31/07/2019

# MODULE - 1

## INTRODUCTION TO NTM PROCESSES

- **Definition :-**

NTM is a machining process which makes use of energy sources for the removal of material from the workpiece.

The different types of energy sources include mechanical, thermal, chemical or electro chemical etc..

- **Reason or need for NTM processes**

(i) Machining of hard materials like carbides stainless steels involves high stresses, friction and residual stresses which might not be possible through traditional machining due to high tool wear & cost and thus NTM is must.

(ii) Machining of very small diameter holes, cavities and difficult geometrical shapes is not possible through conventional machining.

(iii) Composite materials with high non-homogenous structures cannot be machined with conventional techniques.

(iv) The material with high flexibility, low strength cannot be processed easily by conventional methods.

(v) Machining to a very high surface finish with close dimensional accuracies for the product is possible only through NTM methods.

## Classification of NTM processes :-

*** Imp

The classification of processes is mainly based on the type of energy sources used. They are classified into three types.

(i) Mechanical energy.
(ii) Chemical or electrochemical energy.
(iii) Thermal energy.

### (i) Mechanical energy :-

In this the excess material is removed by the mechanical errosion of the workpiece material. (a) Ultrasonic machining
(b) Abrasive jet machining
(c) Water jet machining.

This processes utilize mechanical energy for material removal.

### (ii) Chemical / Electrochemical energy :-

In this the removal of workpiece material takes place by the mechanism of ion displacement or by chemical dissolution using acids, chemical reagents etc....

The different processes come under this include

(a) Chemical m/c (b) Electrochemical m/c
(c) Electrochemical grinding (d) Electrochemical honing.

(e) Electrochemical deburring.

(iii) Thermal energy :-

In this process the removal of material takes place with the help of thermal energy which melts and vapourises the material. This can be possible when the heat energy is concentrated on a very small area on the workpiece.

This different processes which utilize thermal energy include:

(i) Laser beam m/c
(ii) Plasma arc m/c
(iii) Electrical discharge m/c
(iv) Electron beam m/c

* Comparison b/w Traditional & Non traditional machining (Imp)

| Traditional m/c | Non Traditional m/c |
|---|---|
| (1) There is physical contact b/w workpiece & cutting tool. | • There is no physical contact b/w workpiece & cutting tool. |
| • The cutting tool should be harder than the workpiece. | • The cutting tool need not be harder than the workpiece. |
| • It results in formation of macroscopic chips. | • It results in formation of microscopic chips. |
| • Poor surface finish is observed & the less accuracy of the dimensions can be easily seen. | • A very good surface finish with close accurate dimensions can be seen. |
| • Doesn't require a skilled labour. | • It requires a skilled & experianced labour for operating the machine. |

| | |
|---|---|
| • Capital cost is less & requires ~~less~~ minimal maintance. | • Capital cost is high for the setup & requires regular maintanance. |
| • The metal removal rate is limited due to mechanical property of the material. | • The metal removal rate has no limitations. |
| • The overall setup of equipment is easy. | • The overall setup is complex. |
| • Tool life is less due to maximum tool wear. | • Tool life is more as the tool ~~ware~~ wear rate is minimum. |
| • Requires more time for the machining process to get a complete well defined product. | • Comparitively less time. |

• <u>Process Selection</u> :-

The various factors that need to be considered before selecting NTM process are as follows.

(i) Properties of the work material
(ii) Shape to be machined.
(iii) Physical parameters of the process.
(iv) Process capabilities.
(v) Economic considerations.

(i) <u>Properties of the work material</u>:- indicate the hardness, softness, conduction, non-conduction, brittle and ductile nature of the material. Some processes may be suitable for machining where as other processes may not be suitable.

Ex:- Ultrasonic machining is suitable for ceramics and glasses but electrochemical machining & electric discharge machining is not suitable as both these materials are non conducting.

ECM & EDM are suitable for super ~~copper~~ alloys but USM is not possible to this material. Hence selection of process becomes an important factor.

(ii) Shape to be machined :- USM & LBM (Laser Beam) are not suitable for machining deep holes. But it is possible by other processes. Selection of the process also depends upon ~~the~~ the shape to be machined.

(iii) Physical parameter of the process :- It include power, voltage potential, gap between the cutting tool & workpiece etc... These factors are important before selecting the process because the variation in this physical parameters results in change in the dimensions of the required product.

(iv) Process Capabilities :-

The process capabilities of NTM process include the metal removal rate, surface finish, tollarance etc.... These parameters are different for different NTM processes. Plasma arc machining has higher metal removal rate compared to ultrasonic machinging. Electrochemical machining has excellent surface finishing property.

(v) Economic considerations:-

These include the costs related to the equipment, tools used, power requirements and other miscellaneous costs. Abrrasive jets, ultrasonic & plasma arc machining require less capital investment compared to other processes. Tooling cost for ECM & EDM is high. Power consumption for electrochemical machining is less as compared with other processes.

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- Advantages :-

1. It doesn't involve toxic gases.
2. It is a dust free process.
3. The health hazards related to cutting materials is minimized in NTM processes.
4. It doesn't involve heat affected zones there by reducing the mechanical stresses.
5. A fine surface finish, sharp cuts can be obtained.
6. Soft materials can be easily machined.
7. Complex shapes and intricate geometries can be machined.
8. This processes can be automated.

- Limitations :-

1. The equipment cost is high.
2. The water used in some of the processes can be recirculated, but this has to be filtered regularly.
3. The human operators need extra safety measures during operations.
4. ~~It~~ In adoptibility of the processes for the materials crossing the thickness limitations or very thick materials are difficult to machine using NTM processes.

## Applications :-

1. Non-metallic materials such as glass, graphite fibre, reinforce, and other brittle materials can be machined.
2. Used in aircarft, industries for profile cuttings.
3. Helps in removal of surface irregularities.
4. Also used in cleaning and descaling operations.
5. Used in cutting of printed circuit boards.

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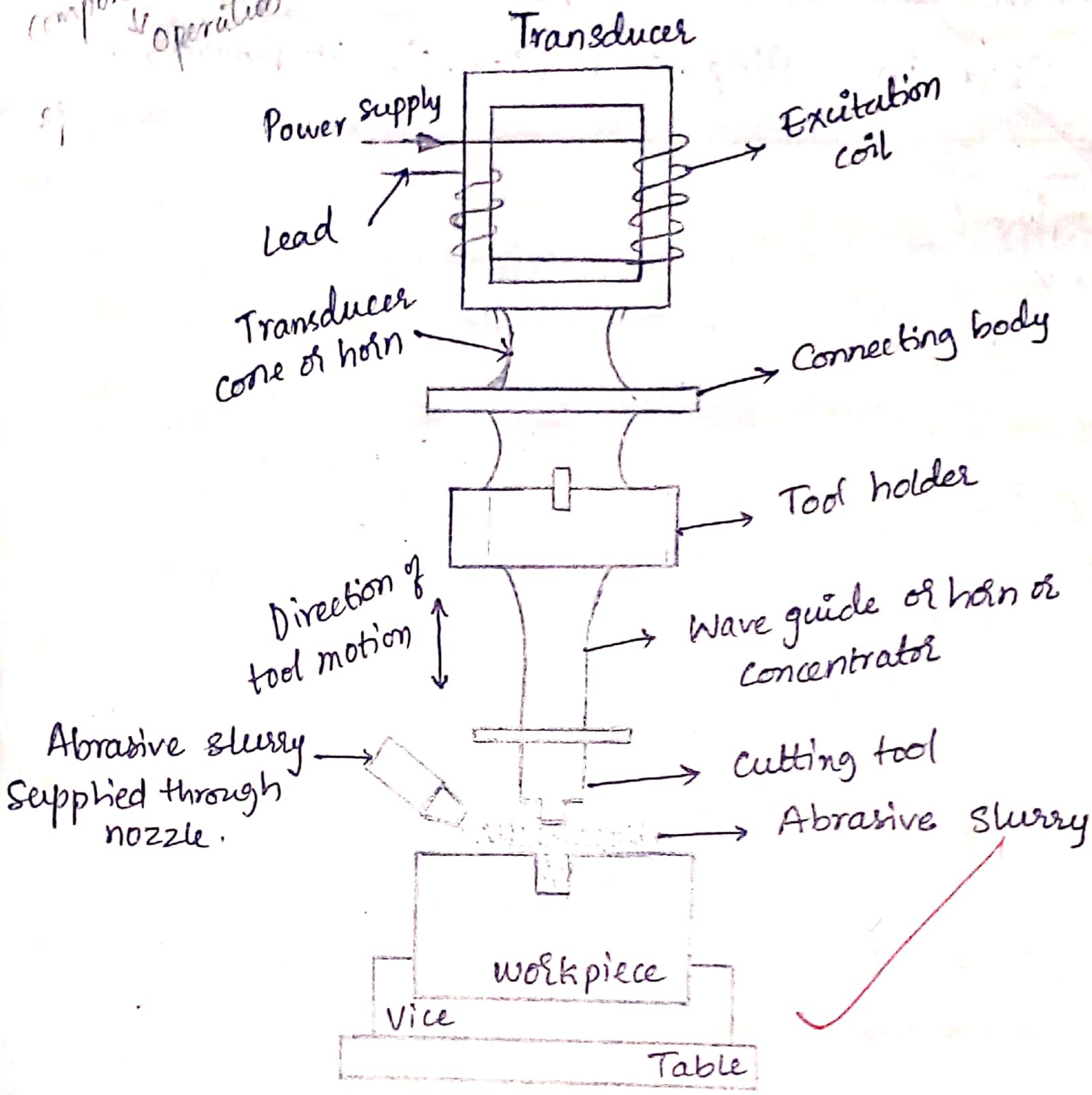
# MODULE - 2

# ULTRASONIC MACHINING

• ① Ultrasonic machining equipment :-

components & principle of operation




Components of Ultrasonic machining inculde

(i) Power supply

(ii) Transducer.

(iii) Tool holder

(iv) Cutting tool

(v) Abrassives

(i) Power Supply :-

The power supply used for ultrasonic machining is high power sine wave generator, that converts low frequency electric power to high frequency electric power nearly to the order of 20,000Hz. This electrical signal is supplied to transducer.

(ii) Transducer :-

A transducer is a device which converts high frequency electrical signal into a high frequency mechanical motion which results in vibrations. This vibration of the transducers helps the tool coming in contact with the abrassives to remove the material from the workpiece. The transducers available are piezioelectric type & magnetostrictive type.

The Piezioelectric materials like quartz, zirconate. When they mechanically stressed a potential difference can be observed and this is directly proportion to the Stress applied and it also results in increase in size of this materials. When the current is removed the materials retain their original size.

(iii) Tool holder :-

The high frequency mechanical motion obtained from the transducer is transmitted to the tool holder. The tool holder helps in supporting the tool. In addition to this function the tool holder transmits the length of the stroke to the tool by the help of wave guides. This tool holders can be either amplified or non-amplified type.

(iv) Cutting tool :-

The tool used in this process has the Same shape to be machined upon the workpiece. Major of this process used uses cutting tool made up of ductile materials like stainless steel, mild steel, etc... The size of the tool is smaller as compared to the workpiece. The attachment b/w the tool and the tool holder can be obtained by soldering or brazing.

(v.) Abrassives :-

The abrassives are hard tiny particles usually suspended in a liquid, supplied b/w the tool & the workpiece. The abrassive slurry is stored in a reservior and supplied through a nozzle exactly at the cutting zone between the tool workpiece interface. The liquid used in the abrassive slurry helps in removal of the material due to the cavitation effect.

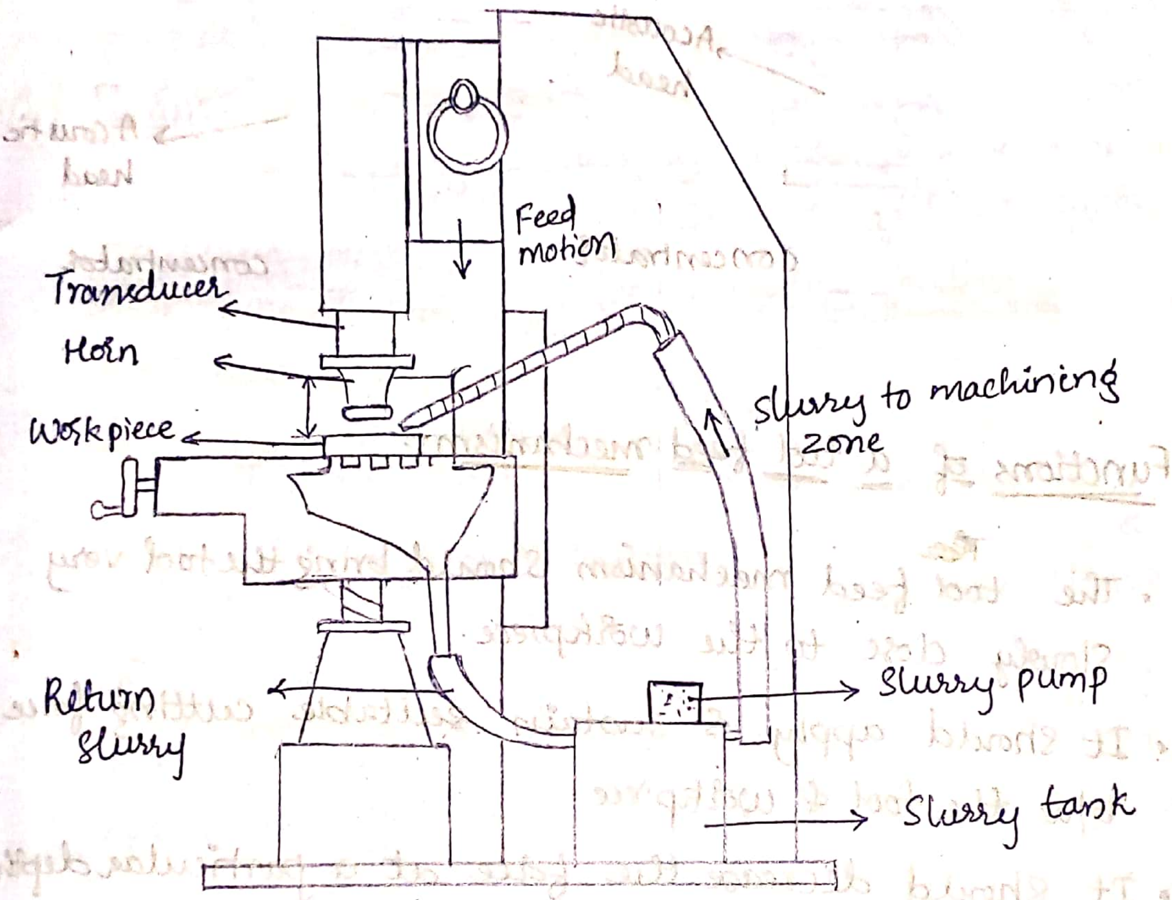
- Principle of Ultra Sonic machining :-

It is based on the principle that when a tool vibrating with high frequency is brought closer to the workpiece with abrassive particles in between them, the vibrating energy of the tool can remove the material from the workpiece.

- Need for Ultrasonic machining

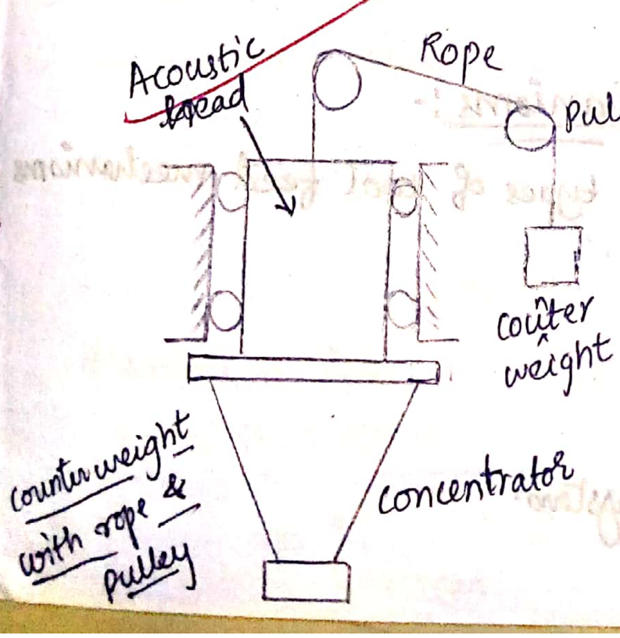
Materials like glass ceramics, hardened steels, carbides etc.... are difficult to be machined using conventional methods. As ultrasonic machining is non-chemical process and it doesn't change the microstructural properties of the materials, it becomes an easy option to carry out.

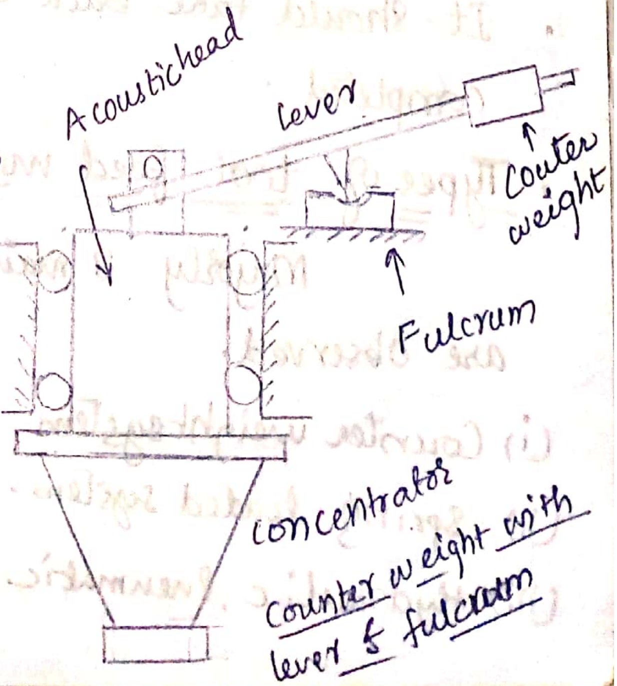
② **USM Equipment** :- *Explain the equipment components.*



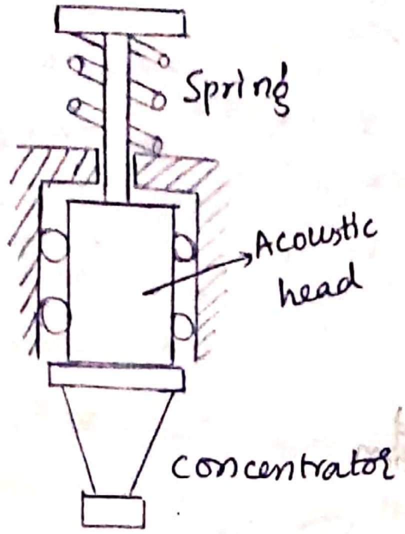

• **Tool Feed mechanism** :- *Imp*

(a) Counter-weight system :-

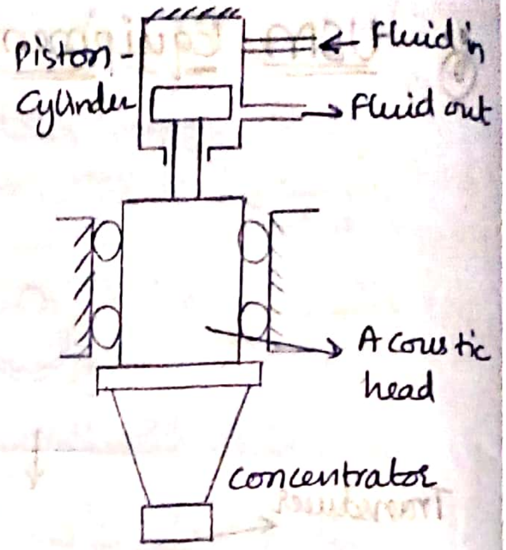


(b) Spring loaded system




(c) Hydraulic (pneumatic) system




## Functions of a tool feed mechanism:-

- The tool feed mechanism should bring the tool very slowly close to the workpiece.
- It should apply & sustain suitable cutting force b/w the tool & workpiece.
- It should decrease the force at a particular depth.
- It should have a tolerance limit to get the desired size at the exist point.
- It should take back the tool after machining is completed.

## Types of tool feed mechanisms:-

Majorly 3 main types of tool feed mechanisms are observed.

(i) Counter weight systems.
(ii) Spring loaded systems.
(iii) Hydraulic, Pneumatic systems.

(i) Conuter weight system :-

In counter weight system the feed force is the difference b/w the weights of the transducer and tool holder. And counter weights attached through a lever or a pulley system. The force is adjusted by changing the weights

(ii) Spring loaded system :-

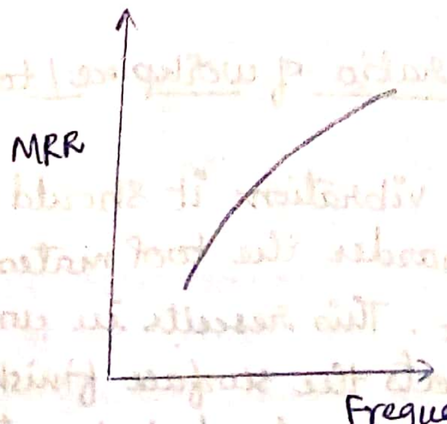
In spring loaded system the feed force is adjusted with the help of springs and it is quite sensitive to the changes in cutting conditions.

(iii) Hydraullic, Pneumatic system :-

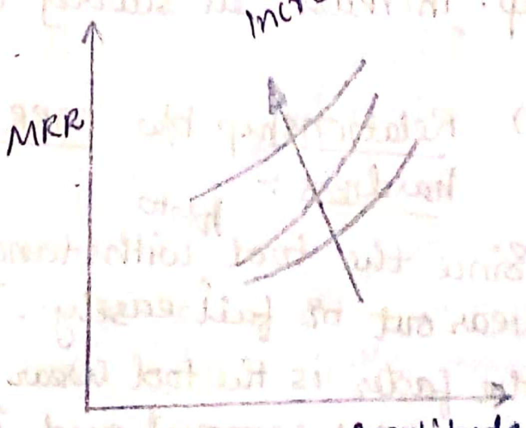
The most preferable mechanism in USM is hydraulic & Pneumatic system. This uses piston & cylinder arrangement ~~rota~~ with a suitable liquid or air as the working substance to apply the required feed force. It is very easy to control and retrive the mechanisms once the whole process is accomplished.

- USM parameters which affect the MRR

(i) Effect of Amplitude frequency of MRR :-



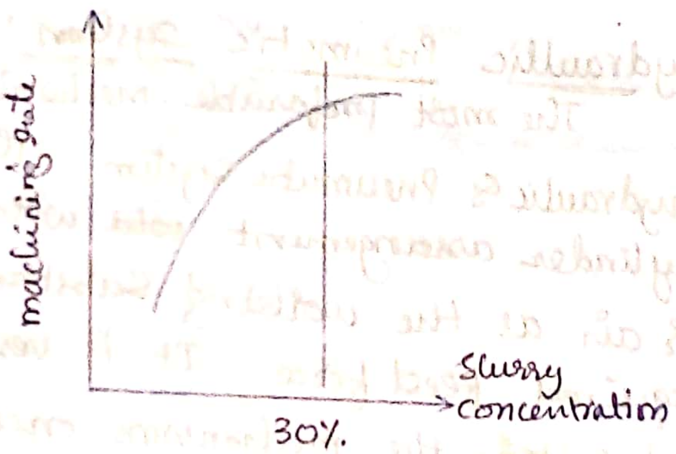
(a)



(b)

The amplitude and frequency when increased automa-tically increases the rate of metal removal. This determines the velocity of the abrassive prattcles at the interface b/w the workpiece & the cutting tool. At larger amplit-udes the kinetic energy rises which inturn increases the mechanical chipping action. The range of frequency is b/w 15-30KH of that of amplitude is 25-100 micro meters. Increase in these 2 parameters tends to increases the surface roughness.

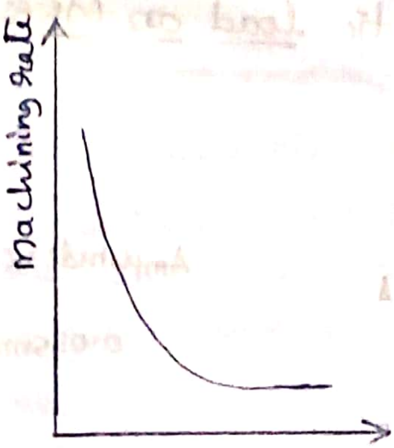
(2) <u>Relation between MRR and slurry concentration</u>:-




From the graph shown it is observed that a percentage concentration of 30-35% is recomended for good metal removal rate. The concentration of slurry should be periodi-cally checked to have increased metal removal rate. when the concentration goes beyond the recomonded % the MRR drops and hence it is highly recomonded for a periodical check-up. Increase in slurry concentration increases the viscosity.

(3) <u>Relationship b/w MRR and ratio of workpiece/tool hardness</u>:-

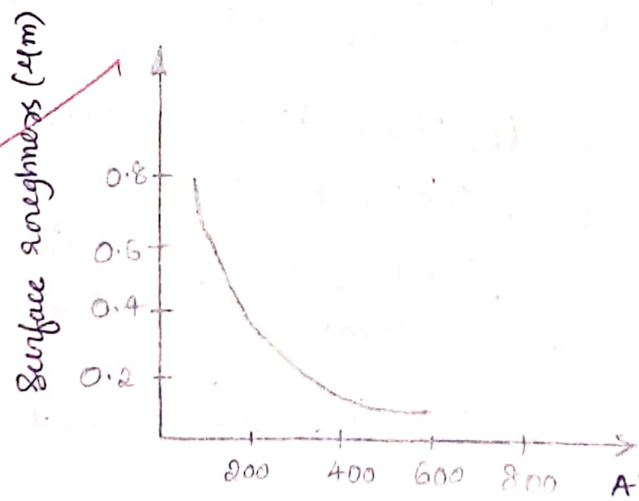
Since the tool has to withstand the vibrations it should not wear out or fail easily. The harder the tool material the faster is the tool wear effect. This results in unfavarar-ble metal removal and it effects the surface finish. Alloy steels & Stainless steel are prefered tool materials.




4) Types of Abrassives :-

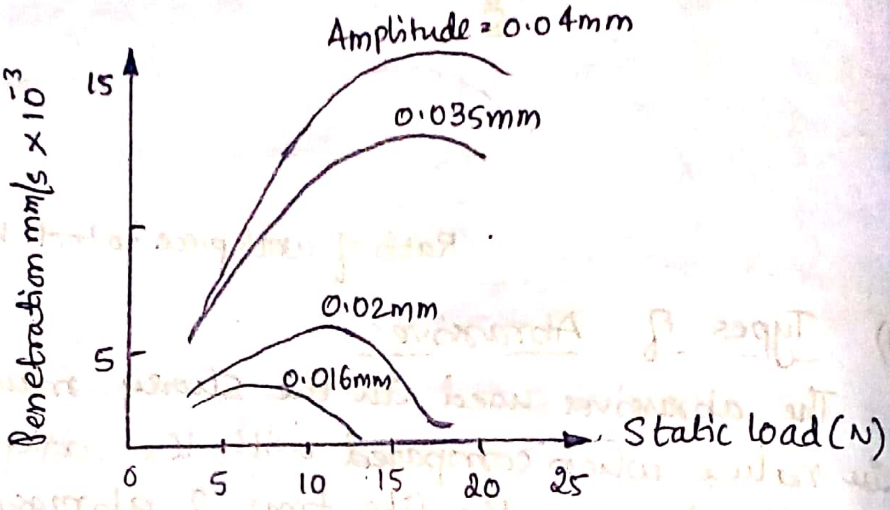
The abrassives used in the slurry must be harder in nature when compared with the workpiece material. this will increase the life time of abrassives and also the maching. Preffered abrassives include boron carbide, & silicon carbide. Boron carbide is the costlier ~~material~~ ~~for~~ abrassive for though materials.

5) Effect of abrasive size on MRR & surface finish




The size of abrassives is denoted in grids. The normal range of abrassives range from 240 to 800 grids. Higher the grit size the more will be the metal removal but it has adverse effect on surface finish. Therefore grits of nominal size giving both higher MRR and surface finish should be used.

6. Effect of Static load on MRR :-




The graph shows the effect of static load on metal removal. In practice increase in static load results in deep penetration of the abrassives on the work surface. When the static load goes beyond the limit, the depth of penetration decreases as shown in figure.

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• Process Capabilities of Ultrasonic Machining :-

(i) Work piece harder than 40-60 hardness number like carbides, ceramics, tungsten, glass etc.... which cannot be machined by conventional methods can be processed by ultrasonic machining.

(ii) Tolerances range between 7-25 microns can be easily processed.

(iii) Holes upto 76 microns can be drilled having a depth of 51mm can be achieved.

(iv) The linear material removal rate ranges from 0.25 micron to 0.75 microns.

(v) Aspect ratio of about 40:1 can be achieved.

## Advantages :-

- USM can be used for machining for hard, brittle & non-conducting materials.
- The heat generated at the work surface is minimum then by resulting in negligible physical changes of the workpiece
- It doesn't cost any distortion to the workpiece.
- Non-metal machining which is not possible by EDM & ECM processes are processed by USM to a good effect.

## Disadvantages :-

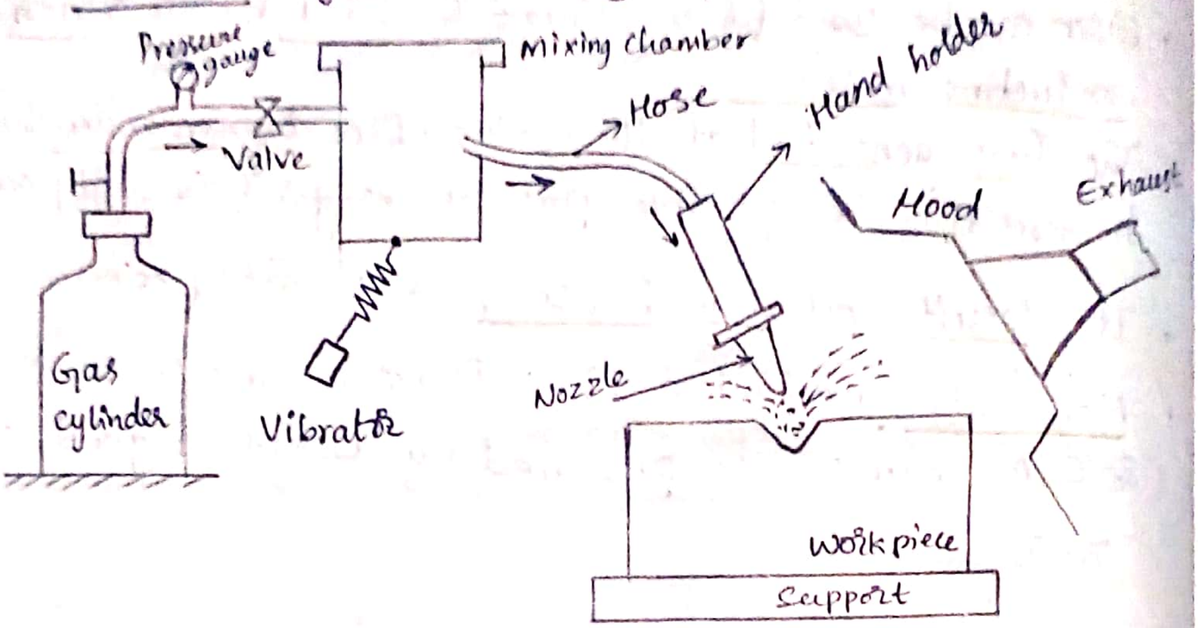
- Overall metal removal rate compared to other proses is slow.
- If the slurry is not maintained periodically holes can-not be drilled to a deeper lengths.
- Tool wear rate is high because of presence of abrassi-ve particles.
- To use USM process the minimum hardness required is 45.

## Applications :-

- Machining of cavities in electrically non-conducting materials.
- In creating large no. of holes of small diameters.
- In machining complex geometries and irregular shape holes.
- Used in wire drawing, punching & making of dies.
- With suitable abrassives USM can be applied in drilling, milling & machining.

- **Abrassive Jet Machining :-**

- **Abrrassive jet machining equipment :-**




- **Principle of Abrassive jet machining :-**

It works on the principle that when a stream of abrassive particles carried in a gas medium from a nozzle is made to impact on a work surface at a high velocity material from the workpiece is removed.

- **Need for Abrassive Jet Machining :-**

Complex, shaped hard, brittle materials which are sensitive to heat and have a tendency to easily chipout and which are inaccable through conventional methods can be machined AJM.

- **Abrassive Jet Machining Equipment :-**

The main components of AJM equipment includes

(i) Nozzle

(ii) Abrassives

(iii) Carrier Gas

(iv) Metering systems.

(i) Nozzle :-

The function of a nozzle in general is to increase the velocity of the fluids or in some cases to increase the pressure if gas is used. In ATM a nozzle is used to the increase the acceleration of the abrasive particles. The high velocity of the abrasive particles results in abrasive wear as a result the material choosen for making nozzles should be highly wear resistant.

Tungsten carbide is best suited for making the nozzle.

(ii) Abrassives :-

• Aluminium oxide & silicon carbide are the abrassives that are generally used in this process. Silicon carbide is preffered for harder materials.

• The size of abrasives range from 10-50 micro meters and they can also be represented as grid sizes. For cleaning & finishing smaller sized abrassives are used while the larger sized once are used for cutting. Re-use of abrassives is not prefferable as the cutting capacity decreases. The abrassives should get suspended in the carrier gas for smooth flow. Very large size of abrassives block the nozzle exit area.

(iii) Carrier Gas :-

The preffered gases include $CO_2$, nitrogen or air for carring these abrassives towards the workpiece. When air is used it must be filtered and it should be contamination free. The standard pressure ranges from 2 - 8 kg/cm$^2$.

(iv) Meetering Systems :-

This component includes regulators valves, mixing chamber and other controlling devices. The function of this system is to inject an uniform adjustable flow of abrassive particles into the gas stream. The powder of gas & the abrassives is droped from the hopper into the mixing chamber and this gets suspended in the gas by utilizing the vibrator.

- Abrassive Jet Machining Operation :-

In operation the filtered gas is supplied under pressure into the mixing chamber. This mixing chamber contains abrassive particles. This carrier gas & abrassive particles form a jet stream and passed on to the nozzle through a hose. Due to increase in velocity of the jet coming out from the nozzle, the impact of abrassive particles upon the work surface helps in removal of the work material from the surface due to a erosive action.

- Process Parameter or Variables of Abrassive jet machining

The following are the parameters which effect the metal removal rate in this process.

(i) Abressive flow rate & velocity.
(ii) Nozzle tip distance (NTD) or Stand-off distance (SOD)
(iii) Abrassive grain size.
(iv) Mixing ratio (M)
(v) Nozzle design

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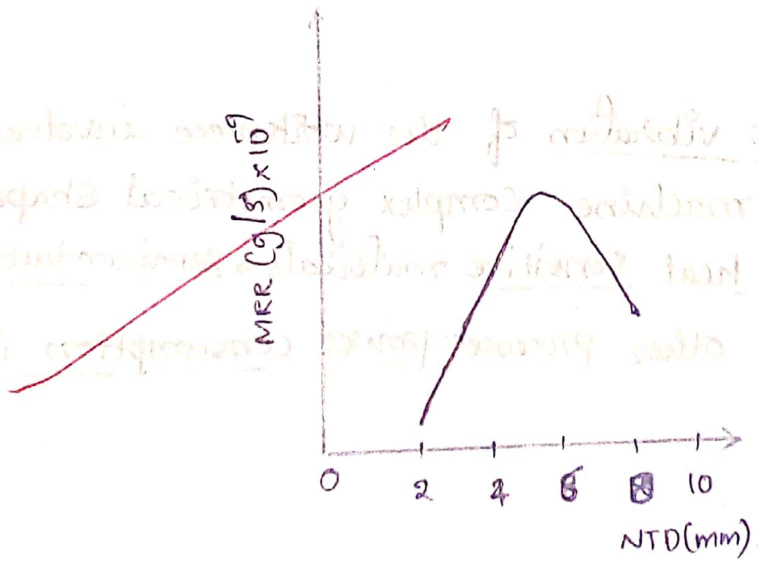
(i) Abrassive flow rate & velocity :-

Increase in the flow of abrassives obviously increases the metal removal rate as the abrassives help in cutting action. However if the abrassives exceed the limit of 14g/min the velocity starts to decrease. The minimum velocity required for errosive action is found to be 150m/sec. The jet velocity is dependent upon the nozzle pressure, the nozzle design, abrassive size etc...

(ii) NTD & SOD :-

The nozzle tip distance is the distance between the nozzle tip and work surface. The MRR initially increa-ses with increase in distance of nozzle to certain extent and then decreases gradually. The increase is found to be maximum at a distance of 8mm and beyond this distance the MRR decreases. However it depends upon the material of the work surface.




(iii) Abrassive grain size :-

The normal size of the abrassives range from 10-50micrometer. An abrassive with larger particle size increases the material removal compared to the smaller ones. However, cores grain size is useful in cutting aswell as good surface finish.

(iv) Mixing Ratio :

It is defined as the ratio no. of abrassive particles per unit volume to the flow rate of carrier gas per unit volume. Higher value of mixing ratio results in higher metal removal. In certain cases larger ~~abrassives~~ volume of abrassives tend to block the nozzle exit.

(v) Nozzle design :-

The nozzle has the function to allow the abrassive particles and carrier gas to strike the workpiece at high velocities. Due to this reason nozzle wear is a common phenomenon. To avoid this the nozzle has to be designed considering this factor with materials such as tungsten carbide and silicon carbide. Normally the nozzles are designed in rectangular or circular shapes.

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Advantages :-

- There is no vibration of the workpiece involved.
- Ability to machine complex geometrical shapes which are heat sensitive materials & semiconducting.
- Compared to other processes power consumption is lower.

Disadvantages :-

- The high pressure & velocity of the jet sometimes results in irregularities on the surface of the workpiece.
- Some materials like rubber, plastic are ineffective to the chipping action involved in AJM process and

thus these cannot be processed.

- Small nozzle tip distance can damage the nozzle
- Recycling of abrassives is not advisable as they loose their cutting strength when reused.

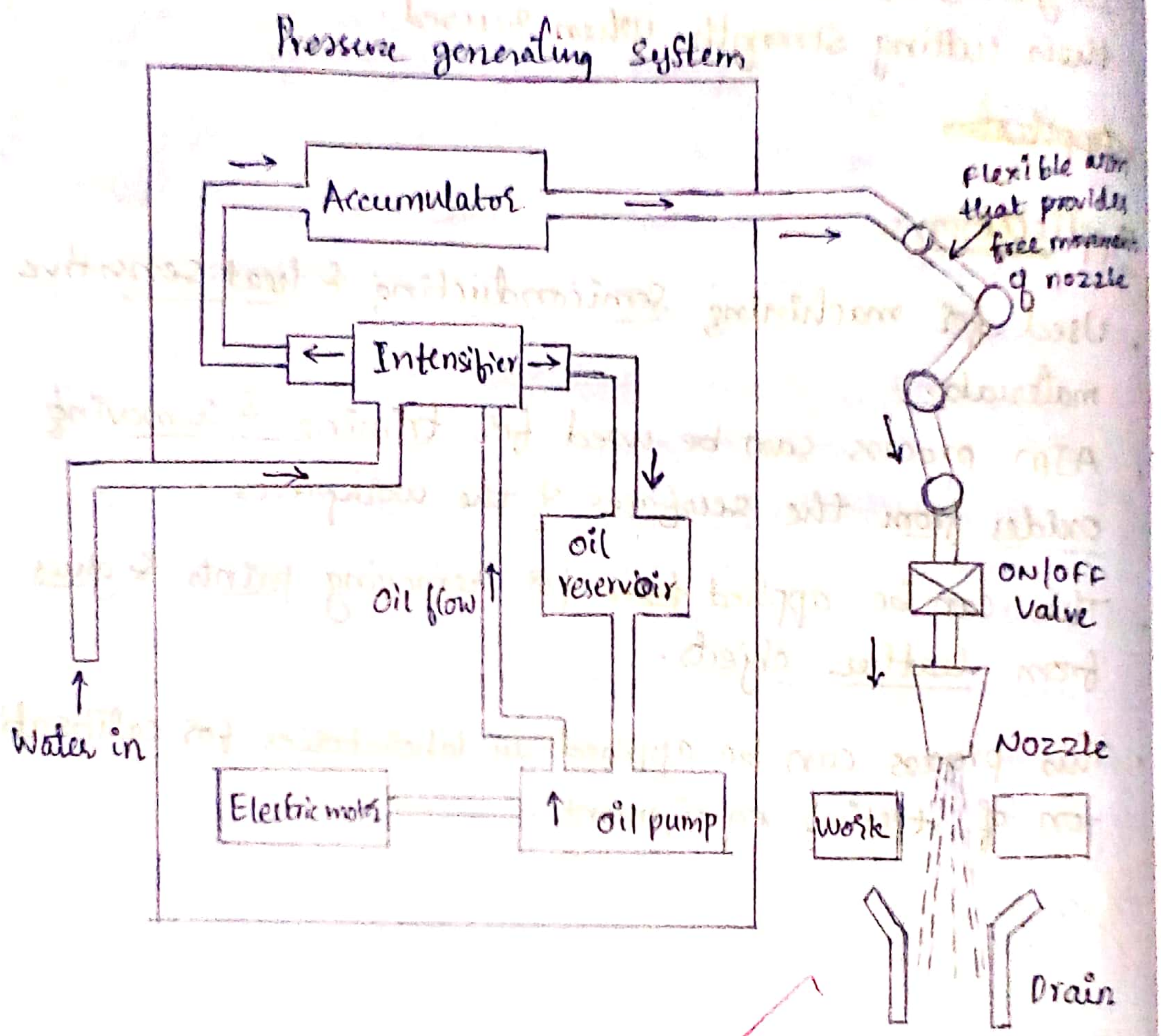
~~Application~~

Application:-

- Used for machining semiconducting & heat sensitive materials.
- AJM process can be used for triming & removing oxides from the surfaces of the workpieces.
- This can be applied ~~from~~ for removing paints & glues from leather objects.
- This process can be applied in laboratories for calibration of testing equipment.

## Water Jet Machining :-

**Equipment :-**




**Principle of Water Jet machining :-**

It works on the principle that for a jet of water with high pressure and velocity strikes at the workpiece errosive action results in removal of the material from the workpiece. The high jet is converted into mechanical action which is capable of cutting soft aswell as thick materials.

- **WJM equipment :-**

The equipment of WJM comprises of the following main parts.

(i) Pressure generating system (ii) Nozzle
(iii) Control valves (iv) Tubing

(i) Pressure generating system consists of a pump, electric motor, intesifier & accumulator. Pumping of water at high pressure is pumped to the intensifier along with oil for smooth functioning of piston cylinder arrange-ment. Pressure of 250MPa is prefferable to avoid damages related to that of intensifiers. Water with required amount of pressure is stored ~~in the~~ an accumu-lator & this pressurized water is used when required.

- The intensifier increases the pressure of water to high values consists of cylinders with different diameters. The accumulator helps in smooth flow of water.

(ii) Nozzle :- It is used for converting the high pressure water entering to velocity jet. The tip of nozzle (orifice) has to be designed ~~as the flo~~ carefully as the flow of water reaches to 900 m/sec during the operation. Hence hard materials are used in the making of nozzle.

(iii) Control Valves :- For a regulating pressure & velocity the control valves are installed at specified points of the equipment. This valves can be manually or electroni-cally controlled.

(iv) Tubing :- This component is used for transporting high pressure water from one component to the other. Stainless steel or composites are used as a jacket or covering for this tubing component.

- Process Parameters of WJM :-

The different parameters which affect the MRR in WJM are ;

(i) Pressure of water (ii) Nozzle diameter
(iii) Stand off distance

(i) Pressure of Water :- The high pressure water may result in better metal removal rate but may cause defects to the metering systems. This also increases the safety & maintanance cost of the operator & the machine. The normal pressure is around 400MPa.

(ii) Nozzle diameter : The normal nozzle exit diameter range from 0.05 to 0.35mm, which gives a coherent length of 3 to 4cm for the process. This dimensions give better MRR.

(iii) Stand off distance :- The standard stand off distance for a better cutting ~~sd~~ should be less than 25mm. Increase in the stand off distance results in change in shape of the diameter of the jet.

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## Advantages :-

- No poisions gases or liquids are used in this process.
- No mechanical ruptures or heat affected zone are observed on the workpieces.
- ~~Health~~ Health hazards related to cutting are minimized in this process.
- The unidirectional flow of cutting helps in machining complicated shapes.
- Materials with 250mm thickness which are very soft can be easily machined.
- No remaining residues of the material are found. (Clean work surface)

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## Limitations :

- Not effective for very thick materials.
- High pressure operation demands for additional safety equipments.
- Slight changes in water chemistry may result in change in physical characteristics.
- Recirculated water must be regularly filtered.

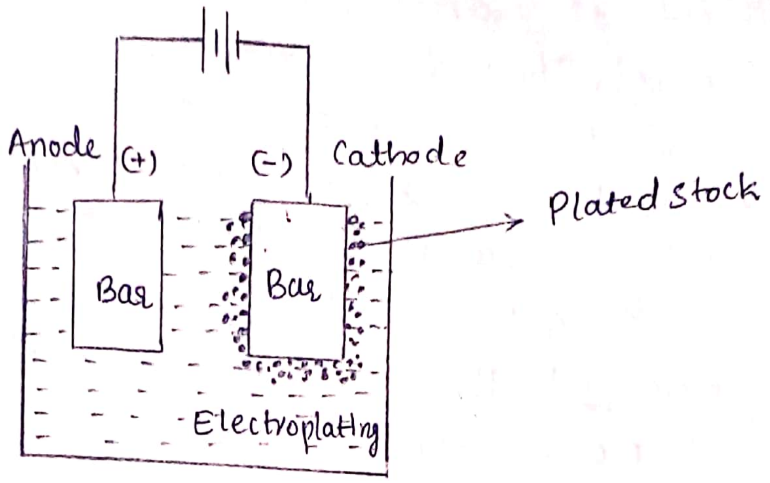
## Applications :-

- Used in aircraft industries for profile cutting.
- Used in cutting tunnel profiles.
- Cutting of printed circuit boards for electronic applications.
- Cleaning & descaling operation.
- This process can be applied for removing surface irregularities.

# MODULE-3

# ELECTRO CHEMICAL MACHINING

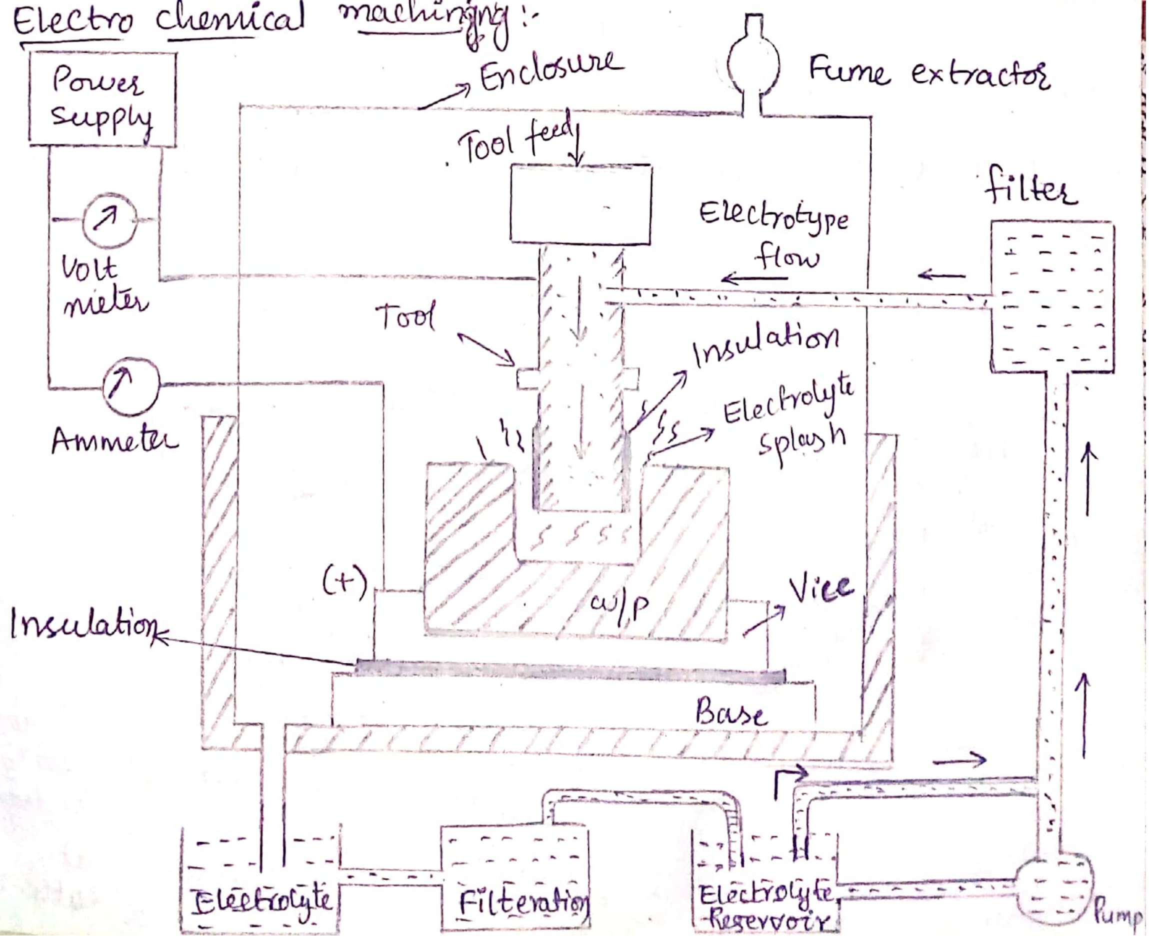
- Electroplating :-




Principle :-

Electrochemical machining works on the principle that when two metallic bars are immeresed in the electrolyte & when the circuit is closed the current passes through the electrolyte and due to this deposition of metal from anode to Cathode takes place. This is reffered to as fraday's law of electrolysis.

- Electro chemical machining :-



## Equipment :-

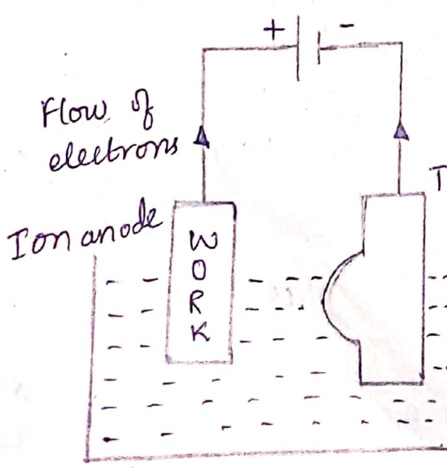
The the ECM equipment consists of following parts
(i) Tool (ii) Electrolyte (iii) Filter (iv) Power supply.

(i) Tool :- The tool used in this process is an electrode connected to the negative terminal of electric circuit. The shape to be formed on the w/p is similar to the shape of the tool. The material selected for the tool should be easily machinable, should posses good stifness, should be resistant to electrolytic pressures etc.... Commonly used electrodes used for this process are aluminum, bronze, Stainless steel, copper etc...

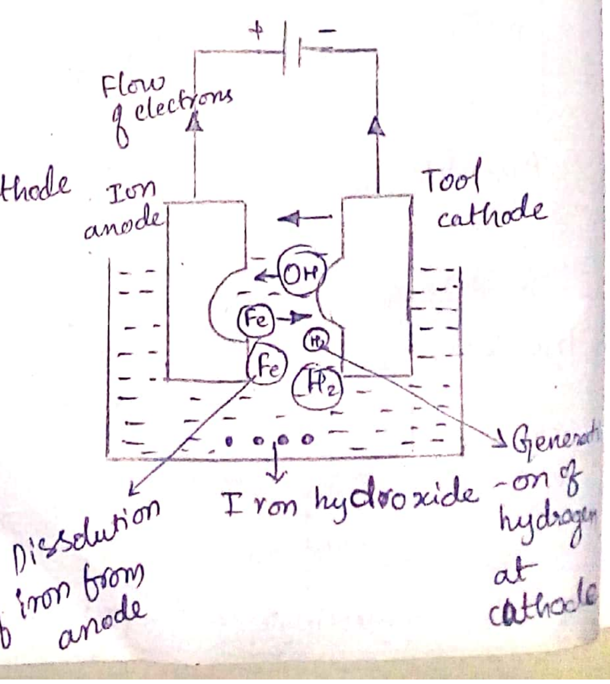
(ii) Electrolyte :- The characteristics of a electrolyte useful for this process should be that it should act as an conductor, allow the passage of current b/w the electrodes, should be low viscous in nature, chemically stable and non-corrosive. Normally ionized salt (Sodium Chloride solution) is commonly used electrolyte.

(iii) Filters :- This are placed in the equipment to avoid the contamination of electrolyte during the process. Normally a filter made up of wire mesh having very thin c/s is used as a filter to remove the impurities.

(a) Tool - work arrangement




(b) Machining process



At some point of time a centrifuge separater can also be used.

(iv) <u>Power Supply</u> :- Normally current in the range of 1000 – 40,000 Ampere is generally required for ECM & requires a voltage of 2 to 25 volts is used.

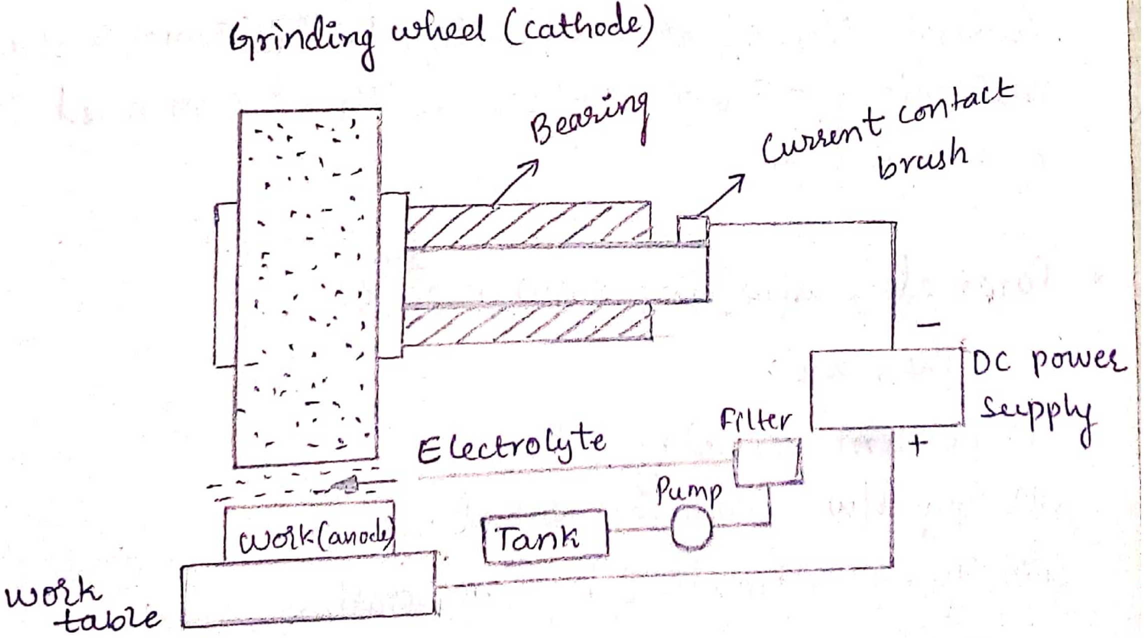
## Chemical reaction During ECM :-

During the electrolysis of the electrodes a low carbon steel w/p with sodium chloride solution gives the following reactions when a potential difference is applied.

$$NaCl \longrightarrow Na^{(+)} + Cl^{(-)}$$

$$H_2O \longrightarrow H^{(+)} + OH^{(-)}$$

- ECG process :-



The positive ions from the w/p of iron rod move towards the cathode tool reactive with the negative ~~hydraxil~~ hydraxyl iron to form iron hydroxide.

$$Fe + 2H_2O \longrightarrow Fe(OH)_2 + H_2$$

---

- **Process Parameters :-**

- **ECG process :-**

One of the applications of ECM is electrochemical grinding. The removal of material in this process takes place due to conducting nature of the workpiece. This process makes use of metallic grinding wheel which as insulating abbrassive particles over it. The insulating particles made up of aluminium oxide or diamond. The grinding wheel acts as cathode and w/p as anode and the electrolyte used here is sodium chloride. When the voltage is applied suitable current densitys are developed, this removes the materials from work surface with a combined effect of ECM & ECG.

---

- **Parameters affecting ECM process :-**

they are

(i) Current density.

(ii) Gap b/w workpiece & tool.

(iii) Type of electrolyte & its concentration.

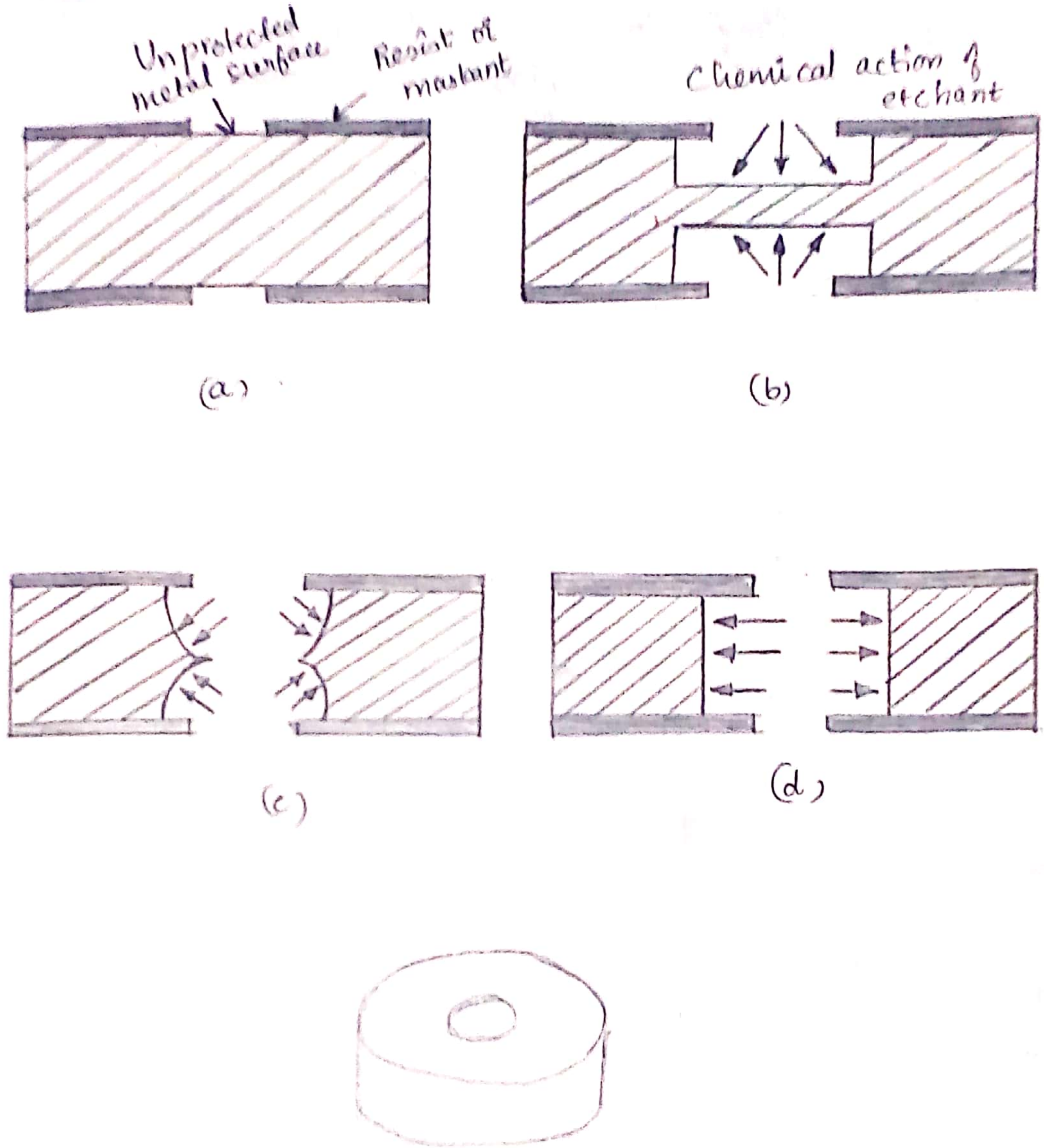
(iv) Velocity of the electrolyte flow.

(v) The tool feed rate.

- **Chemical Machining :-**

- **Types of chemical machining :**

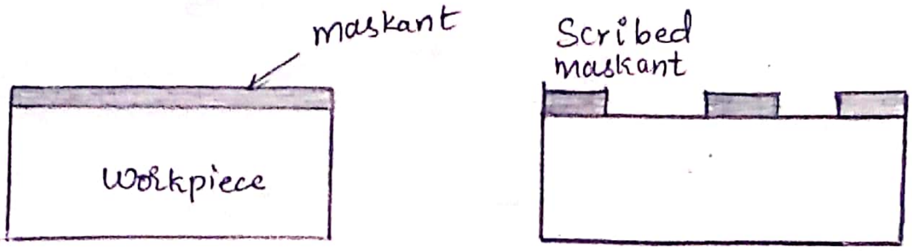
(i) **Chemical blanking :-**



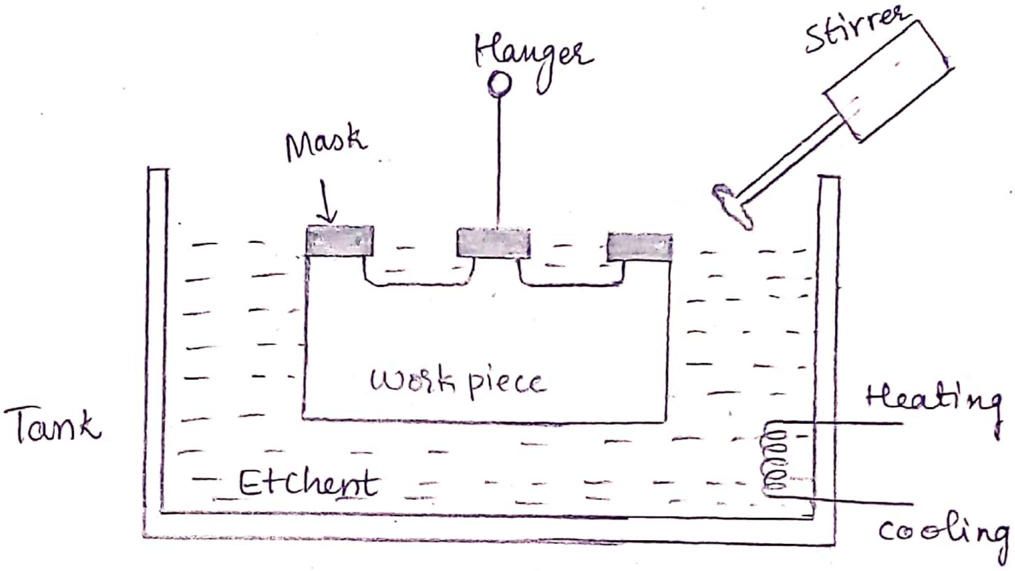

Chemical blanking is a process of producing a part from a thin sheet metal by chemical etching the pheriphery of the desired shape. In this process the workpiece is cleaned throughly. Different types of materials are used for covering the w/p where the material is not to be removed is carried out. This process of covering is called as masking. After this process the material is

Processed through Chemical agents called as etchents which help in removal of the w/p material. After this process the masks which covers the material is removed either by mechanical or chemical process. The material which remains after this process resembles the desired Shape of the w/p.

## • Chemical milling :




(a) (b)




(c)

It is process used to producing shape by chemical etchants only on selective portions of the w/p. This process is carried out only when cavities are required on the materials which are good conductors. This process is similar to chemical blanking process in which the w/p is cleaned first the portion to be left alone is covered with a mask, etchents are applied where the material is removed or cavity is processed and at the end the mask is removed off.

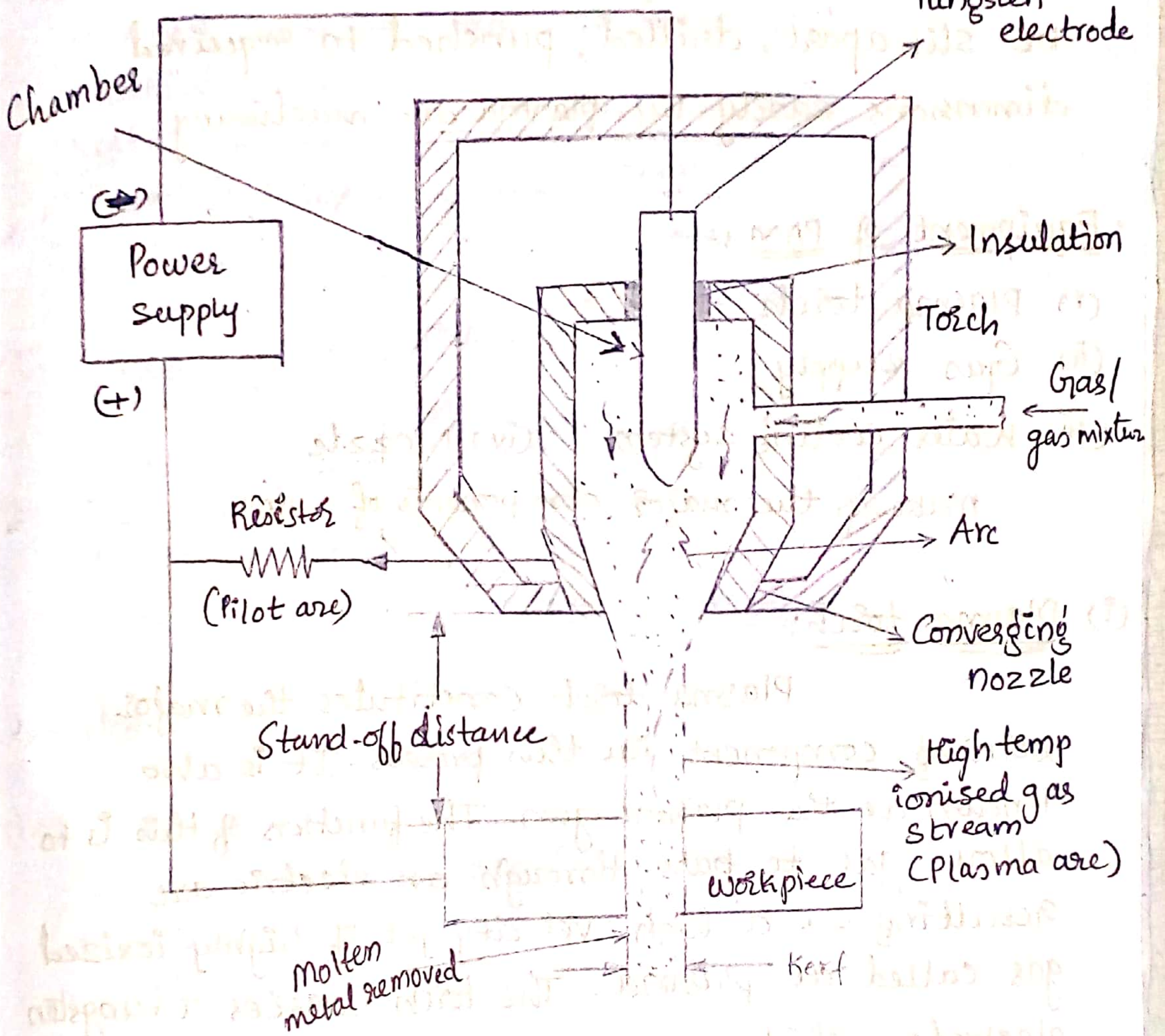
There are different methods for masking the w/p such as.

(i) Photographic resist method

# MODULE - 4

## PLASMA ARC MACHINING & EDM

- Plasma arc machining / cutting :-




Principle of PAM :-
It works on the principle that a high temp plasma obtained by heating gases at high temperatures is being allowed to come in contact with an electrical arc is passed through a nozzle to converge on the workpiece area to be cut/machined.

Plasma is the 4th state of matter. In this state the gas exhibits some unusual properties such as getting electrically conductive and getting responsive to magnetic effects. The temperature ranges from

20,000 to 30,000 °c for generating the plasma state.

**• Need for Plasma arc Machining :-**

The real use of plasma arc machining is when we require to machine very thick metals which are electrically conductive. Thick metals can be slit apart, drilled, punched to required dimensions easily by plasma arc machining.

**• Equipment of PAM :-**

(i) Plasma torch
(ii) Gas supply.
(iii) Water cooling system (iv) Nozzle

makeup the major components of PAM.

**(i) Plasma torch :-**

Plasma torch constitutes the major working component in this process. It is also known as the plasma gun. The function of this is to allow gas to pass through an electric arc resulting in a high velocity jet of highly ionized gas called as plasma. The torch carries a tungsten electrode which connected to negative terminal of the power supply & the positive terminal of the power supply is connected to the workpiece & also to the nozzle through a resistor. The resistor helps in resisting the power supply to a limit of 50 Ampheres.

There are 2 methods of operation of Plasma torch

• Transfered arc mode • Non-transfered arc mode.

The plasma torch can be designed with to various Shapes & size depending upon the type of application required.

• (Modes of Operation of / PAM).

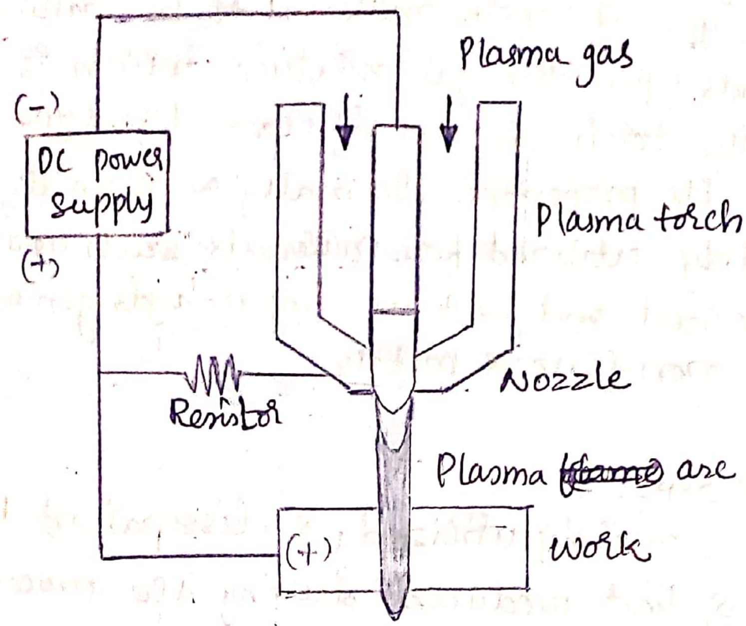
(ii) Gas supply :- On one side of the plasma torch a passage is provided for the supply of gas in to the chamber. The type of gas used in PAM depends upon the type of work material to be machined. It also depends upon the gas mixture which is supplied into the torch depending upon the type of material and its properties. Normally Nitrogen Hydrogen mixture is mainly utilized for materials such as aluminium, stainless steel and carbon. Argon-hydrogen mixture is utilized for non-ferrous metals.

(iii) Water cooling systems :- It is mainly utilized for dissipating the huge amount of heat produced during the process. The water cooling system should be monitered in such a way that it should not effect the intensity of the arc generated irrespective of dissipating the heat generated.

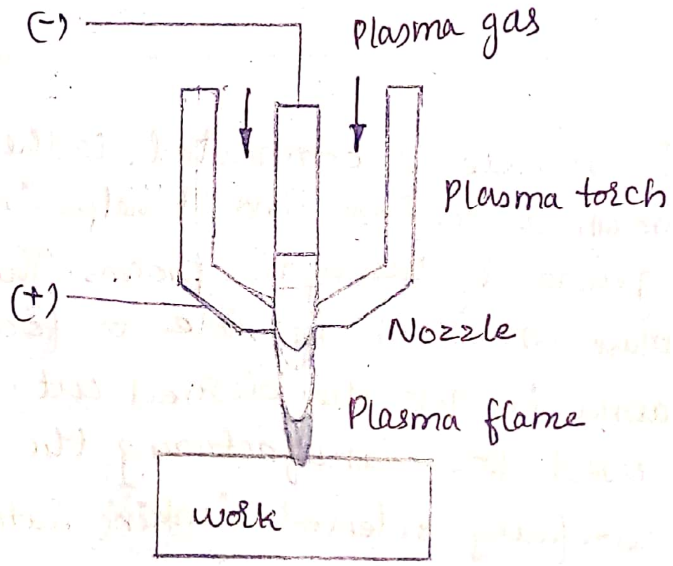
(iv) Nozzle :- The nozzle is connected to the positive terminal through a resistor and it helps in converging the arc generated during the process. The nozzle design also plays an important role to focus the stream of plasma to get the desired cut. Therefore the material used for manufacturing the nozzle should be carefully selected looking into the various applications of this machining.

• Modes of operation of PAM :-

(a) Transferred arc mode :-




(b) Non-Transferred arc mode :-




(i) Transfered arc mode :-

When the electrode is directly connected to negative terminal of power supply and the nozzle connected to the anode with a suitable resistor a pilot arc is generated within the body of the torch. In order to cut the material the arc must be transfered towards the workpiece. This plasma generation with this arrangement is called as transferred arc mode operation. The thermal efficiency is nearly 90% and can be utilized for cutting and machine welding processes.

(ii) Non-transfered arc mode:-

In this mode the arrangement is such that the DC power source is directly connected to the cathode electrode and the anode eliminating the connection to the workpiece. The workpiece doesn't form a part in the electrical system, the operation carried out is known as non-tranfered arc mode operation. The heat generated has less effect as the water cooling system causes the cooling effect resulting in less intensity. The thermal efficiency reduces to nearly to 65%. Hence this process can be utilized for spraying, ceramic working etc...

---

• Plasma torch design:

The plasma torch is designed carefully so that the various gases, coolants and electrical current can flow through it simultaneously, without creating any damage to the equipment. Some of the few designs which needs to be addressed before designing a torch are as follows.

(i) The nozzle design
(ii) The electrodes used
(iii) The plasma gas mixture.
(iv) Insulators.

(i) The nozzle design :-

The nozzle has a function to focus the stream of plasma to obtain the desired cut and shape over the work piece. The nozzle is designed in such a way that the orifice of the nozzle has slight larger area for proper striking of the plasma. The contriction of the orifice depends upon the type of application and the workpiece. The length of the orifice bore (nozzle bore) is directly proportional to quality of cut which results in high density arc.

(ii) The electrodes used :-

During the cokes of operation the plasma torch the cathode electrode is heated up to high temperatures and connecting it to the negative terminal allowing the current to pass through it. The design of electrode should be such that excessive heating doesn't melt the electrode and also the cooling should be in an optimized manner to avoid cracking of the electrode during the operation. For this reason the electrodes tapered end should be made larger and during the transfered arc mode operation the flat phase of the cathode is preffered.

(iii) The plasma gas mixture :-

The plasma gas operates depending upon its mixture. Different gases have different requirements based upon their thermal conductivities, specific heats and power consumptions. For conducting an operation on conducting materials the torch is made to run on Argon gas & electrically conductive monoautomic would be preffered.

(iv) Insulators :-

The torch should be insulated carefully as the temperatures involved in process are very high. The insulated portion should be closer at the arc zone. These insulators help in preventing the damage to the equipments at high temperature operations.

---

• Parameters effecting PAM :-

(i) The torch workpiece distance (Stand off distance)

(ii) Gas flow rate

(iii) Cutting speed.

(i) Stand off distance :- & current varry from one material to the other with different ~~thi~~ thickness levels. The more the thickness of the workpiece the more will be the torch w/p distance. The increase in stand off distance results in the arc diversion. And the arcs spreads over wide area. This effects the thermal efficiency of the arc. On the other hand smaller stand-off distances results in creating spraks in some operations. Therefore optimum SOD must be analysed before starting the operation.

(ii) Gas flow rate :-

The mixture of the gases places an important role in the metal removal as well as cutting of the w/p. The more the thickness of the w/p the more should be the gas flow rate. If the gas flow rate is low the arc generation is difficult. If the gas flow rate and the current passed is high this ~~may~~ result can damage the bore of the nozzle. The breaking of the arc results in double arcing phenomenon which results in nozzle melting. The optimum gas flow rate ranges from 0.4 to 5.6 $m^3$/hour.

(iii) Cutting Speed :- The amount of heat energy transfered by the plasma can be controlled by the surface cutting speed. If the speed is too high the upper edge of the contact phase comes closer to plasma jet which helps in higher metal removal. The optimum speed achieved by advancing the torch and adjusting the heat flow rate should be uniform through out the cutting operation. Under these condition uniform surface finish or uniform cutting dimensions can be obtained with the workpiece.

## Advantages of Plasma Arc Machining :-

- It has faster cutting speeds due to high velocity and temperature of cutting gas.
- It requires minimul operator training.
- The process variables such as type of gas, power, cutting speed can be adjusted for each material type.
- The whole process can be economized for a better quality at minimum cost & time.

## Limitation of PAM

- Due to the high temperature (28,000°c) involved in the process along with high velocity may change the metallurgical characterists of the material.
- Due to the high velocities the noice incured during the process required additional equipments for safe ~~gaur~~ guarding.

• Extra sheilding equipments result in extra equipment costs.

## Applications :-

• The PAM has various applications in industries, but they are mainly used in two applications.

(i) Plasma Arc surfacing.

(ii) Plasma Arc spraying.

(i) Plasma Arc surfacing :-

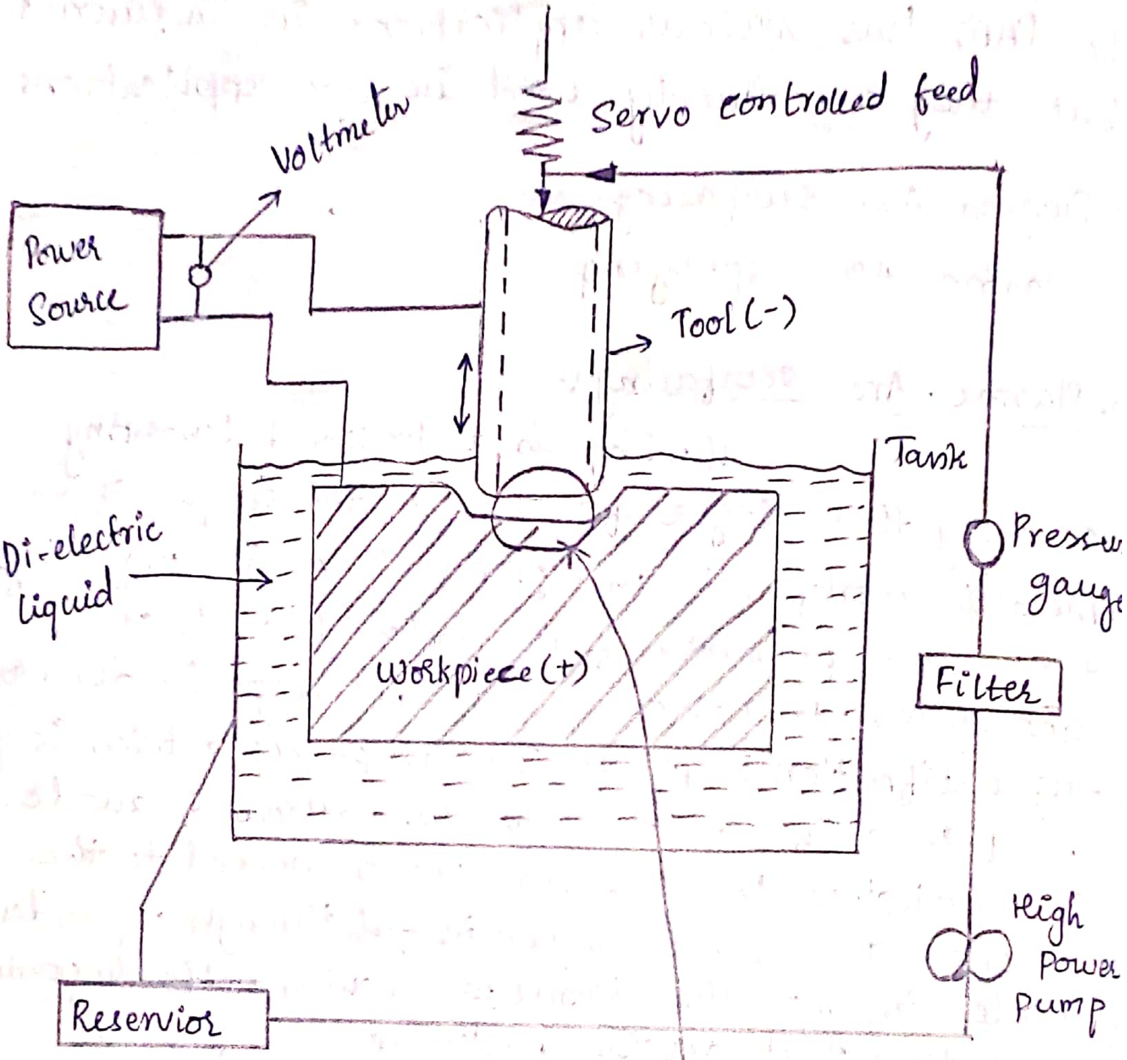
Surfacing is a process of depositing a very thin layer of metal on the surface of a metallic workpiece. This process helps in improving the surface properties of the material such as resistance to corrosion, wear and helps in developi-ng antifriction properties. In this process a torch is used to strike an arc b/w the cathode & anode. The workpiece to be surface is connected to the anode. The metallic power is fed through a powder feeder ~~by~~ into the plasma arc which melts the powder and deposist it over the workpiece.

(ii) Plasma arc Spraying :- It is typically a coating process that involves spraying a metallic powder in a molten state sprayed over a cleaned workpiece surface.

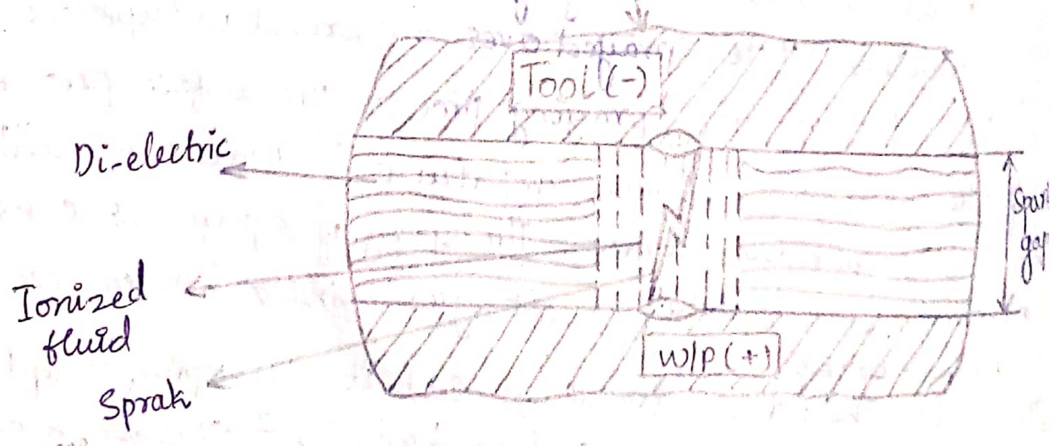
In Plasma arc spraying process the surface preparation of the workpiece is very important to induce the adhesive nature upon the surface. The spraying equipment consist of plasma arc, cooling circuit, gas cylinder & other neccessary accessories.

The PAS has the advantage that it can spray very high melting point materials such as tungsten & ceramic ect. The metallurgical aspects of the workpiece can be improved to very good effect.

- Electric discharge machining (EDM) process




(a) EDM set-up




(b) Enlarged view of metal removal mechanism.

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## Principal of EDM

It is also called as sprak machining. It works on the principle that the errosive effects of electrical discharges taking place b/w conducting materials immersed in a di-electric fluid, when this happens the shape of the tool is impinged upon the workpiece. The potential difference b/w the electrodes is sufficiently high. The di-electric fluid gets ionized under this effect which helps in removal of material from the workpiece electrode. The amount of material removed is washed away by the di-electric fluid.

---

- **EDM Operation :-**

In EDM operation the tool shaped electrode is connected to the negative terminal while the workpi-
-ece is connected to the positive terminal of powersource.
The gap b/w the tool & workpiece is called as sprak gap.
The electrodes are dipped and the gap is filled by di-electric fluid, this gap usually ranges from 0.01 to 0.05mm. When potential difference is applied a sprak is discharged through the fluid. This results in small removal of materials from the workpiece. This mechanism takes place until the required shape is obtained.

---

- **EDM equipment :-**

~~The details regarding~~ The EDM equipment consists of the following component

(i) Power generator.
(ii) Di-electric medium.
(iii) Tool electrode
(iv) Servo feed mechanism

(v) Pumps and fiters

(i) Power generators:-

In EDM process electrical energy in the form of short duration impulses are to be supplied in the machining gap b/w the workpiece & the tool. The different type of EDM generators are;

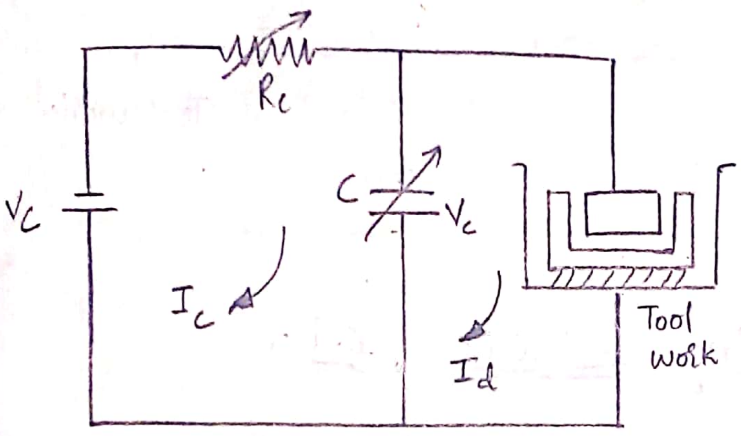
(a) Resistance - capacitance type (R-C type) generator.
(b) Rotary - impulse type generator.
(c) Controlled pulsed circuit.

- In R-C type generator the power source that charges a capacitor across a resistance forms a tooth wave when a potential difference is applied. This charges the capacitor & discharges at the gap. This creates a sprak leading to workpiece machining.
- In Rotary type generator a generator drives with the help of a motor. In this type the capacitor is charged through a diode in the first half of a cycle & in the next half the sum of the charges generated by the generator & capacitor is applied at the gap. The graph is obtained has a sine wave frequency.
- In controlled pulse circuit faster metal removal rate are observed. In this circuit oscillator is selected instead of capacitor to avoid any short circuit situation. The oscillator is also controlled by the gap condition & the pluse range from 1 to 2000 m-s

• EDM equipment :-

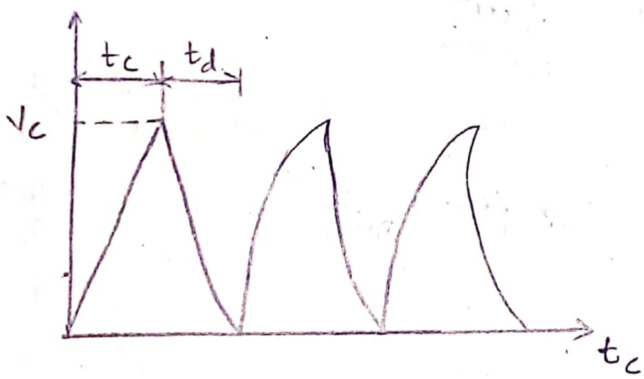
Power generation :-

i) RC type or relaxation generator circuit :-

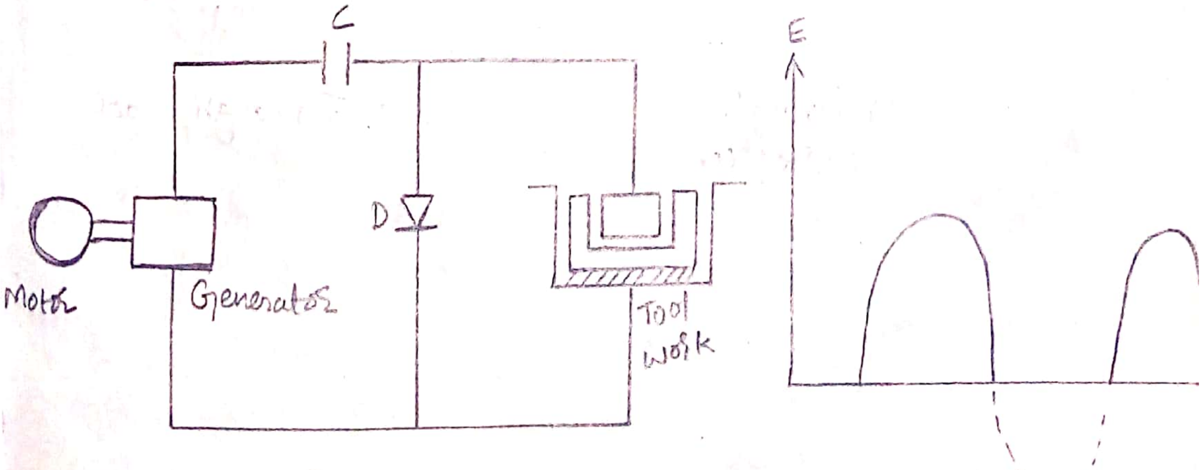



(a)

$t_c$ = Charging time
$t_d$ = discharging time

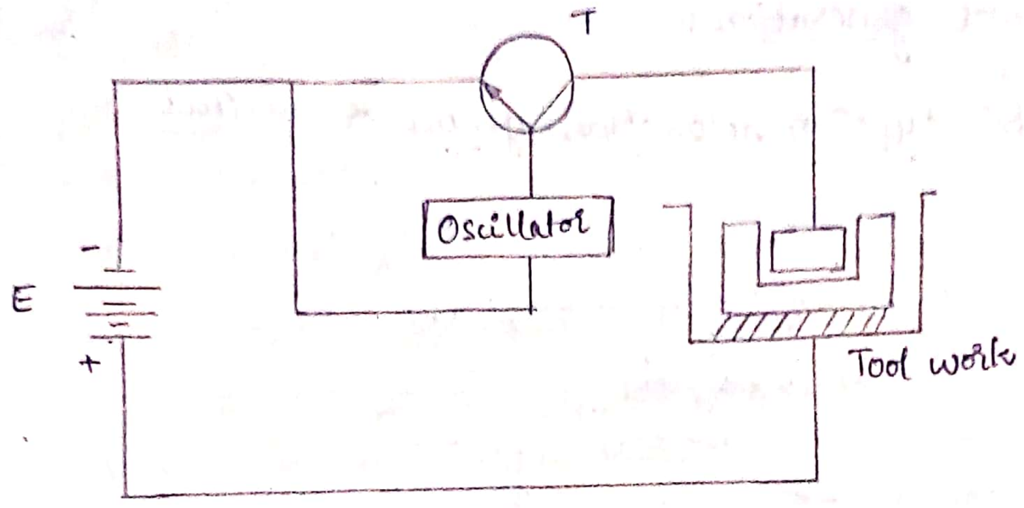



ii) Rotary impulse type generator :-




(a) (b)

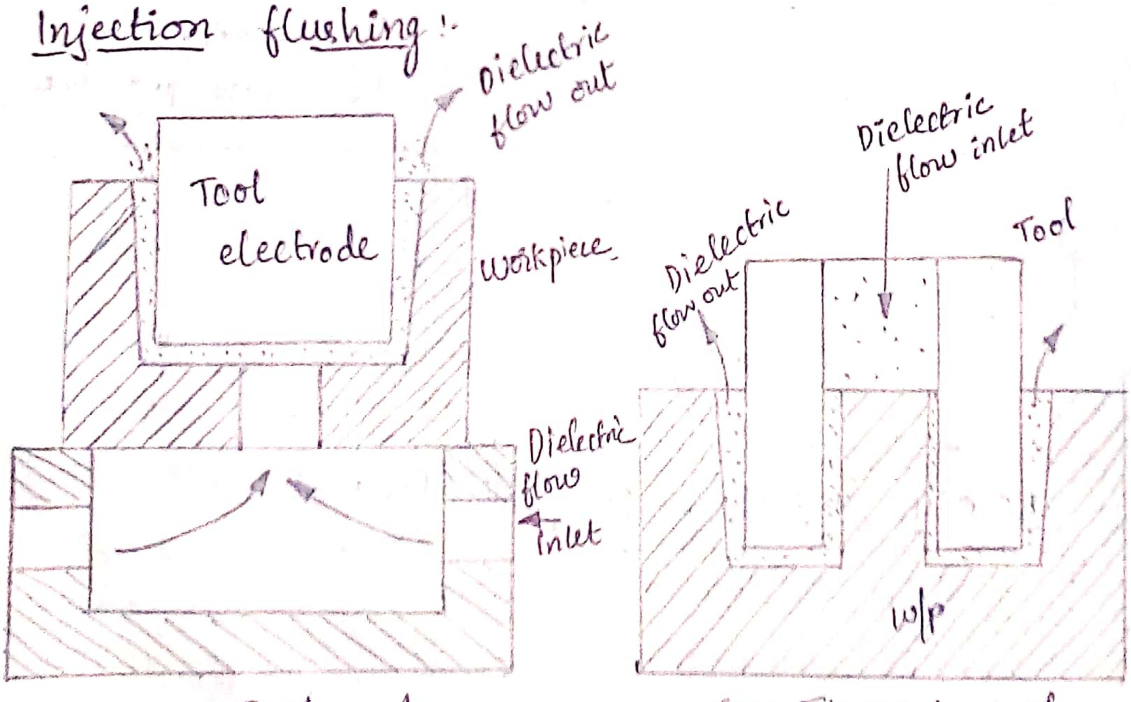
(iii) Transistor based pulse circuit generator :




• Methods of applying dielectric fluid :-

## Flushing :-

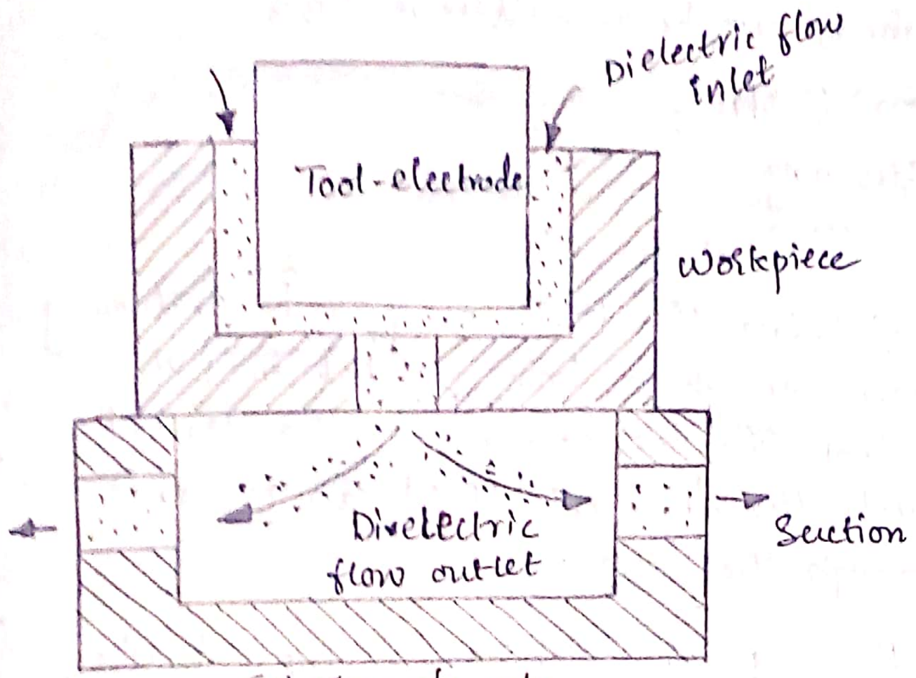
(i) Injection flushing :-



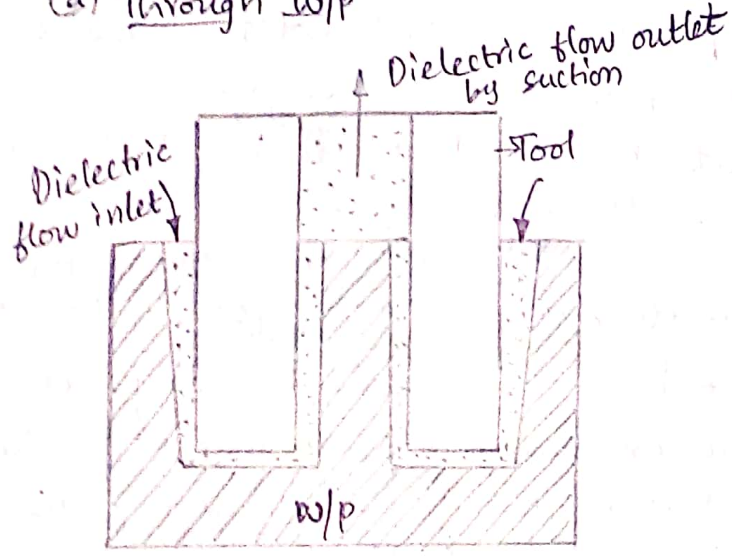

(a) Through workpiece

(b) Through tool

(ii) Suction flushing:-




(a) Through w/p




(a) Through tool

(ii) Di-electric Medium:-

The function of di-electric fluid is to get ionized, act as a sprak conductor, cooling medium etc... It should possess the following properties as a di-electric fluid.

- It should have high dielectric Strength.
- It should de-ionize after the sprak is conducted.
- It should be chemically neutral and provide effective cooling medium for the tool & workpiece.

There are different methods to apply the dielectric fluid b/w the gap. Some of the methods are flushing.

In flushing we have different types.

(a) Injection flushing.

(b) Side flushing.

(c) Suction flushing.

- In Injection flushing the fluid is applied continously in to the gap through a hole drilled into the workpiece or tool. The tool can be also be drilled through which the dielectric fluid can be made to flow through the gap.

- In side flushing the technique is applied when it is impossible to drill holes. Nozzles are used to force the fluid in to the gap. care should be taken that the fluid is distributed equally through out the gap.

- In suction flushing tapered effect of the components that resulted in injection flushing can be avoided. In this process vaccum is required for suction process & this is provided by charging the pump & Obtaining the output by clearly filling the gap & allowing the tool to machine the workpiece.

---

(iii) Tool electrode:-

In EDM process the shape of the tool is similar to the shape to be done on the workpiece. The tool should have the properties such as good conductor of heat & electricity. It should be easily machinable, it should resist errosion and available at minimum cost.

(iv) Servo feed mechanism :-

This servo feed mechanism is used for moving the tool automatically at a proper rate and also maintaining constant gap b/w the tool & the workpiece. The servo feed mechanism can be either in the form of electric motor driven, hydraullically operated etc.... In this mechanism the tool is held in a chuck fitted to a spindle to which the rack is attached. The spindle movement is given by rack and pinion arrangment controlled through a gear driven by a motor. The motor used here is a shunt motor which helps in reversible action of the tool.

---

(v) Pumps & filters :-

Pumps are used for circulating the dielectric fluid at a suitable pressure at the sprak gap. And the filters are used for removing away the impurities during the machining process:

---

- Parameters affecting EDM process :-

The following are the parameters which affect the metal removal rate in EDM process

(i) Influence of the sprak frequency.

(ii) Influence of the current.

(iii) The sprak gap.

(i) The effect of decreasing the current and increasi-ng the frequency results in improved surface finish in veiw of small ~~greater~~ crater size upon the workpiece.

(ii) The amount of material removed and the type of surface finish required depends upon the current in the discharged Spark. The increase in current helps in the removal of more material from the w/p & vise versa

(iii) The sprak gap b/w the tool & w/p ranges from 0.01 to 0.05mm. The smaller the gap the closer is the accuracy of surface finish.

(iv)

(v)

- The heat affected zone in EDM:-

In EDM process at the sprak area there are three zones formed. Zone 1 is called as re-cast layer

2nd zone is heat affected zone.

Zone 3 is converted zone after machining.

· Ap

(i)

- Advantages:-

(i) Extremly hard materials with close tolarances can be obtained easily

(ii) Delicate sections of the w/p can be processed with out change in structure of w/p.

(iii) Higher ~~~~ MRR can be observed in the materials.

(iv) The cutting tool pressure can be adjusted if the machinging has to be done on thin w/p

- Limitations :-

(i) This process is suitable only for conducting materials.

(ii) Sharp corners can not be machined.

(iii) Higher rate of power consumption.

~~ELECTRO~~

(iv) Some times during the process overcuts are observed due to the influence of sprahs.

(v) Many no. of tool wear cases.

---

**Applications :-**

(i) The process of EDM can be applied for various applications but specifically they are used in electrical discharge grinding & wire electrical discharge machinging.

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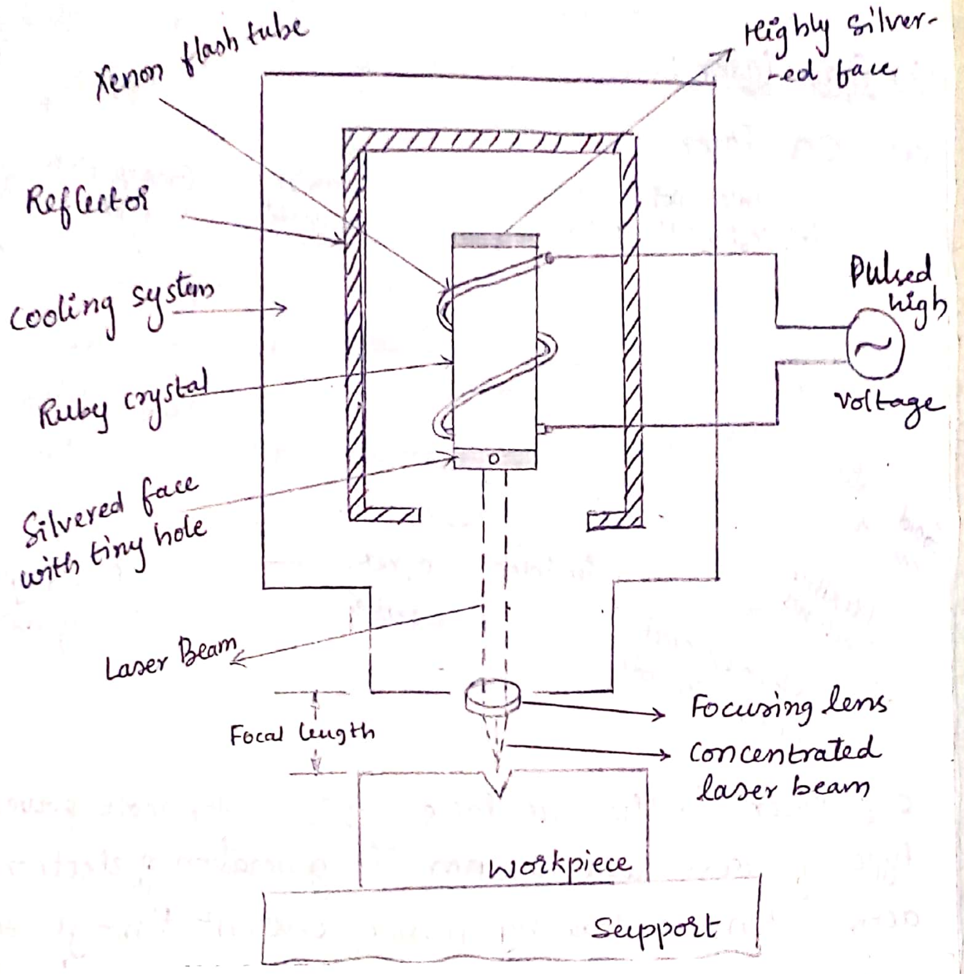
# MODULE-5

# LASER BEAM MACHINING

- Schematic of Laser equipment :-




The main components which make up Laser beam equipment are ;

(i) Ruby crystal.

(ii) Xenon flashtube.

(iii) Focusing lens.

(iv) Cooling system.

(i) Ruby crystal :- It is cylindrical in shape which forms the core of the equipment. It is made up of aluminium oxide, combined with chromium. Both the ends of ruby crystal are made parallel to each other, in which One end is highly silvered, so that it absorbs maximum incident light. The other end of this ruby crystal is partially silvered and a small hole is provided from which the laser beam emerges out.

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i) <u>Ruby crystal</u>:- It is cylindrical in shape which forms the core of the equipment. It is made up of aluminium oxide, combined with chromium. Both the ends of ruby crystal are made parallel to each other, in which One end is highly silvered, so that it absorbs maximum incident light. The other end of this ruby crystal is partially silvered and a small hole is provided from which the laser beam emerges out.

(ii) <u>Xenon flash tube</u>:- The function of the xenon flash tube is to maximize the incident light on the ruby crystal. Hence the ruby crystal is sourrounded by the Xenon flash tube. The power supply is connected to this tube. As a result the pulsed voltage is converted into electrical energy and followed by the light energy.

(iii) <u>Focusing lens</u>:- The laser beam that comes out of ~~than from~~ from the tiny hole of the ruby crystal possess low power density & in a scattered manner. The focusing lens is here utilized for converging the lazer beam at a particular spot which enhances the intensity of the laser beam. This is required for cutting of materials.

(iv) <u>Cooling System</u>:-
This system utilizes either liquids or nitrogen gas/air for cooling the ruby crystal as anormous amount of heat is generated during the lasing action.

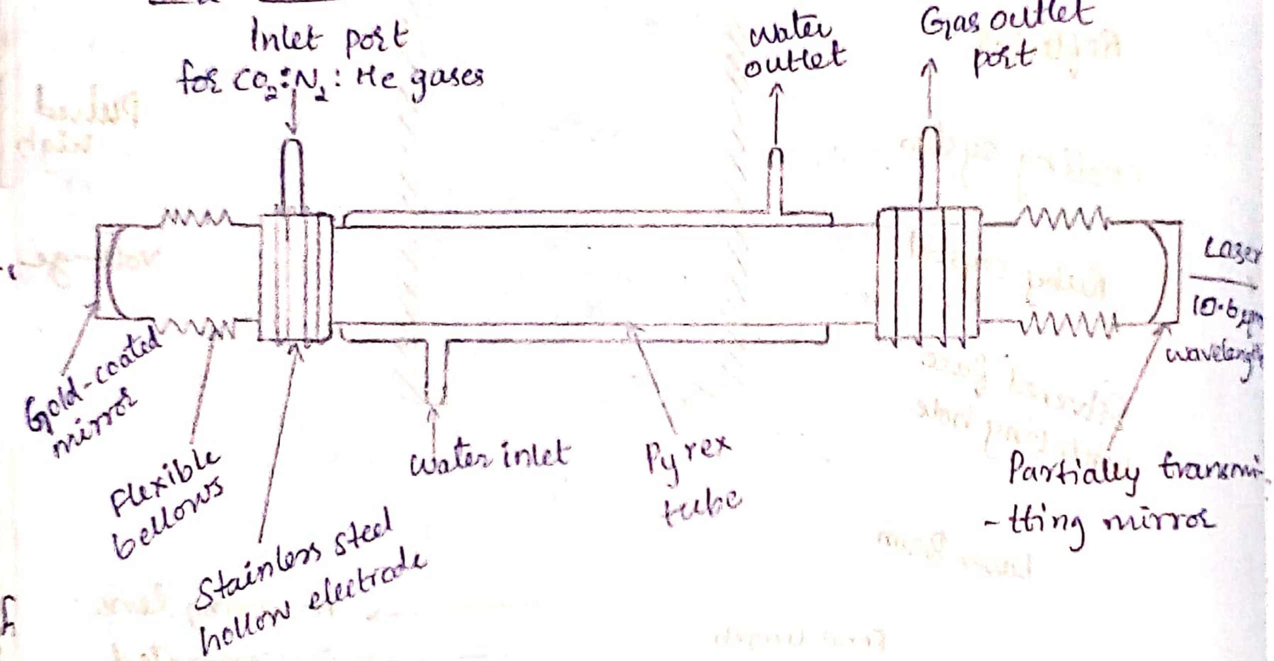
• Types of Laser :

(i) Gas laser.

(ii) Solid state lasers

(i) Gas laser :-

(a) $CO_2$ laser :-

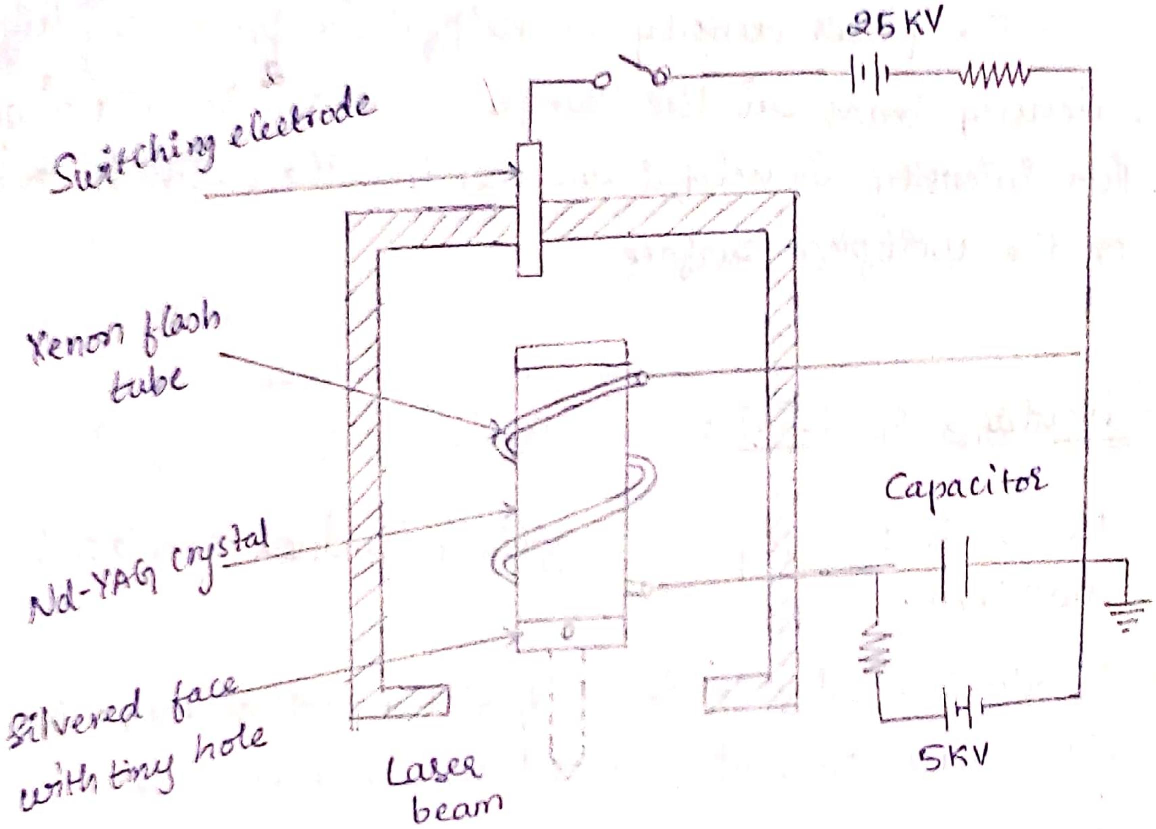



$CO_2$ laser is the gas laser which is the most powerful type of lasers used in LBM. The generation of electrons of active atoms is done by passing current through the gas. A high voltage is applied at both the ends which leads to formation of gas plasma. This results in population inversion phenomenon and lasing action. The reflector re-directes the photons as a part of laser beam for machining. In this laser $CO_2$, $N_2$ & He are mixed together in the chamber. $CO_2$ acts as lasing medium. $N_2$ helps in absorbing the plasma & He acts as cooling agent.

(b) ~~Nd-YAG~~

(ii) Solid state laser

(a) Nd-YAG Laser :- (Neodymium - Yitrium Aluminium Garnet)




This is a type of solid state laser used as lasing medium having the formula $Nd:Y_3Al_5O_{12}$. These lasers are optically pumped using high pressure mercury or Xenon flash tube. A typical solid state laser uses Xenon flash tube of helical form and it is operated in pulsed modes by charging & discharging the capacitor. This laser normally produce infrared lights & these are suitable for making a hole to a depth of 6 times that of the beam.

## Parameters of Laser beam machining :-

The parameters which effect the metal removal rate in LBM are Power density & laser beam, workpiece & interaction time.

- The power density is helpful in producing high intensity beam in the range of $1.5 \times 10^2$ to $1.5 \times 10^4$ W/cm² This intensity is helpful in melting the desired spot on the workpiece surface.

## Advantages of LBM :-

- Non metals irrespective of their hardness can be machined.
- If the removal of material from the work surface is in small amounts, laser beam can be used.
- It doesn't require any force for machining process.
- The entire process can be done automatically.
- The operation of machining can be done at a rapid pace.
- Apart from cutting & drilling ~~laser~~ LBM can be used for marking & heat treatment purpose ~~upon~~ on the surface of the material.

## Limitation :-

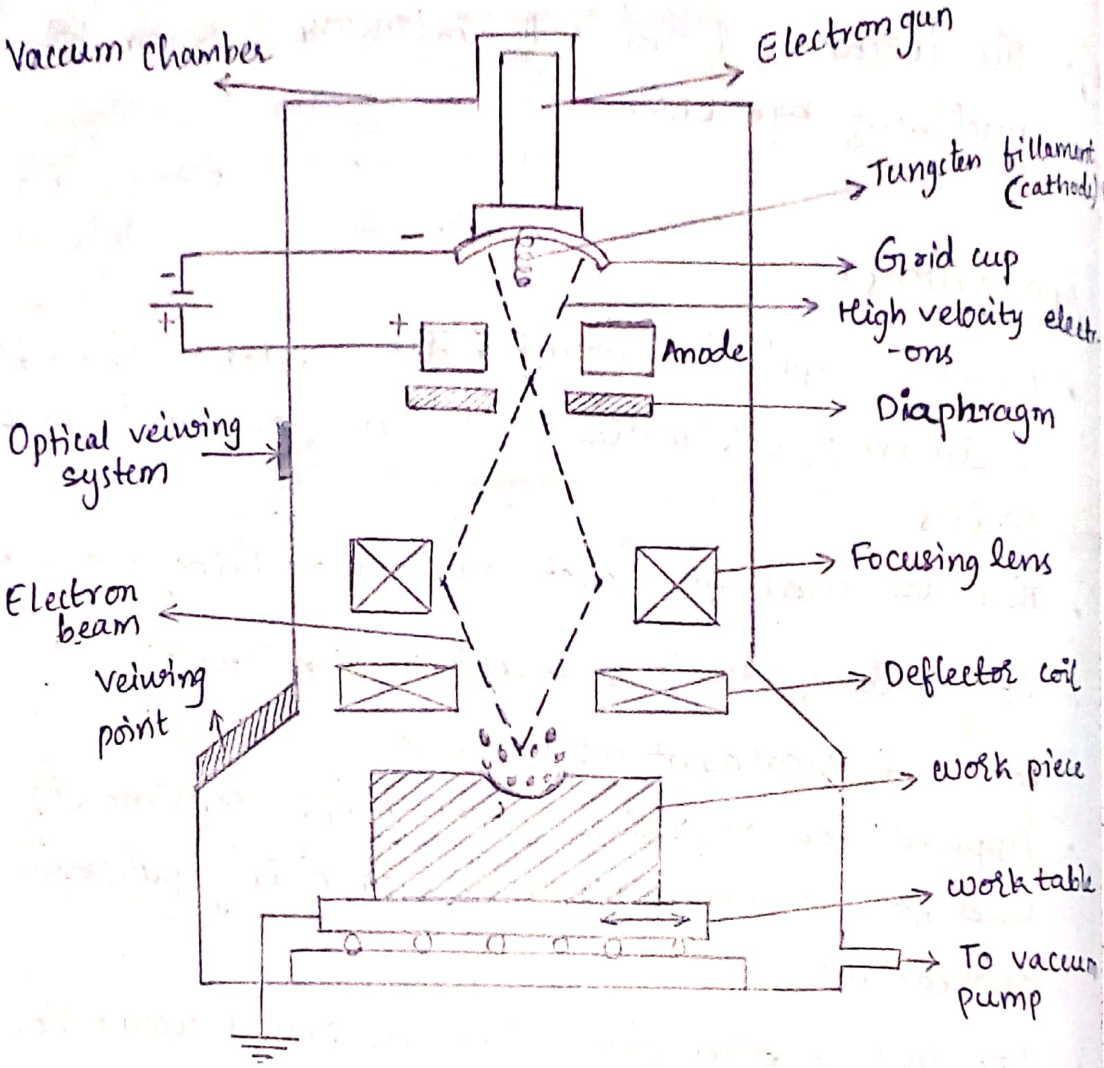
- This process is mainly used for machining thin sections.
- It has low thermal efficiency.

- Taper are normally found during drilling.
- Overall metal removal rate is less.
- The thickness of materials is limited to 50mm for machining by LBM.

## Applications :-

- LBM is applied in automobile sectors, aircraft industries, electronic industries, nuclear & civil sectors.
- This are used for exact micro machining processes.
- For welding, drilling & cutting of materials.
- For heat treatment applications.
- Applied for marking in electronic systems (or) used for alpha-numeric (or) bar coding ~~purpose~~, applications.
- For micro ~~fab~~ fabrication in printed circuit boards.

• Electron Beam Machining (EBM) :-




• Principle of EBM :-

In electron beam machining process the stream of electrons generator is directed against the workpiece where the kineotic energy of electrons is converted into thermal energy, that melts and vapourizes the material surface to be removed.

• Equipment of EBM :-

The main components of EBM include

(i) Vaccum chamber.

(ii) Electron gun.

(iii) Magnetic deflection coils

(iv) Work table.

(i) Vaccum Chamber :- This component encloses all other parts during the operation. The vaccum chamber serves many purposes, the main reason for using the vaccum chamber is that the radiations emitted or the electrons emitted from the fillament if exposed to the atmosphere they get oxidized. The electrons loose their energy when they collide with the ~~air~~ molecules. Due to these ~~reso~~ reasons the enitre process is carried out in a vaccum chamber.

(ii) Electron beam Gun :- This component is mainly responsi-ble for emission of electrons. It consists of the tungsten fillament, anode and the grid cups. The tungsten fillament is connected to a negative terminal of the power supply, the anode is connected to the ground potential and the grid cup is negatively biased with respect to the fillament. The high velocity electrons are passed to the next component once they emitted.

(iii) Magnetic deflection coil :- The immediate component next to the electron gun is the magnetic deflection coil which makes the electron beam deflect to the position required on the workpiece.

(iv) Work table :- The work table in this operation is made to be postable so that the electron beam coming out can be deflected and striked upon the surface of the workpiece where it is required.

## Operation of EBM :-

In operation the tungsten fillament inside a Vaccum chamber is heated to about 2500°C. This results in emission of electrons from the fillament. This emitted electrons are guided by the grid cup to travel towards the anode. The anode helps in acceleration of electrons which increases the velocity of the electrons, concentrated by the diaphragm & focusing lens & directed towards the workpiece by the magnetic coil. The K.E of electrons is converted in to heat energy which rises the temp of the workpiece, melting takes place, vapourises the material and finally results in removal of small amount of material.

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## Parameters of EBM :-

The MRR in EBM process is affected mainly by the following parameters.

(i) Beam current (ii) Pulse duration (iii) Lens current.

(i) **Beam current** :- It is directly related to no. of electrons emitted by the fillament. The normal range of this current ranges from 200 micro Ampere to 1 Ampere. The increase in the current increases the energy per pulse delivered to the workpiece.

(ii) **Pulse duration** :- This parameter is nothing but no. of pulses during a single pass. This affect the both depth & diameter of the hole to be machined. High pulse duration helps in making deep holes. Shorter pulse duration create thermal effects on the workpiece

(iii) Lens current :- This parameter distinguishes the distance b/w the focal point & the electron beam. A higher power density results in fine spots upon the workpiece whereas a small diameteric hole is obtained. Larger diameteric hole can be obtained with increase in beam diameter but the intensity doesn't remain the same & also the MRR reduces.

## Advantages:-

- No tool wears are observed.
- Effective machining can be done as heat can be concentrated at a particular spot.
- Extra cutting forces are not required in EBM process.
- workpieces are not subjected to any other physical, metalar--gical changes.
- The holes of different shapes can be obtained by deflec--ting the beam as required.

## Limitations :-

- Vaccum chamber requirement is must for this process. this results in limitations to the size & shape of workpiece.
- Higher power consumptions to heat the fillament.
- Overall metal removal rate is minimized as compared to other process.
- It is suitable for small & fine cuts only.

Applications :-

- This process is applied in micro finishing operations.
- Applied for thin section machinings.
- Used in application for electro microscopic.
- Heat treatment applications.