

**BHUBANANANDA ODISHA SCHOOL OF ENGINEERING, CUTTACK**  
**DEPARTMENT OF MECHANICAL ENGINEERING**



**LECTURE NOTE OF Mechatronics**

SUBJECT: Mechatronics

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## Chapter 1

Non-conventional Machining process / Non-traditional Machining process.

The machining process in which material removal takes place with the help of human force is known as traditional or conventional machining process.

The machining process in which the removal of material takes place from the workpiece surface with the help of modern automated machine is called non-conventional or non-traditional machining process.

Non-conventional / Non-traditional machining process

(i) Material removal takes place with the help of automated machine

(ii) It consume less time for machining

(iii) Workpiece produce in this case are more accurate.

(iv) Surface finish of the work piece is high.

(v) There is less chance of error.

(vi) It is reliable for mass production of workpiece

conventional / traditional Machining process.

(i) Material removal takes place with the help of human force.

(ii) It consume more time for machining

(iii) Workpiece produce in this process are less accurate.

(iv) Surface finishing of the work piece is low.

(v) There is more chance of error.

(vi) Mass production is not possible in this case.

(vii) Machining process setup is more costly

(vii) machining process is less costly.

(viii) It consume large amount of electricity

(viii) It consume less amount of electricity.

### Types of non-conventional Machining process

- ① Abrasive jet machining (AJM) ✓
- ② electro chemical " (ECM) ✓
- ③ Electro discharge " (EDM) ✓
- ④ plasma arc " (PAM) ✓
- ⑤ Laser beam " (LBM) ✓
- ⑥ electron beam " (EBM) ✓

### Abrasive jet machining (AJM)

→ The non-conventional machining process in which material removal takes place with the help of abrasive particles is known as abrasive jet machining.

→ An abrasive is a particle having more than one cutting edge.

### Types of Abrasive :-

there are two types of abrasives they are

(i) Natural :-

Ex sand, diamond, silica.

(ii) Abrasive :-

Silicon carbide, tungsten carbide etc.

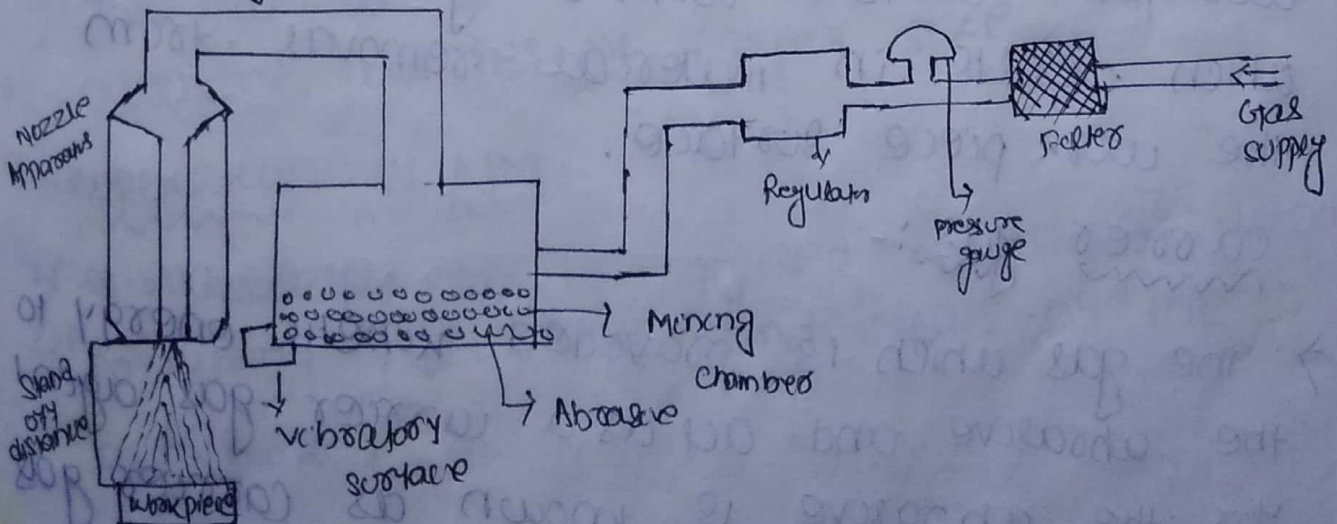
Properties of abrasive :-

- It must be very hard.
- Must have high toughness.
- It should be irregular in shape.
- The edge of abrasive should be very sharp.

Construction of AJM :-

→ It consists of a gas supply a filter, pressure gauge to measure the pressure. It also consist of a regulator to maintain the pressure. It has a mixing chamber is associated with a vibratory source to mix the abrasive and the gas in well manner. The set up for AJM is consist of a nozzle apparatus through which abrasive are bombarded on the work piece surface

Working principle :-



→ The air is passed through the filter to remove the impurities. The pressure gauge measures the pressure of the gas and the regulator regulated the pressure of the gas. Then <sup>the</sup> gas is ~~then~~ passed to mixing chamber containing abrasive particles.

→ In the mixing chamber the gas is mixed with the abrasive particles due to the variation of the mixing chamber from the mixing chamber the mixture of the gas and abrasive particle passes on the nozzle apparatus having tungsten carbide tip with a velocity of 200 m/sec to 400 m/sec. In this process the stand off distance (distance between nozzle tip and workpiece) must be taken as 0.7 mm to 1 mm and the size of nozzle abrasive must be between 10 micron to 40 microns.

→ The abrasive with the gas collides over the workpiece surface with a greater velocity which results in material removal from the work piece surface.

Carrier gas :-

→ The gas which is provided kinetic energy to the abrasive and act as a carrier gas agent for the abrasive is known as carrier gas.

Ex :- Carbon dioxide, Argon, Nitrogen

MRR → It is material removal rate or the amount of material removal in  $\text{kg}/\text{cm}^2$ . The MRR for AJM lies between  $2.8 \text{ kg}/\text{m}^2$ .

### Advantages :-

- This process can be utilised for machining of brittle material like iron, tungsten, carbide etc.
- It can be utilised for having holes.
- AJM result in less damage to the surface.
- The surface have a good surface finish by controlling the grain size.
- The AJM process material removal rate is very high.

### Disadvantages :-

- The holes of the AJM process are not uniform and taper in shape when the depth is more.
- The abrasive particles may remain embedded in the workpiece surface.
- The material removal rate is very slow for abrasive particles of larger size.

### Application of AJM :-

- AJM process can be utilised for cutting, drilling, polishing, pebbling and clean of the workpiece.

# Electro Discharge Machining (EDM)

→ The non-conventional machining process where material removal takes place with the help of electrical spark and electron discharge from the tool is known as electron discharge machining. (EDM).

## Dielectric fluid :-

→ A fluid which is capable of conducting electricity though it is known as dielectric fluid

EX:- ethylene, kerosene etc.

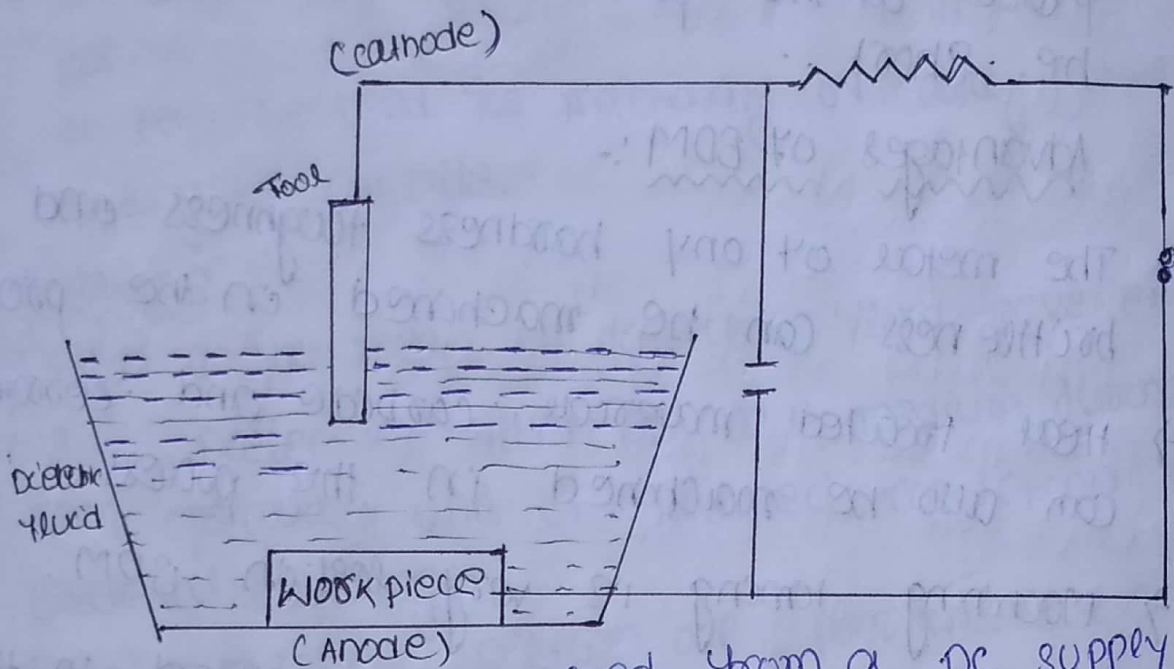
## Construction :-

→ The setup for EDM consist of a container of dielectric fluid. The work piece is taken as anode and it is fully immersed in dielectric fluid. The tool is made cathode and it is responsible for the emission of electrons.

→ The electric circuit consists of a variable resistance capacitor and DC power supply. A suitable spark gap of 0.001 to 0.05 mm. A DC supply source having 30V to 200V is utilise to create a spark between the tool and the work piece material.

→ The capacitor in the CRT is used to store energy and the resistor is used to oppose the excess flow of electrons.

Working principle:-



→ When a voltage is supplied from a DC supply power source across the spark gap then the emission of free electrons takes place from the tool (cathode) with a very high velocity. Due to the electric field produced between the cathode and the anode the electron start flowing towards the anode in dielectric fluid medium.

→ In other word electrical discharge takes place from cathode to the anode which result in heating. In anode surface upto Temp of 1800°C. The anode surface become heated off and when the electron hit the surface. It melts and evaporate the melted particles on the workpiece surface are cooled and washed away with the help of dielectric fluid.



The flow of electrons stops when the DC power supply source is switched off.

→ Due to the erosion of the metal, spark gap is increase and the spark next takes place at the point where the distance will be short.

### Advantages of EDM :-

- The metal of any hardness toughness and brittleness can be machined in the process
- Heat treated material, carbide and ceramics can also be machined in this process.
- Machining time is very less in EDM.
- The accuracy of the work produced in this process can be as high as  $0.005 \text{ mm}$ .
- There is no contact between the workpiece and tool so, there is no danger of wear and tear of tool and work piece.

### Disadvantages of EDM :-

- Power required is very high.
- Material removal rate is very slow.
- It cannot produce sharp corners.
- Work piece material must be electrical conductor.
- In this process the surface finishing is not so good & smooth.

## Applications of EDM :-

- It can be used to create mold cavities.
- It can be used to make holes of 0.1mm diameters.
- It can be used to make internal gear profiles.
- It can be used to manufacture dies for process tool.
- It can be used for machining of alloy steel and tungsten carbide.

## Questions

Q) What do you mean by dielectric fluid give example?

ANS :- Dielectric fluid act as a medium during the EDM operation and it produced condition for electrical discharge.

EX :- kerosene, silicon oil, paraffins oil etc.

Q) What are the function of dielectric fluid?

ANS :- It act as a medium during EDM operation it is act as a coolant in the workpiece surface.

→ It act as a coolant for tool material.

→ It carries away the eroded material particles.

→ It provide suitable condition for electrical discharge.

Q) Give example of the tool used in EDM process.

ANS :- Tungsten carbide, Graphite,

Brass tungsten, etc.

# Electrochemical Machining (ECM)

→ ECM can be defined as a non-conventional machining process in which material removal takes place with the help of controlled dissolution of an anode in an electrolytic cell.

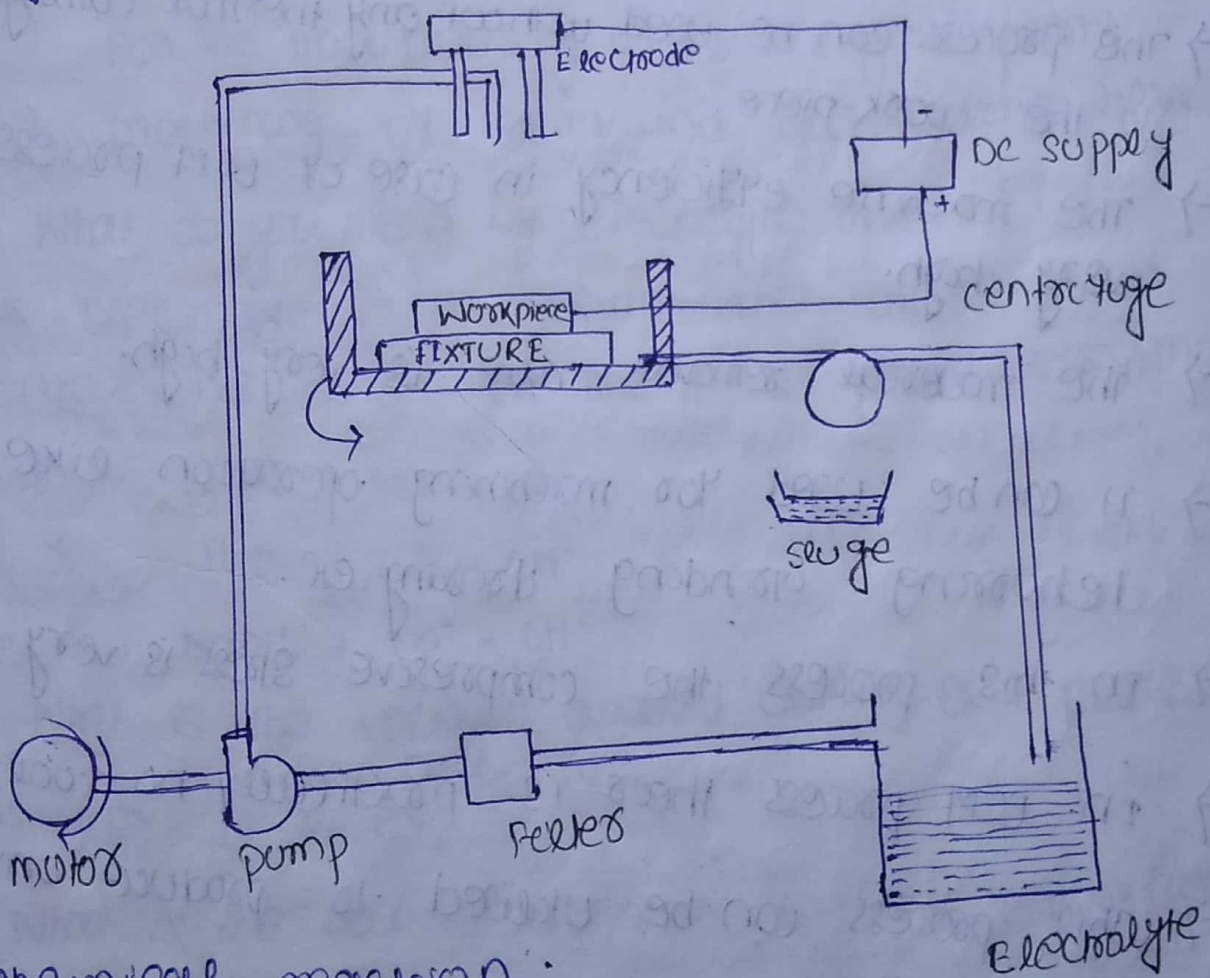
## CONSTRUCTION :-

→ The ECM set-up consists of a reservoir containing electrolyte it also consists of a filter to remove the impurities present in the electrolyte. It consists of a pump which is used to supply the electrolytic cell consists of electrode which is taken as cathode and it also consists of workpiece that is taken as anode. Both the cathode and anode are dissolved or immersed in electrolytic solution. A DC supply is present between the cathode and anode.

## Working principle :-

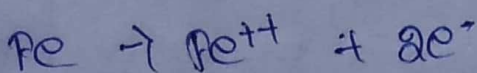
→ In ECM process the workpiece is taken as anode and the electrode are taken as cathode the gap between the electrode and the workpiece is 0.05 mm to 0.5 mm and electrolyte usually is taken inside the electrolytic tank (when the tank is called a DC supply is provided between the electrodes).

having a magnitude of 6 eV. This voltage results in a very high motivating force which pulls the metallic ions from the workpiece. A high current density is used in this process. The process of the reaction between the metallic ions and electrolyte result in the formation of metallic hydroxide in this way metal is removed from the workpiece surface with the help of chemical reaction. ECM also result in evolution of hydrogen gas.

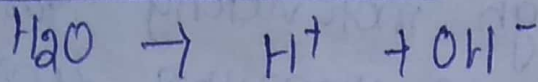


Chemical reaction :

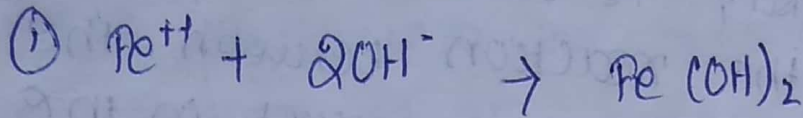
At Anode



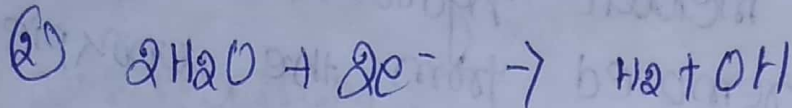
At Cathode (Tank)



Chemical reaction of ECM



Metallic Hydroxide



Advantages :-

- ECM can be used for the machining of very tough and brittle material.
- This process can be used without any thermal damage to the work piece.
- The machine efficiency in case of ECM process is very high.
- The material removal rate is very high.
- It can be used for machining operation like deburring, grinding, drilling etc.
- In this process the compressive stress is very less.
- In ECM process there is practically no tool wear.
- This process can be utilised to produce any shape of work piece.

## Disadvantages:-

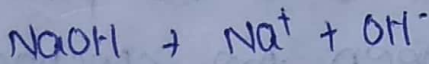
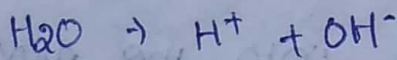
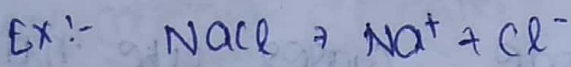
- In this process only metals which are good conductors of electricity can be machined.
- The energy consumption for ECM set up is very high.
- The surface finish achieved during ECM process is not so smooth.

## Application of ECM

- (i) Deburring.
- (ii) Electrolytic grinding.
- (iii) Deep hole drilling.
- (iv) For the manufacturing of Aero engine parts.
- (v) Machining of steam and Gas turbines blades.

Q What do you mean by electrolyte give ex?

ANS Electrolyte is a solvent which breaks down into ions when electricity is passed through it.



Q What is the voltage applied during ECM process

ANS ~~60v~~ 6 ev.

Q What is the Gap between the tool and workpiece in ECM process.

ANS:- 0.05 to 0.5 mm

Q What the function of an electrolyte?

ANS:- It removes the slag or sludges from the work piece surface.

→ It cools down the heat produced during the reaction.

→ It completes the electrical ckt between the tool and the work piece.

→ It helps in the formation of sludges.

PLASMA ARC MACHINING (PAM):-

The non conventional machining process in which material removal takes place with the help of direct electron bombardment and high temperature is known as plasma arc machining.

Construction of PAM :-

→ The setup for PAM consist of an electrode which is taken as cathode and a nozzle apparatus which is taken as anode. Gases like hydrogen nitrogen etc are fed into the PAM set up.

The electrical ckt between the electrode and the nozzle is completed with the help of a

DC supply source. Insulators are also used on this process.

Working principle of PAM :-

When a flowing gas is heated up to a high temperature of  $16500^{\circ}\text{C}$  then the gas becomes partially ionised. These form of the gas is known as plasma.

- In this process hydrogen or nitrogen gas is heated when they are subjected to the electron collision.
- When the DC supply source is powered on, then an electrical arc is produced between the cathodic electrode and anodic nozzle. The molecule of gas gets disassociated ~~due~~ to due to the collision with the electron produce due to the electric arc.
- This plasma is then passed through the anodic nozzle towards the work piece. When the plasma hits the work piece surface then it melts and erode due to the very high temp of the plasma. In this way material removal takes place in case of plasma arc machining.
- The material removal rate can be increased by increasing the flow of gas or plasma towards the workpiece surface.

### Application of PAM:

→ PAM can be use

- (i) For cutting hard and tough material.
- (ii) It is use for machining of stainless steel and carbon steel.
- (iii) It can be used for machining of delicate profiles from ceramics.



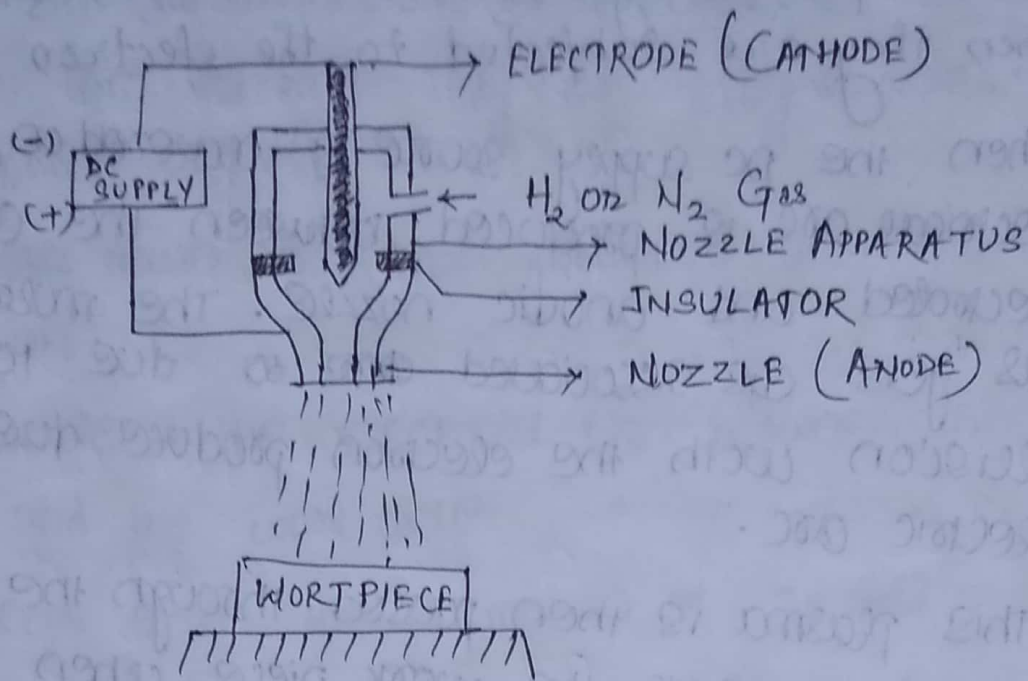


FIG - PLASMA

### ADVANTAGES :-

- Due to the high temperature of the plasma arc it can be used for the machining of hard and tough material.
- PAM can be use for the production of Deep holes.
- This process results in better surface finish.
- The material removal rate of PAM process is also very high.
- This process can be utilised for the machining of crystalline materials.
- PAM process can be utilised for various profiles than can't be made by using other non conventional machining process.

## Disadvantages:-

- This process results in high energy consumptions.
- Due to the high temp of the plasma arc the surface of the work-piece gets temp affected and results in heat affected area on it surface.
- The plasma is suppose to be released out of the nozzle so, the nozzle apparatus must with stand high temp.

Q How much temp is produced during the production of plasma ~~are~~ inside the nozzle apparatus?

AN:-  $16500^{\circ}\text{C}$ .

Q What type of electrode are used in PAM.  
Give example?

ANS:- The electrode which are capable of producing electrons or electric arc are suitable for PAM.

Q Ex:- zinc, Alloys, Tungsten carbide, Aluminium Graphite etc.

Q What is the function of insulator used in PAM?

ANS:- Insulator helps in controlling the flow of gases or plasma arc from the nozzle as there not good conductor of electricity they can repel an electric arc very easily.

Q What is the material used for the nozzle?

ANS:- The nozzle of the PAM set up are generally copper alloys.

Q What is the current density used in PAM process for the production of plasma arc?

ANS:- 1000 Amp/cm<sup>2</sup>

Q Which gas are used in PAM process?

ANS: Hydrogen and Nitrogen.

### LASER BEAM MACHINING (LBM)

It is the non-conventional machining process in which material removal takes place with the help of laser beam.

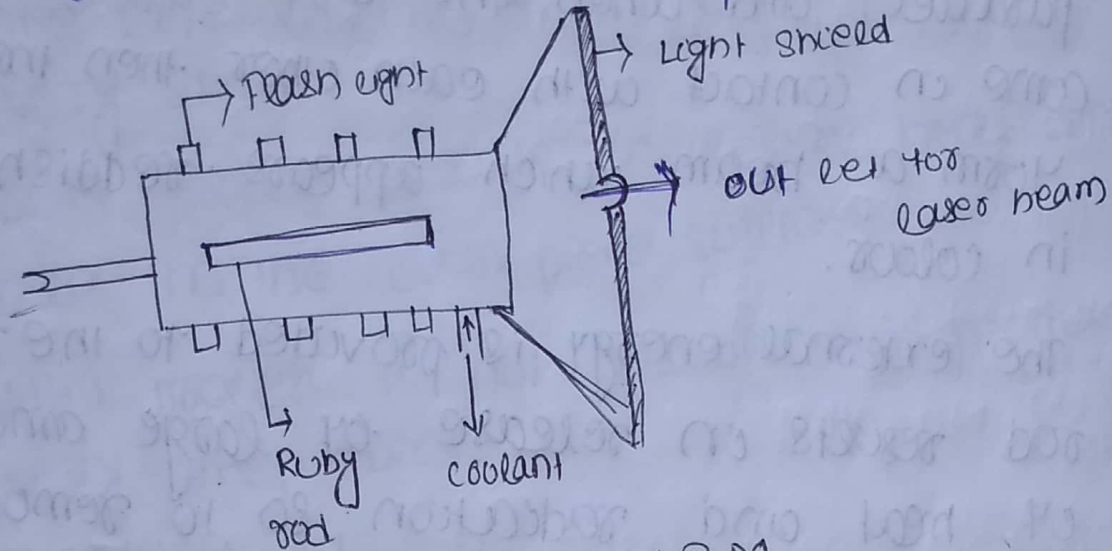
### Construction of laser beam machining:-

→ The apparatus for laser beam machining set up consist of a ruby rod in which Aluminium is the main ingredient. The impurities like Chromium is also present in 1:5000 ratio. This impurities are very important for the production of laser beam.

→ The set up also consist of flash light that is use to provide excitation energy to the atoms coolant are also provided in this set up to remove the unwanted

heat produce during laser beam production.

→ A light shield is present to produce the laser beam into a desirable wave length. The set up for the laser beam machining is accumulated inside a protected environment.



### Working principle for LBM

→ When ever an atom gets some energy from any external source then it shows three kind of behaviour.

(i) The atom is not excited as the magnitude of energy is less.

(ii) The atom is not excited as the magnitude of energy is less. It absorbs the energy and remain in the same energy level.

(iii) The atom gets excited and starts liberating different radiation.

→ When the flash light provide external energy to the ruby rod then the chromium particles receives the energy and starts emitting radiation of various colours.

→ This emission of radiation is not possible in ground level. The emission takes place in excited excited state.

→ The ends of the ruby rod are flat and parallel and when the different radiation come in contact with each other then they form a beam which appears reddish in colour.

→ The external energy is provided to the ruby rod results in release of large amount of heat and radiation so to remove the excess amount of heat coolant are circulated across the L.B.M. set up

### Advantages :-

→ LBM process can be utilised for making a very small holes in hard and thin materials.

→ The surface finish produce during LBM process is very smooth.

→ In L.B.M process we can obtain an accuracy of 0.01 mm to 0.1 mm.

→ LBM process can also utilised during the machining of rotating parts.

## Disadvantages :-

- The LBM process results in very low material removal rate.
- The set up for LBM is very costly.
- The life of the flash light are also very short.
- LBM process results in severe heat affected area in the work piece surface.
- LBM process is not able to produce very deep holes.

## Application of LBM

- LBM process can be used for micro machining production.
- LBM process can be used for cutting complex profile during en
- It can also be use during micro drilling.
- LBM process can also be use for selective heat treatment of the materials.
- It can also be use to project intense energy to a small area to melt weld or ignite materials on the workpiece surface.
- It can also be used for drilling of very thin and small holes.
- It can be utilised for the machining of parts during micro-boring operation.

→ Laser beam also an important role to play during medical operation.

Q What is laser?

ANS:- Laser stands for Light Amplification by Stimulated Emission of Radiation.

Q Write down any two source for laser beam production.

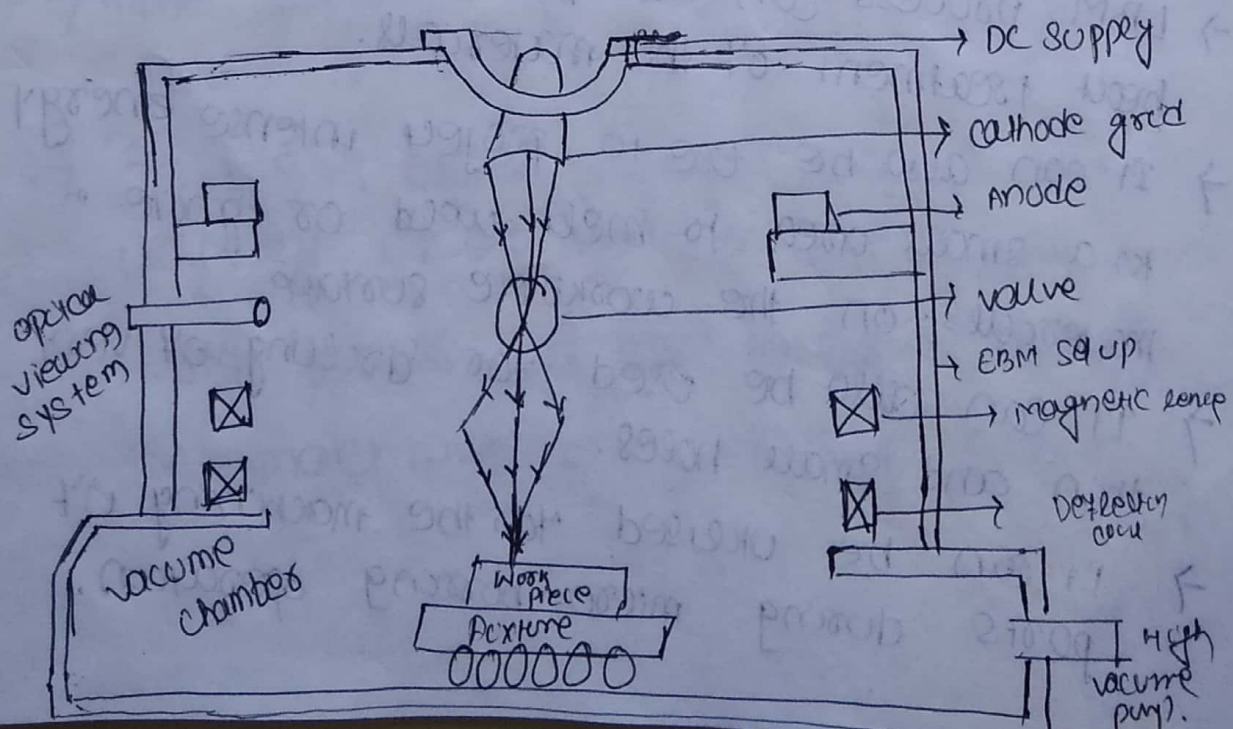
ANS:- (i) Ruby rod

(ii) Nd-YAG

Electron Beam machining (EBM):-

It can be defined as a non-conventional machining process in which material removal takes place with the help of electron beam is known as EBM.

Construction of electron beam machining



The set up for EBM process consist of a DC supply source having a voltage intensity of 30 kV. The cathode grid which is ~~is~~ negatively biased is responsible for the emission of current or flow of electrons. The anode used in EBM process is connected to the cathode so that the electron don't deviate from their path and approach to the next element.

→ The magnetic lens are provided which gives a particular shape to the beam and to reduce the divergence of the electron beam and produce a high focused beam. Deflection coils are used to focus ~~beam~~ the electron beam on a particular spot on the workpiece surface. High vacuum environment inside the EBM set up. Optical viewing system is also provided to check the formation and divergence of electron beam.

### Working Principle of EBM

→ The EBM process is started when a high voltage 30 kV DC supply is provided to the cathode grid. when cathode grid is supply with the required voltage then it starts producing electric current. The electric current here produce high velocity electrons which moves towards the anode which is placed after cathode grid.

→ Now this high intensity electron beam passes through the anode and with the help of a valve it is controlled.



The diverged beam then passes through magnetic lense which is responsible for controlling the divergence of the beam and increasing the intensity of the beam.

→ The electron beam then reaches the deflection coils which focus it into a particular spot on the work piece surface.

The material is removed when the high intense ~~to~~ electron beam collided with the work piece surface and the kinetic energy of the electron beam is converted into heat energy. In this way the heat energy melts the work piece surface and eventually it vapourises.

### Advantages:-

- EBM process can be utilise for the drilling purposes in case of very tough material.
- very hard and heat resistant material can also be machined and welded with the help of ~~a~~ EBM process.
- No physical damage occurs in the work-piece surface during electron beam machining.
- No tool wear takes place occurs during EBM process.

→ In EBM process there is no contamination of the set up since the EBM process is carried out inside the vacuum chamber.

→ Holes as small as 0.002 mm in dia. can be produced during EBM process.

### Disadvantages :-

→ The initial cost for the EBM set up is very high.

→ EBM process can be carried out only in the vacuum chamber.

→ Skilled operators are required to perform the EBM process.

→ The power consumption in EBM process is very high.

→ In EBM process proper care should be taken to avoid heat affected area.

→ This process is not suitable for the machining of workpiece where less amount of material is to remove.

### Application

→ EBM process is utilized in drilling industry to produce deep holes.

→ This process is suitable for welding of highly reactive material.

→ This process is suitable for machining of turbine blades for aero engines and nozzles of the nuclear reactor.

→ very precise holes of 0.002 mm can be produced in EBM process.

Q Why electron beam machining is carried out in vacuum chamber?

EBM is carried out in vacuum chamber because the kinetic energy of electron beam may get reduce due to its collision with the air molecules.

Q What is the DC voltage supplied during EBM process?

ANS 30 kV.

Q What is the function of magnetic lens, and deflection coils.

ANS :- magnetic lens control the divergence of the beam and increase the intensity of the beam. deflection coils use to focus the electron beam on a particular spot on the work piece surface.

Q What is the accuracy that can be achieved during EBM process

ANS 0.002 mm

# Automation

## Chapter 2

✓ The ~~technic~~ technique, method or system of operating or controlling a process by highly automatic means and reducing the human involvement to a minimum level with the help of automatically operated devices with out continuous input from an operator is known as automation.

✓ Need for the automation :- (Advantages, object)

- increased in overall productivity.
- improved quality of the manufactured product.
- increase in consistency of the product.
- Reduced human labour cost and expenses.
- It can complete task where a high level of accuracy is required.
- installation in operation reduces cycle time.
- It reduces injuries to the human labour.
- Replaces human operators in task that involve very hard and monotonous physical work.
- It performs task that are beyond human capabilities.
- It replaces human in task done in dangerous environment.

- It reduces operation time and work handling time.
- It provides high level jobs in the development field.
- It provides a safer working condition.

### Disadvantages of Automation :-

- It is very costly since the automated devices and electronic gadgets are very expensive.
- It can result in unemployment for a large section of industry workers.
- It consumes huge amount of energy.

### Types of Automation :-

There are three types of automation. They are

- (i) Fixed Automation
- (ii) Programmable Automation
- (iii) Flexible Automation

#### (i) Fixed Automation :-

In this automation process automated equipments are fixed in a sequence of producing assembly operations. Each of the operation in the sequence is very simple and mostly follows a simple linear path.

→ It is difficult to change the sequence of the process. This automation is also known as hard automation.

Advantages :-

→ Low unit cost.

→ Automated material handling and high production rate.

Disadvantage

→ High initial investment.

(ii) Programmable Automation :-

In this automation process the production equipment is design with the capability to change the sequence of the operation to produce different products of different configuration. This operation is controlled by a program so, that it can be read and interpreted by the system. New programs can be prepared and entered into the system to produce new products.

Advantages :-

→ Flexible to deal with design variations.

→ Suitable for batch production.

## Disadvantages:-

→ High investment for the automated equipments.

## ii Flexible automation:-

A " " system is capable of producing a variety of parts with virtually no time loss.

The changed for a new product is made which results in no time loss. The system is re-programmable and the physical set up can be altered.

## Advantages:-

→ continuous production of variable mixture of products.

→ Flexible to deal with product design variation.

## It's advantages:-

→ cost of the equipment is extremely high.

→ It requires a highly skilled operator.

# NUMERICAL CONTROL (NC) SYSTEM

Chapter - 5

## NUMERICAL :-

Numerical stands for any thing that contains numbers, symbols, and letters.

## CONTROL :-

Control means to direct, show direction and to assign different duties.

## Numerical control system :-

It can be defined as a method of automation in which various functions of the machine tools are controlled with the help of numbers, symbols, letters.

In other words NC system is the method of automation in which machine tool is controlled with the help of numbers, symbols and letters.

## Function of NC system :-

- Starting and stopping the motion of machine tool.
- controlling the speed of the machine tool.
- positioning the tool tip at a desired location.
- Guiding the machine tool to control the movement of the tool.



→ changing the tool in the spindle.

## Main components of NC system.

The Numerical control system consists of these main components. They are.

- (i) Machine control unit.
- (ii) part program
- (iii) program loading system.
- (iv) NC tools.
- (v) Servo electric mechanism.
- (vi) control panel.

(i) Machine control unit :- (MCU)

→ The MCU consists of important toolings for the part to be machine. It performs the various controlling function under the program control. It is mounted separately and it also controls the motion of the cutting tools, spindle speed, feed rate, tool change, cutting fluid application and various other function of the NC system.

## (ii) part program :-

part program is a very important software which contains numbers, symbols and letters. It is the detailed plan for the manufacturing of a particular product in any NC system. It is very similar to a computer program with a specific format that is codes.

Some ~~typical~~ <sup>typical</sup> examples of part program are.

(i) S 125.0 X 120.0 Y 30.0

(ii) S 120.0 X 30.0 Z 20.0

(iii) F 50.0 Z 30.0 Y 50.0

## (iii) programming coding system :-

The human characters can't be directly entered into the machine control unit. So we need a part coding system that can be easily understood by the machine control unit.

The normal program is need to be converted into the form of codes.

## (iv) NC tools :-

The Numerical control tools are the tools which performs various operation on the work piece surface such as milling, grinding, reaming etc.

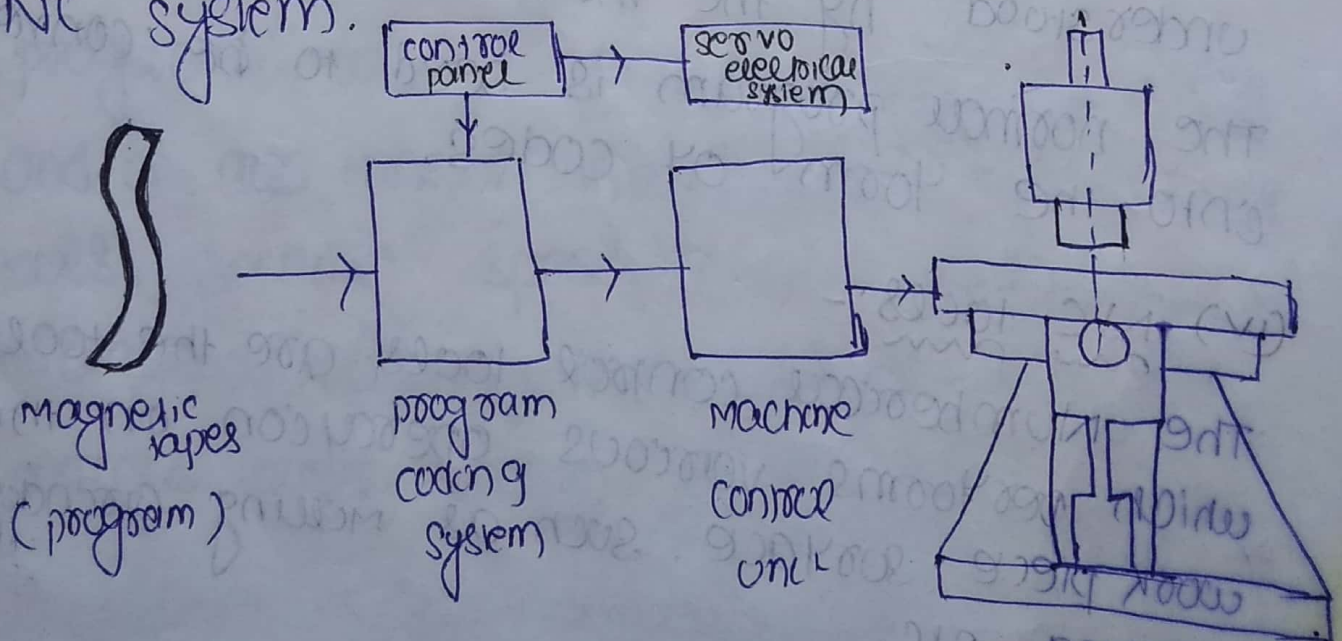
NC tools perform these functions according to the program decoded by the part coding system or program coding system and the NC tools are controlled by MCU. Machine control unit.

(v) servo electric mechanism:-

It contains all the servo electrical equipment such as motors, transducers etc. which helps in the movement of the NC tool and it also measures the speed of the machine tool.

(vi) control panel:-

A control panel consists of various fuses and switches which control the flow of electricity to the different parts of the NC system.



## Types of NC coordinate system :-

These are various types of NC coordinate system which can be classified according to the relative movement of the tool with respect to the work. They are.

i) point to point NC system.

ii) straight cut NC system.

iii) contouring NC system.

## (i) point to point NC system :-

→ " " " " " " " " is also known as positioning system.

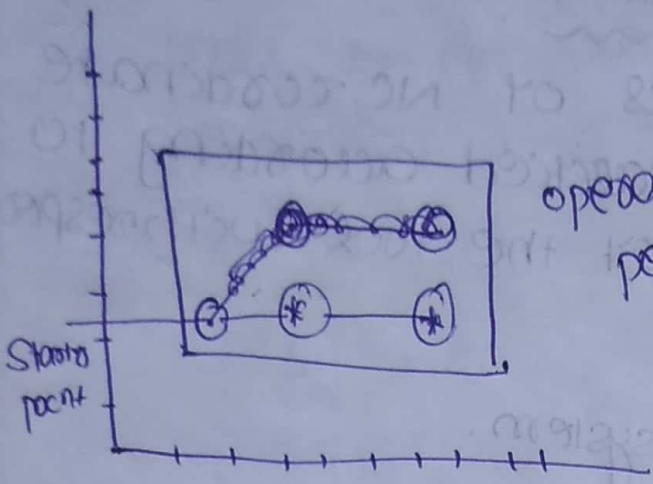
→ In PTP system, the objective of the machine tool is to move the cutting tool in a predefined location.

→ The speed and path of the movement is not imp in P.T.P system.

→ Once the tool reaches the desired location, the machining operation is performed at that location.

→ For Ex NC drill machine is a good example of P.T.P system. The spindle tool is positioned at the particular location and the drilling of the hole takes place under P.T.P system.

→ P.T.P system can be used in drilling and spot welding operation.



operation performed in PTP system

(ii) Straight cut NC system :-

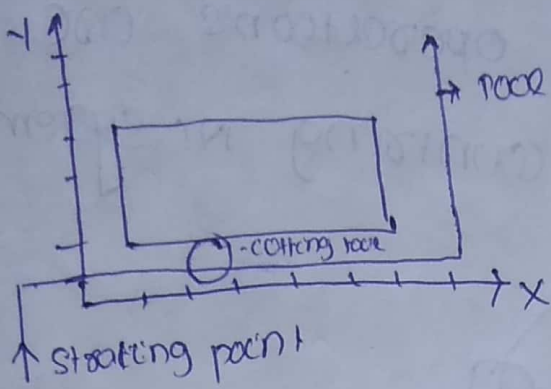
→ " " " " is capable of

moving the tool parallel to one of the measure axis. At a suitable rate for machining.

→ It appropriate for performing milling operations of rectangular configuration work piece

→ In this type of NC system, it is not possible to combine movements in more than a single axis. ~~There~~ These type angular cuts are not possible in the work piece surface in case of straight cut NC system.

→ This type of system is also capable to perform operation which are performed by PTP NC system:



(iii) contouring NC system :-

→ " " " " " " is ~~the~~ the most complex, most flexible and most expensive type of NC system.

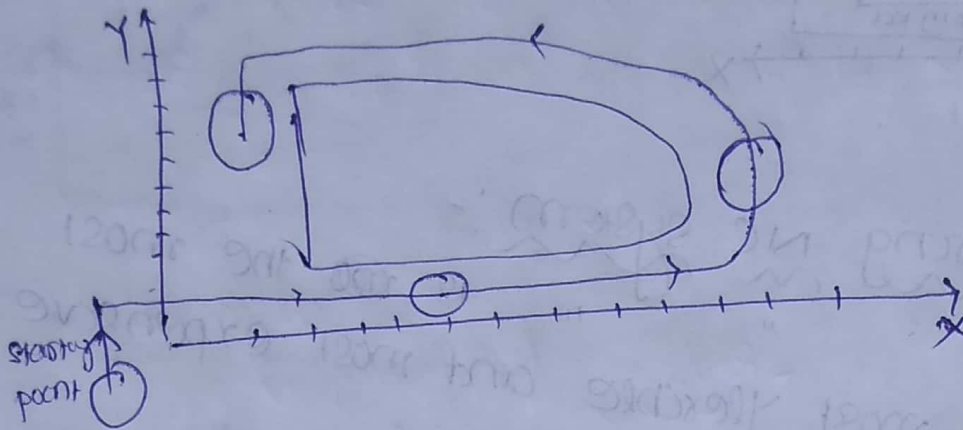
→ This NC system is capable of performing operations which are performed in PTP NC system and straight cut NC system.

→ The most imp feature of contouring NC system is their capacity for controlling the movement of the tool in more than one axis.

→ The path of the cutting tool is continuously controlled to generate the desired geometry of the work piece. For this reason contouring NC system is also known as continuous path NC system.

→ circular path, conical shapes, straight or plane surfaces of any orientation can be machined easily with the help of contouring NC system.

→ Milling and turning operations are common examples of contouring NC system.



### Part programming:-

The " " in the NC system can be defined as the procedure by which the sequence of the processing steps to be performed on the NC machine is ~~planned~~ planned and documented.

→ It involves the preparation of punched tapes which are used to transmit the information of the operation to the cutting tool.

→ The part programming consists of a various ~~codes~~ codes used by the manufacture during the machining operation. The sum of the gmp code or function are

- (i) coordinate function.
- (ii) feed function or F-code
- (iii) speed function or S-code

- (v) preparatory function or G-code.
- (vi) Miscellaneous function or M-code.

(i) Coordinate function :-

The " " of the tool tip are program for generating a given component geometry. The coordinate value are specified using the word address, X, Y, Z etc. This are used along with the decimal point depending upon the resolution according to the need.

For Example X 45.0 Y 35.201  
Z 289.208 X 46.51

(ii) Feed function or F-code :-

The feed is determine in terms of velocity of the tool into the work piece. The feed function generally signified the feed of the tool and it is designated with the word 'F'. The feed function or feed rate is program and controlled by the NC system. This is actually the speed with which the tool moves penetrating into the work-piece.

For example :-

X 38.26 F 45.00

(iii) Speed function or S-code :-

The " " " " is designated with the word S. The speed function signified the speed of the spindle.



In most of the CNC machine they need to have a proper G-code to control the speed of the tool. The speed can be set directly on the revolutions per minute (Rpm) mode.

For example

G1500 where spindle speed is set to be 1500 rpm.

(iv) Tool function / T code :-

The " " signifies the selection of the tool during the various stages of the machining operation. The tool function is designated with the word 'T'. All NC machine are generally provided with various types of tool with automatic tool changers which changes the tool and set the tool in few seconds. The T code may have two or more digits depending upon the capacity of the NC system.

For example T15 which means tool number 15 to be brought into the spindle replacing the already present tool on the spindle.

## (v) preparatory function / G-code 1 amp

- ✓ The " " of G code is a preset function which is associate with the movement of machine axis & the geometry of the workpiece.
- ✓ It is designated by the word 'G'.
- ✓ It is possible to include more than one G-code in a NC part program.
- ✓ The G-code are operational when the NC control system is working.
- ✓ The G-code which ~~is~~ remain operational can be canceled by using another G-code from the same group.
- ✓ The preparatory function are generally present in all machining centre to control the movement of the machine in various axis.
- G-code are also instrumental in active plane selection. They are also used for rapid positioning of the tool in various axis.

code

function

G00

point to point positioning.

G01

Line interpolation.

G02

circular interpolation

~~anti~~ clockwise.

G03

Circular interpolation

anti clockwise.

G104

Dwell

G105

Hold

G106

parabolic interpolation

G107

unassigned

G108

Acceleration of feed rate

G109

Deceleration of feed rate

G110

Linear interpolation for long dimension  
(10 to 100 inches)

G111

Linear interpolation for short dimension  
(up to 10 inches)

G112

unassigned

G113 - G116

Axis designation

G117

XY designation

G118

XYZ

G119

ZX

G120

circular interpolation for long dimension - clockwise

G121

circular interpolation for short dimension - clockwise

G122 - G129

unassigned

Q1.30

circular interpolation for long dimension anti clockwise.

Q1.31

circular interpolation for short dimension anticlockwise

Q1.32

unassigned.

(vi) Miscellaneous Function / M code :- Gmp

✓ This function actually operate some controls on the machine tool and ~~to~~ this function also effect the running of the machine.

→ The miscellaneous function is designated by the word M. The M code used in case of automatic NC system are always standardised by the ISO.

- The miscellaneous function generally control the other important function which are not assigned to any of the coding system.

code

✓ M00

✓ M01

✓ M02

✓ M03

✓ M04

✓ M05

✓ M06

✓ M07

✓ M08

Function

program stop / Spindle stop.

programming stop.

End of program.

spindle on cw.

spindle on ccw.

spindle stop.

~~coolant supply~~ coolant supply on.

coolant supply NO2 on.

coolant supply NO2.

✓ M09

coolant off

✓ M10

clamp

✓ M11

unclamp

M12

~~stop~~ unassigned

M13

spindle on c-wt coolant on

M14

spindle on c-wt coolant on

M15

Rapid transverse in positive direction

M16

Rapid transverse in negative direction

M17 - M18

unassigned

M19

spindle stop at specified angular position

M20 - 29

unassigned

M30

program stop at end of tape

M31

interlock by-pass

✓ M 32 - 35

constant cutting

M 36 - 39

unassigned

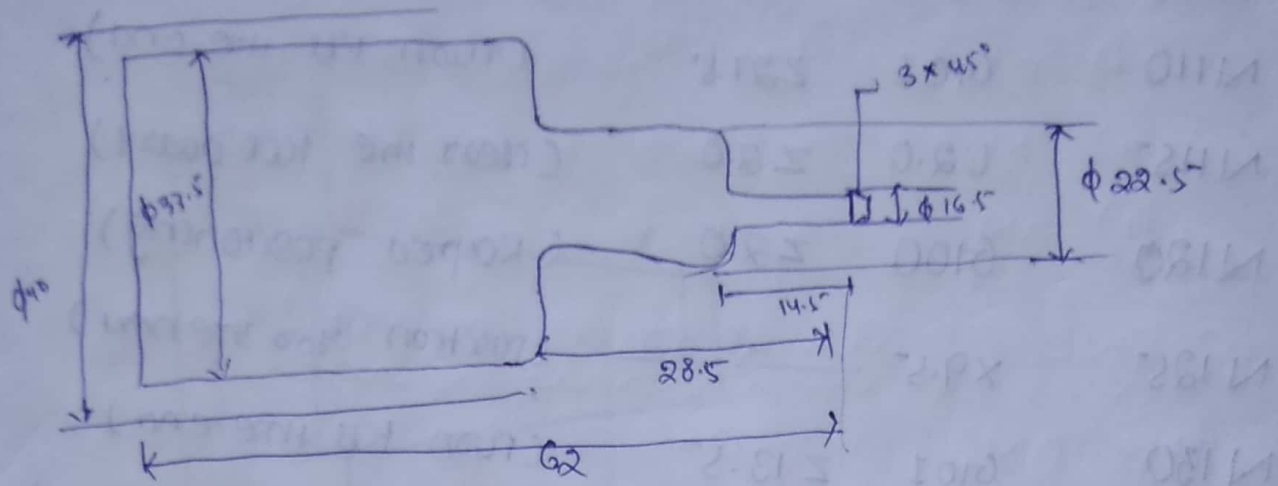
✓ M 40 - 45

gear change

M 46 - 49

unassigned

a write a part program for the machining operation on lathe.



N010 G121

N015 G150 S4000 (set spindle at 4000 rpm)

N020 M06 T0101 (Facing tool)

N030 G196 S3000 (set spindle speed at 3000 rpm)

N035 G100 X22.0 Z0 M03 (position at clearance plane for facing)

N040 G141 (nose radius)

N045 G101 G198 X.05 F0.3 (Feed 0.3)

N050 G140 G100 X50.0 Z240.0 (position of the tool)

N055 S200 S200 M06 T0202 (Rough turning tool)

N060 G142 (nose radius)

N065 G100 X17.75 Z2.0 (position at clearance plane for rough turning)

N070 G101 Z33.5 F0.35 (turning till the end)

N075 U20 W2.0 (clear the tool)

N080 G100 Z2.0 (Rapid positioning)

N085 X15.75 (position for next cut)

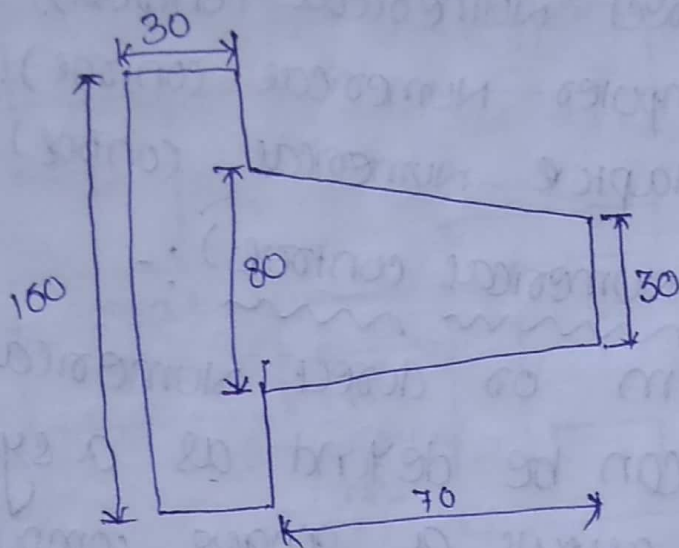
N090 G101 Z27.5 (turn till the end)

N095 U20 Z2.0 (clear the tool)

N100 G100 Z2.0 (Rapid positioning)

N105	X13.75			(position for next)
N110	G01	Z27.5		(turn till the end)
N115	U2.0	Z2.0		(clear the tool away)
N120	G100	Z2.0		(Rapid positioning)
N125	X9.5			(position for the next)
N130	G01	Z13.5		(turn till the end)
N135	U2.0	W2.0		(clear the tool away)
N140	G100	Z2.0		(Rapid positioning)
N145	X9.5			(position for the next)
N150	G01	Z13.5		(turn till the end)
N155	U2.0	Z2.0		(clear the tool from the material)
N160	G40	G00	X50.0 Z40.0	(position the tool)
N165	G300	M06	T0303	(finish turning)
N170	G42			(give nose radius)
N175	G00	X5.0	Z2.0	(Rapid positioning)
N180	G01	X5.25	Z0 F0.15	(start the contour)
N185	X2.85	Z3.0		(position the tool)
N190	Z12.5			(position the tool)
N195	G02	X10.25	Z14.5 R2.0	(Rapid positioning)
N200	G01	X11.25		(finish turning)
N200	M02			(end of program)

Write the part program for the fig given



N05 G94 M06 T0101  
 N10 G100 X0 Z0 M04 S600  
 N15 ~~G01~~ G01 X30 F30  
 N20 G101 X80 Z70  
 N25 G101 X100  
 N30 G101 Z30  
 N35 G100 X120  
 N40 G100 Z10  
 N55 M05  
 N60 M30

Extension of NC system :-

The Numerical control system can be further extended and produced into advanced NC system this advanced NC system have the qualities of the basic Numerical control system and it also had some advanced technology associated with it.



The extended NC system are

- i) DNC (Direct Numerical Control).
- ii) CNC (Computer Numerical Control).
- iii) ANC (Adaptive Numerical Control).

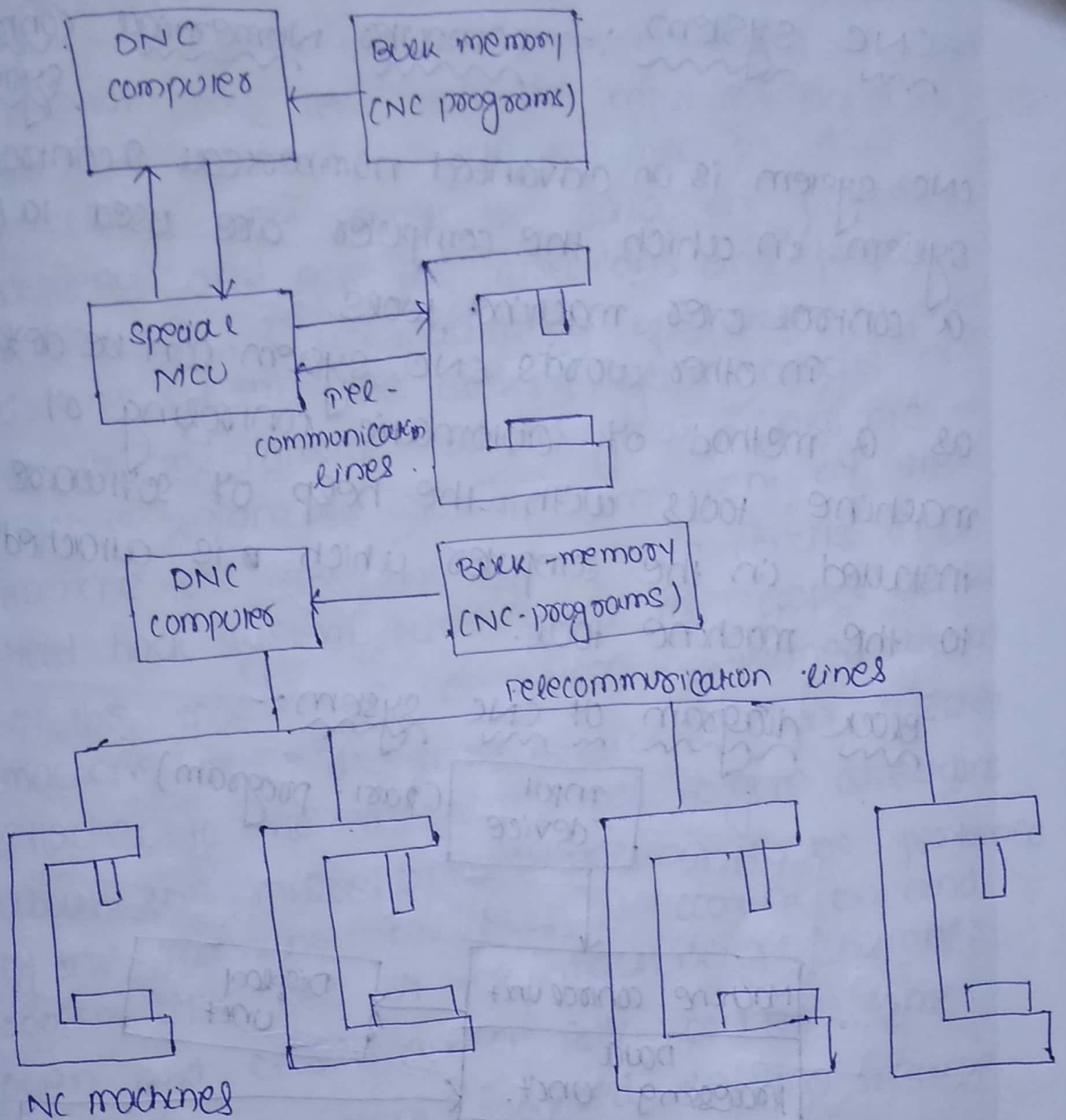
(i) DNC (Direct Numerical Control) :-

The DNC system or direct Numerical control system can be defined as a system in which that allows a single computer to be networked with one or more machine that used computer. This network is typically a broad band version.

The DNC system is utilised to control a network of computers through a single computer basically known as server. DNC system have a very easy and effective programming.

The DNC system consists of high level of decision making through computers.

Block diagram of DNC system :-



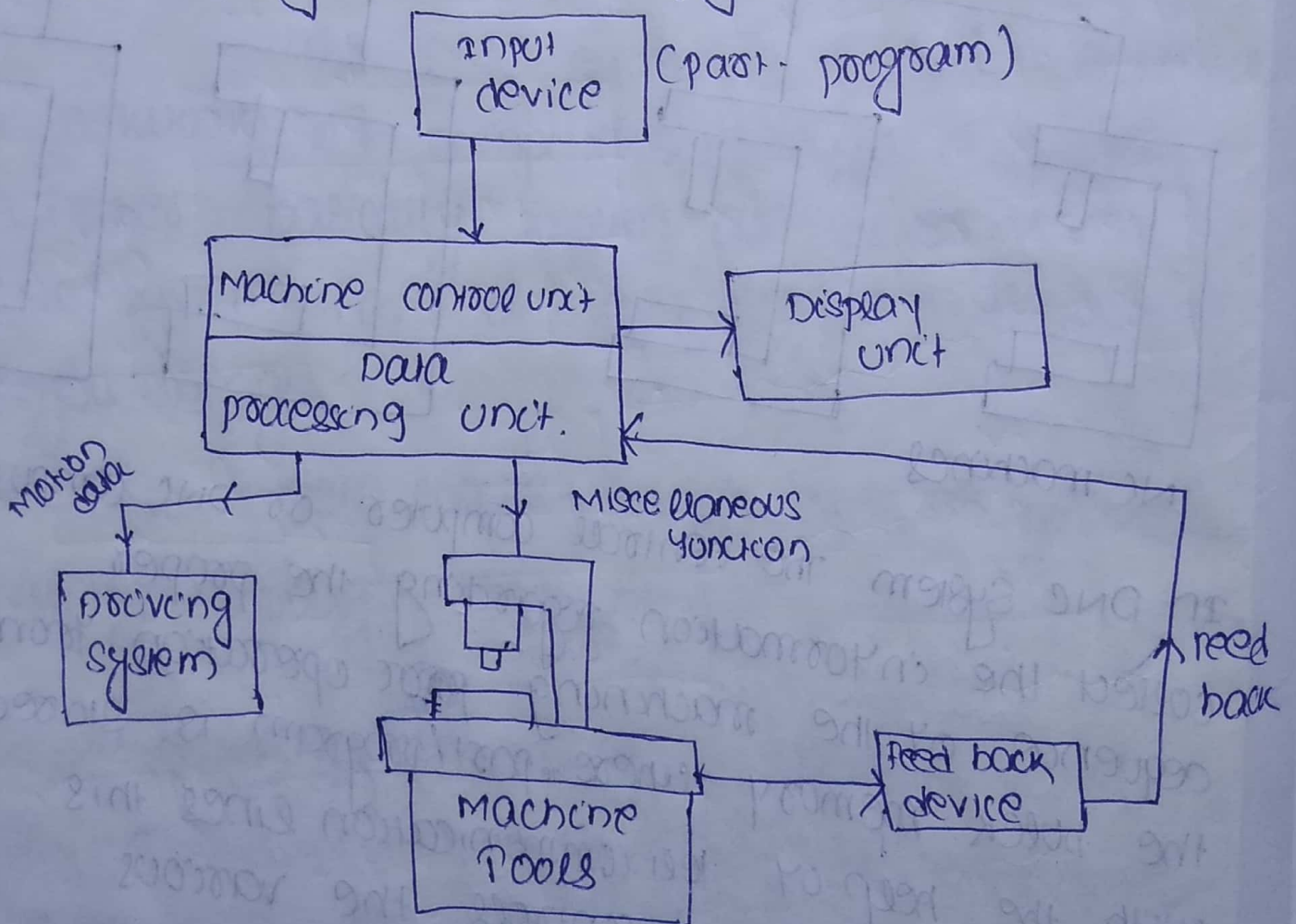
In DNC system the central computer or DNC computer collect the information regarding the proper sequence of the machining operation from the bulk memory where the part program is stored with the help of telecommunication lines this central DNC system controls the various machine tools. In this type of system one central computer can be utilised to control a number of machine tools.

CNC system :- computer Numerical control system

CNC system is an advanced numerical control system in which the computers are used to have a control over machine tools.

In other words CNC system can be defined as a method of automatic controlling of machine tools with the help of software installed on the computer which is attached to the machine tool.

Block diagram of CNC system :-



~~Introduction~~  
In CNC system the input data in terms of part program are feed into the input device. The machine control unit with the help of data processing unit process the data in proper sequence and give the directions and proper procedure of the machining operation to the driving system. The driving system consists of all the mechanism such as gears, links etc which is responsible for the movement of the machine tool. The CNC system also consists of a feed back system which gives the proper details of the machining operation performed by the machine tool. The machine control unit is also attached to the machine tool to give directions about the miscellaneous function to be performed by the machine tool. Such as coolant on and coolant off, gears of the machining chamber open and close and it also controls the various displacement required in the machine tool.

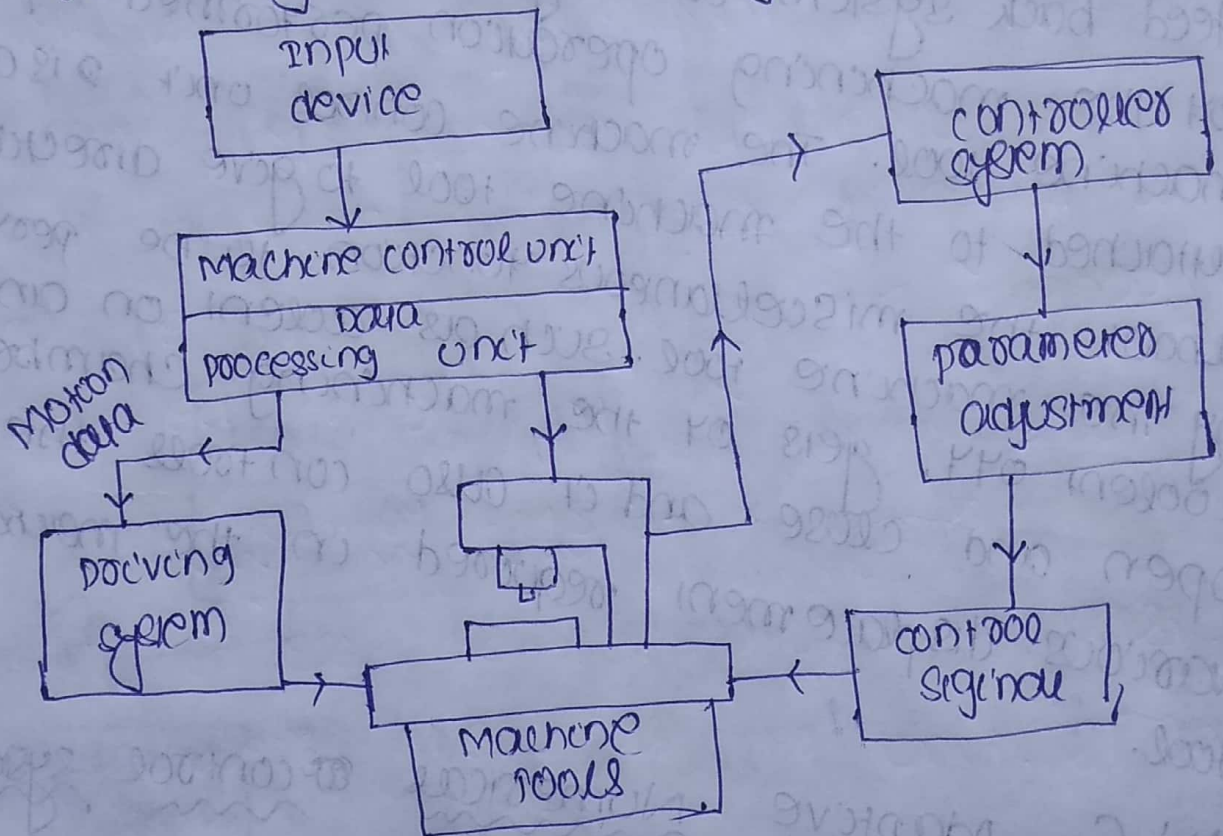
AN/C Adaptive Numerical control system

→ The adaptive control system is the system in which, it has the ability to modify its own operation to achieve the best possible mode of operation.

In other words ANC system can be defined as the system which is capable of automatically adapting them self to the machining process going on.

→ ANC system is a very versatile system which can modify the machining operation at any time during the production according to the changing need.

Block diagram of ANC system



The ANC system consists of an input device into which the part program is feed the machine control unit with the help of the data processing unit process the data and the required

information regarding the machine operation is sent to the driving system. The driving system give direction and information required for the machine tool to perform the machining operation.

Similarly the machine tool is attached to the controller system which inspect the every motion of the machine tool. Any variation needed during the machining operation is adjust by the parameter adjustment system. The parameter adjustment system sends a control signal to the machine tools which helps in the adjustment of a particular parameter or variation needed during the machining operation.

ROBOTFlexible Manufacturing System (FMS)

It can be defined as the manufacturing system in which the manufacturing process can be modified at any point of time and the process which allows any kind of changes in the quality quantity as well as the replacement of the product.

FMS can be considered as a most flexible manufacturing system which has the ability to change the operation executed on a part.

Advantages of FMS :-

- It reduces the manufacturing cost.
- It lowers the cost per unit of the product.
- It increases the efficiency in the manufacturing process.
- It results in greater productivity.
- It results in improved quality.

- It increases the system reliability.
- It reduces the cost of inventories.
- It increases the production rate.
- It reduces the cycle time.

Disadvantages of FMS :-

- The FMS results in high set up cost.
- It can be considered as a complicated system.
- The maintenance of FMS is very complicated.
- It requires skilled labours.
- FMS process requires a lot of ~~research~~ research and pre planning.

Main component of FMS :-

The FMS consists of the following main components. They are

- 1) Workstation
- 2) Material handling & storage system.
- 3) computer control system.
- 4) operators.



## 1. Workstations :-

central

→ Workstation is the place where the actual manufacturing process is carried out. These are various workstations involved in a FMS.

→ The time required to move one component from ~~work~~ one workstation to another workstation is known as lead time.

→ The workstation used in the FMS as a processing unit which is designed for different type of ~~manu~~ machining operation:

→ The Load/unload station in the FMS is the physical interface of the FMS.

→ The raw materials enter the workstation and finished parts exit the workstation.

→ The loading & unloading of the components are done either manually or with the help of automated material handling system.

The most common example of workstation is a CNC machine unit.

## 2. Material handling & storage systems :-

→ The second most important component of FMS is material handling & storage system.

→ The material handling system is the system which is responsible for the transfer of components from one work station to another work station.

→ The various other function of material handling system are (i) It is capable of moving any component in the system from one machine to another machine.

(ii) It also helps in loading & unloading of components in various work stations. The loading & unloading can be done with the help of human involvement and automated machine like robots.

(iii) It also act as a temporary storage because the component travelling from one work station to another work station requires sum amount of time. ~~the more~~

(iv) → material handling equipment involves various automated machine as well as human involvement.

### ③ computer control system :-

→ The FMS includes a ~~com~~ distributed computer system which consists of a central computer which controls the individual machine as well as the other components.

→ The function of the computer control system are

(A) It controls the work stations for performing the machining operation.

(B) It also distributes the instructions to various work stations.

(C) It controls the production by providing the desired daily production rates.

→ The computer control system is also responsible for controlling the tool life at a particular work station.

→ The various other functions performed by the computer control system are

tool control, product control, tool location, tool life monitoring, performance monitoring etc.

#### ④ operators :-

- The operators are the human force involved in the FMS process.
- Humans are needed to manage the operation in the FMS.
- The common function performed by the operators in FMS are
  - (A) Loading raw material in to the work-station.
  - (B) unloading the finished parts from the work stations.
  - (C) Changing and setting the tools.
  - (D) Maintenance and repair of the equipments.
  - (E) NC part programming
  - (F) overall management of the system.

# ROBOTICS

## CHAPTERS-

### Robot :-

According to industrial robot association, a robot can be defined as a multi functional manipulators design to move materials, parts, tools and other devices with the help of programmed motion for the performance very similar to a human being.

### Robot Anatomy :-

The anatomy of a robot refers to the basic structure of a robot.

In other words the robotic anatomy includes the different part of the robots that are used to move material, parts, tools and other devices from one workstation to another workstation.

The robotic anatomy consists of the following main components they are

(i) Manipulators :- The manipulator is the most important component of the robot. Manipulators are developed by the integration of links and joints.

They are the parts of the robot which are used for moving the tool into the work piece. Manipulators are also used to adjust the tools. They are similar to the wrist of the human.

2) End-effectors:- The end-effectors is considered as the hand of the robot. The end-effectors are the components which are used to hold the manipulator. The tools and grippers are the main components of the end-effectors.

- i) The grippers are used to pick and place different objects.
- ii) The tools are used to carry out operations such as spray painting, spot welding on a particular work piece surface.

3) Robot joints:- The robot joints in a robot's are capable of performing sliding and rotating moments of a components.

4) Robot kinematic:- The science behind the assembling of robots is based on the principle of kinematics. In other words kinematic of the robot is responsible for performing all its various functions whether it is movement, holding, the tool or unloading and loading of the work piece.

## Robot configuration:-

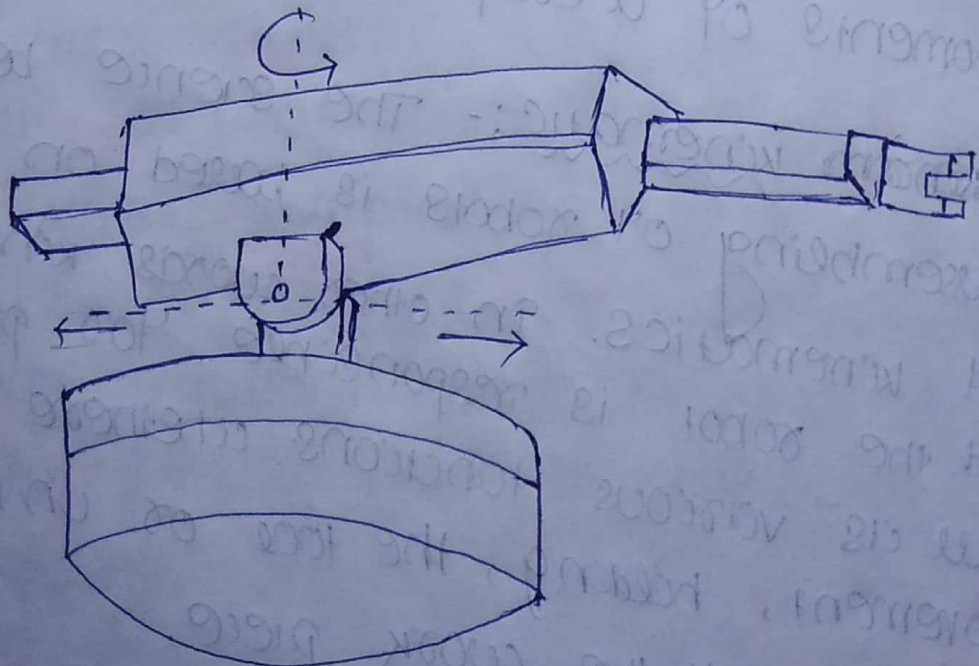
The robotic configuration of a robot refers to the configuration in which the robot is capable of moving.

For Ex:- In the direction like  $x, y$  &  $z$  axis, in an articulated manner: cylindrically, ~~spherically~~ spherically etc.

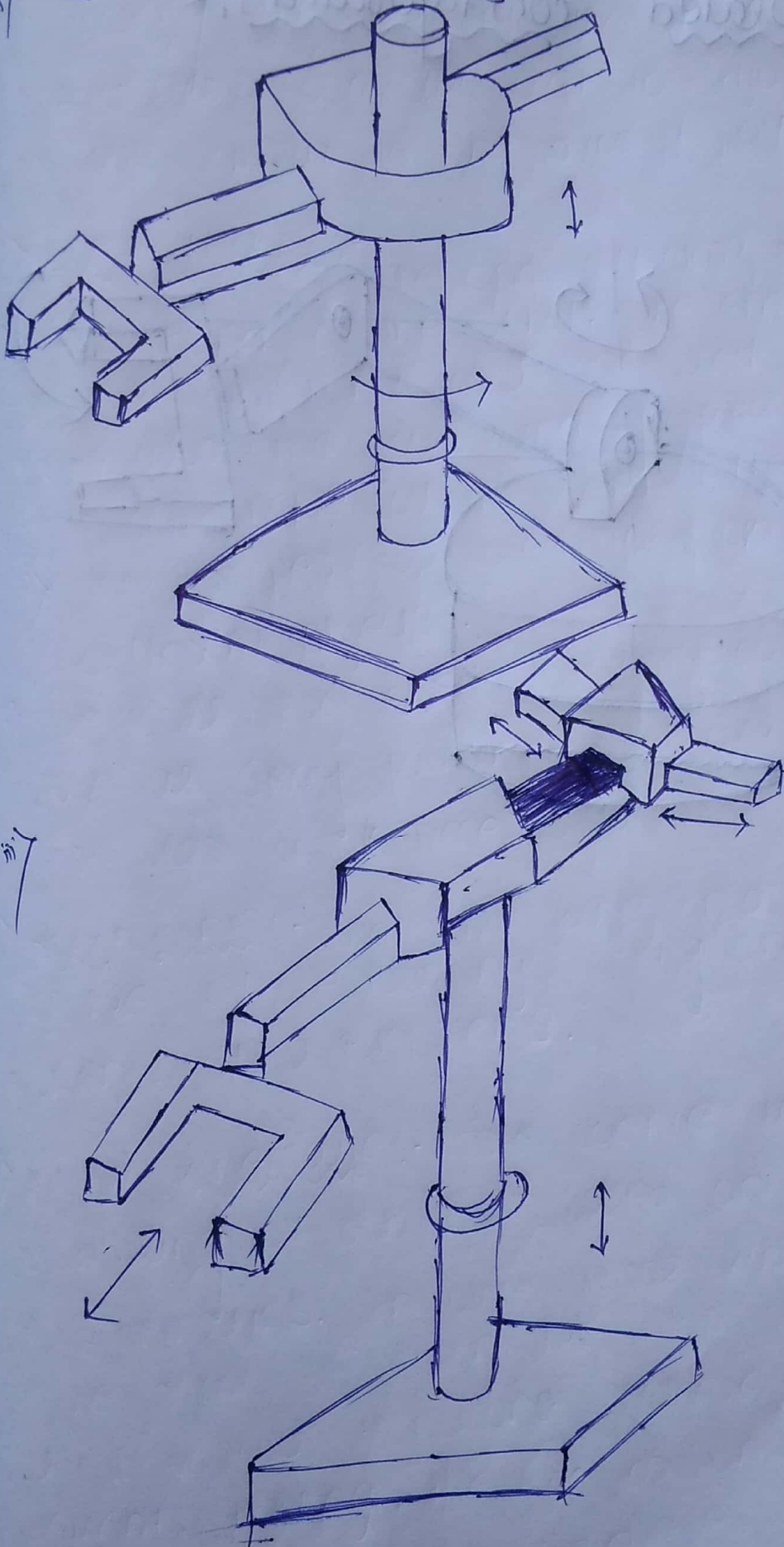
There are basically 4 robotic configurations they are

- i) polar coordinate configuration (spherical)
- ii) cylindrical configuration
- iii) cartesian configuration
- iv) Articulated configuration

### i) polar coordinate configuration:-



ii) cylindrical configuration.



cartesian configuration.



iv) Articulated configuration :-

