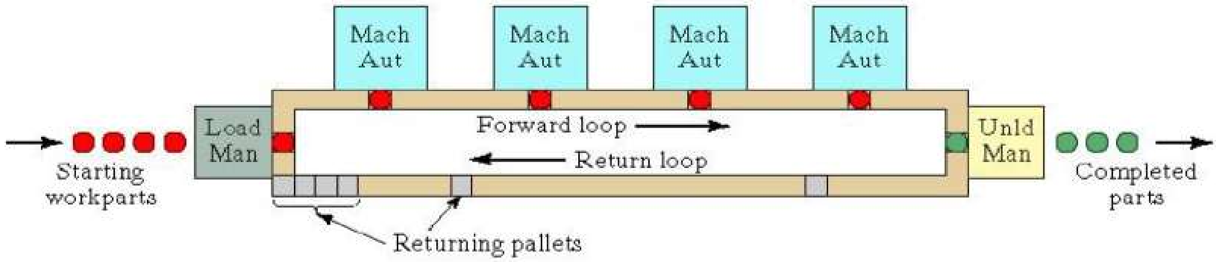




Loop layout:

- Workstations are organized in a loop that is served by a looped parts handling system.
- In the first figure parts usually flow in one direction around the loop with the capability to stop and be transferred to any station.
- Each station has secondary handling equipment so that part can be brought-to and transferred-from the station work head to the material handling loop.
- Load/unload stations are usually located at one end of the loop.
- An alternative form is the rectangular layout shown in the second figure. This arrangement allows for the return of pallets to the starting position in a straight line arrangement.





Ladder layout:

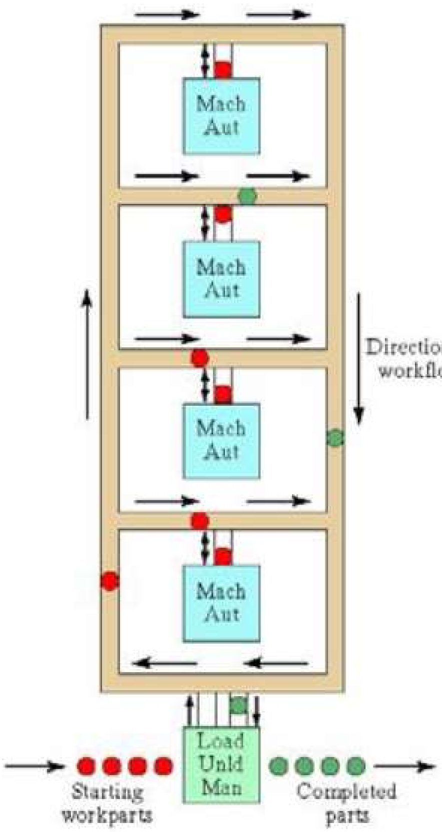
- This consists of a loop with rungs upon which workstations are located. The rungs increase the number of possible ways of getting from one machine to the next, and obviates the need for a secondary material handling system.
- It reduces average travel distance and minimizes congestion in the handling system, thereby reducing transport time between stations.

Open field layout:

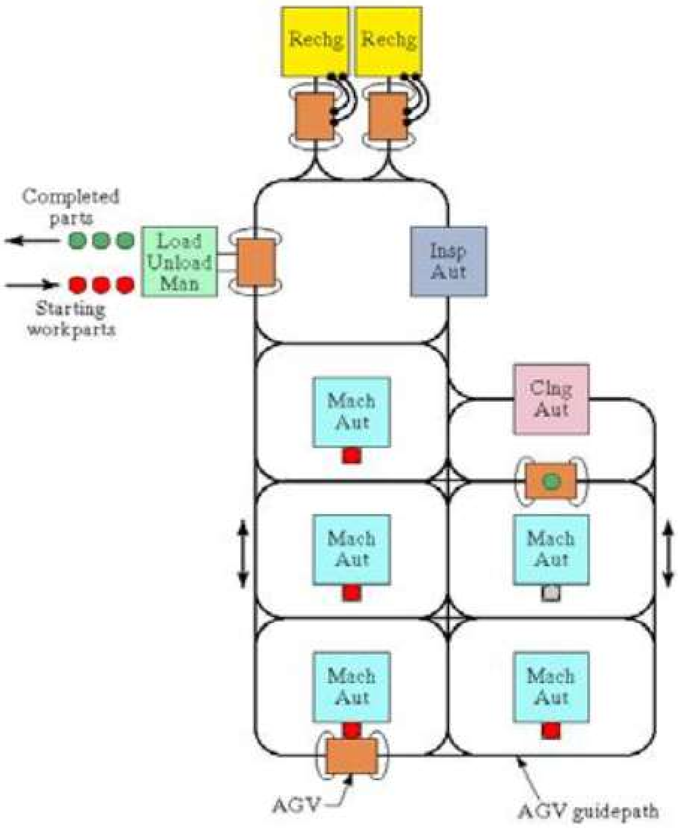
- It consists of multiple loops and ladders, and may include sidings also. This layout is generally used to process a large family of parts, although the number of different machine types may be limited, and parts are usually routed to different workstations—depending on which one becomes available first.

Robot-centered layout:

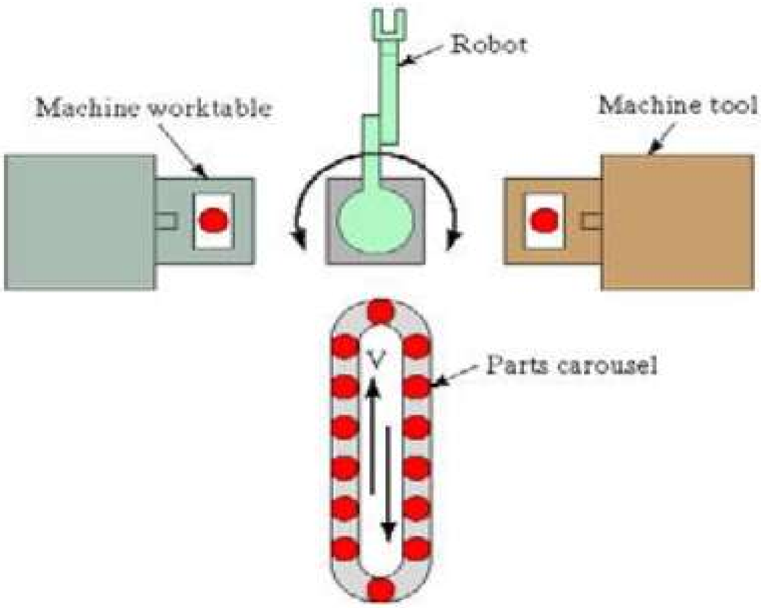
- This layout uses one or more robots as the material handling system.



(Ladder layout)



(Open field layout0



(Robot-centered layout)

3. Computer control system:

- To operate, the FMS uses a distributed computer system that is interfaced with all workstations in the system, as well as with the material handling system and other hardware components.
- It consists of a central computer and a series of micro-computers that control individual machines in the FMS.
- The central computer co-ordinates the activities of the components to achieve smooth operational control of the system.
- The following control functions are as follows:

  Workstation control:

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

  Distribution of control instructions to workstations:

  - A central computer is required to handle the processing occurring at disparate workstations; this involves processing of part programs to individual workstations, based upon an overall schedule held by the central computer

  Production control:

  - Management of the mix and rate at which various parts are launched into the system is important.
  - Input data required for production control includes daily desired production rates, number of raw work parts available, work-in-progress etc.

  Traffic control:

  - This refers to the management of the primary handling system that moves the parts between stations. is essential at the right time and in the right condition.

  Shuttle control:

  - This control system is concerned with the management of the secondary handling system, to ensure the correct delivery of the work part to the station's work head

  Work piece monitoring:

  - The computer must monitor the status of each cart or pallet in the primary and secondary handling systems, to ensure that we know the location of every element in the system

  Tool control:

  - This is concerned with managing tool location (keeping track of the different tools used at different workstations, which can be a determinant on where a part can be processed), and tool life (keeping track on how much usage the tool has gone through, so as to determine when it should be replaced)

Performance monitoring and reporting:

- The computer must collect data on the various operations on-going in the FMS and present performance findings based on this.

Diagnostics:

- The computer must be able to diagnose, to a high degree of accuracy, where a problem may be occurring in the FMS.

Module-6

CAD:

- Computer-aided design (CAD) is the use of computers (or workstations) to aid in the creation, modification, analysis, or optimization of a design.
- CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing.
- CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. The term CADD (for Computer Aided Design and Drafting) is also used.

Benefits of CAD:

1. **Increase in the productivity of the designer:**
   The CAD software helps designer in visualizing the final product that is to be made, it subassemblies and the constituent parts. The product can also be given animation and see how the actual product will work, thus helping the designer to immediately make the modifications if required. CAD software helps designer in synthesizing, analyzing, and documenting the design. All these factors help in drastically improving the productivity of the designer that translates into fast designing, lower designing cost and shorter project completion times.
2. **Improve the quality of the design:**
   With the CAD software the designing professionals are offered large number of tools that help in carrying out thorough engineering analysis of the proposed design. The tools also help designers to consider large number of investigations. Since the CAD systems offer greater accuracy, the errors are reduced drastically in the designed product leading to better design.
3. **Better communications:**
   The next important part after designing is making the drawings. With CAD software better and standardized drawings can be made easily. The CAD software helps in better documentation of the design, fewer drawing errors, and greater legibility.
4. **Creating documentation of the designing:**
   Creating the documentation of designing is one of the most important parts of designing and this can be made very conveniently by the CAD software. The documentation of designing includes geometries and dimensions of the product, its subassemblies and its components, material specifications for the components, bill of materials for the components etc.
5. **Creating the database for manufacturing:**
   When the creating the data for the documentation of the designing most of the data for manufacturing is also created like products and component drawings, material required for the components, their dimensions, shape etc.
6. **Saving of design data and drawings:**
   All the data used for designing can easily be saved and used for the future reference, thus certain components don't have to be designed again and again. Similarly, the drawings can also be saved and any number of copies can be printed whenever required. Some of the component drawings can be standardized and be used whenever required in any future drawings.

CAM:

- Computer-aided Manufacturing (CAM) is the term used to describe the use of computerized systems to control the operations at a manufacturing plant. These computerized systems assist manufacturers in various operations such as planning, transportation, management, and storage.
- CAM helps manufacturers improve their time to market capabilities, and create precise dimensions.

Benefits of CAM:

1. **Improves Machining Capabilities:**
   By using a CAD-CAM system, manufacturers can improve their machining capabilities. For example, when a manufacturer takes up a complex 3-axis machining task, they rely on the combination software to create a tool path for machining projects such as molding. The CAM system automates the process, and makes it easier for manufacturers to complete the project in time.
2. **Improves Client Accessibility:**
   The CAD-CAM software allows manufacturers to receive CAD files from their customers. After receiving these files, they can set up the machining tool path, and perform simulations, which helps them calculate the machining cycle times. The software allows manufacturers to minimize errors, execute projects easily, and deliver products to the market within a shorter turnaround time.
3. **Helps Improve Productivity of CNC Machines:**
   Most CAM-CAD systems provide high–speed machine tool paths, which help manufacturers minimize their cycle times, reduce tool and machine wear. High-speed tool paths enable manufacturers to improve their cutting quality and accuracy. This type of high- speed machining helps improves the productivity of the CNC machine by more than 50%.
4. **Helps Reduce Material Wastage:**
   As CAM–CAD software feature simulation features, it helps a manufacturer to visually inspect the process of machining. This allows him to capture tool gouges, and collisions at an early phase. This feature contributes to the overall productivity of a manufacturing set up. This also helps them eliminate mistakes, as well as reduce material wastage.

Difference between CAD & CAM:

BASIS FOR COMAPARISION	CAD	CAM
Basic	CAD is the implementation of digital computers in engineering design and production.	CAM is the implementation of computers in transforming engineering designs into end products.
Involved process	Definition of a geometric model, definition translator, geometric model, interface algorithm, design and analysis algorithms, drafting and detailing, documentation.	Geometric model, process planning, interface algorithm, NC programs, inspection, assembly and packaging.
Requires	Design conceptualization and analysis.	Control and coordination of the necessary physical processes, equipment, materials, and labor.
Software	AutoCAD, Autodesk Inventor, CATIA, SolidWorks	Siemens NX, Power MILL, Work NC, Solid CAM

CIM:

- Computer-integrated manufacturing (CIM) refers to the use of computer-controlled machineries and automation systems in manufacturing products.
- CIM combines various technologies like computer-aided design (CAD) and computer-aided manufacturing (CAM) to provide an error-free manufacturing process that reduces manual labor and automates repetitive tasks.
- The CIM approach increases the speed of the manufacturing process and uses real-time sensors and closed-loop control processes to automate the manufacturing process.
- It is widely used in the automotive, aviation, space and ship-building industries.

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.
- The need to meet the design and manufacturing requirements of aerospace industries after the Second World War necessitated the development these technologies.
- The implementation of CIM required the development of whole lot of computer technologies related to hardware and software.

CIM Software & Hardware:

- CIM Hardware comprises the following:
    - 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.
    - 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
    - Monitoring
    - Production Control
    - Manufacturing Area Control
    - Job Tracking
    - Inventory Control
    - Shop Floor Data Collection
    - Order Entry
    - Materials Handling
    - Device Drivers
    - Process Planning
    - Manufacturing Facilities Planning
    - Work Flow Automation
    - Business Process Engineering
    - Network Management
    - Quality Management

Benefits of CIM:

1.CIM improves the short run responsiveness consisting of:

- Engineering changes
- Processing changes
- Machine down time or unavailability
- Operator unavailability
- Cutting tool failure
- Late material delivery

2.CIM improves long run accommodations through quicker and easier assimilation of:

- Changing product volumes
- New product additions and introductions
- Different part mixes

3.CIM reduces inventory by:

- Reducing lot sizes
- Improving inventory turnovers
- Providing the planning tools for Just – in Time manufacturing

4.CIM increase machine utilization by:

- Eliminating or reducing machine setup
- Utilizing automated features to replace manual intervention to the extent possible
- Providing quick transfer devices to keep the machines in the cutting cycle.