Unconventional Machining Process
Unit-I

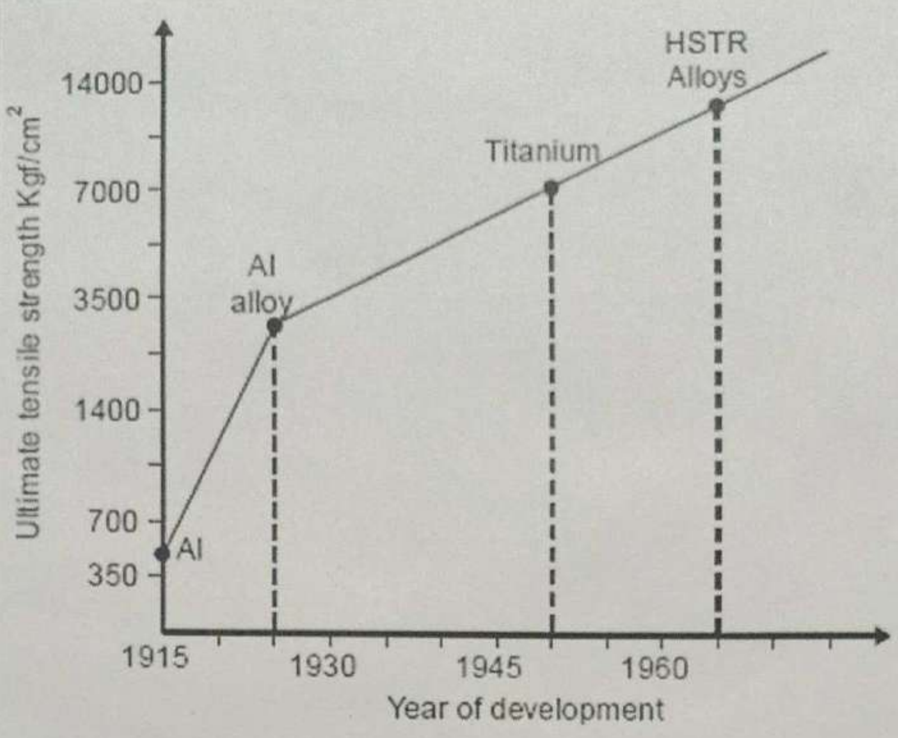
What is Unconventional Machining Process :-

.) Since begining of the human race, people have evolved tools and energy sources to power tools to meet the requirements for making the life more easier and enjoyable

.) In the early stage of mankind, tools were made of stone for the item being made. When iron tools were invented, desirable metals and more sophisticated articles could be produced.

.) In 20th century products were made from the most durable and consequently the most unmachinable materials. In an effort to meet manufacturing challenges created by these materials, tools have now evolved to include materials such as alloy steels, carbide diamond & ceramics.

.) A similar evolution have taken place with the Methods used to power our tools.



Trend of increase of material strength

.) Every time new tools, tool materials and power sources are utilized, the efficiency & capabilities of manufacturers are greatly enhanced. Since 1940's, a revolution in manufacturing has been taken place that once again allows manufacturers to meet the demands imposed by increasingly sophisticated designs and durable but in many cases nearly unmachinable, materials.

.) Merchant has displayed the gradual increase in strength of materials with year wise development of materials.

.) The result has been the introduction of new machining process es used for material removal, known today as unconventional machining processes.

Conventional Machining Process	Unconventional Machining Process.
.) Material removal primarily rely on electric motors and hard tool materials to perform tasks such as sawing, drilling & broaching	.) Non traditional machining processes harness unconventional energy like electro-chemical, plasma & high velocity jets of liquid & abrasives.
.) Material removal takes place by macroscopic chip formation	.) Material removal may occur with chip formation or even no chip formation may take place.
.) Physical tools are needed	.) Physical tools are not needed.

Need for UCMP:-

.) Conventional Machining suffered the requirement of the industries over the decades.

.) Batnus work materials as wellas innovative geometric design of components were putting a lot of pressure on capabilities of conventional Machining process.

.) Economical Constraints.

.) With the development in UCM process, currently there are often the first choice and not an alternative to conventional processes for certain technical requirements.

Classification of UCMP:-

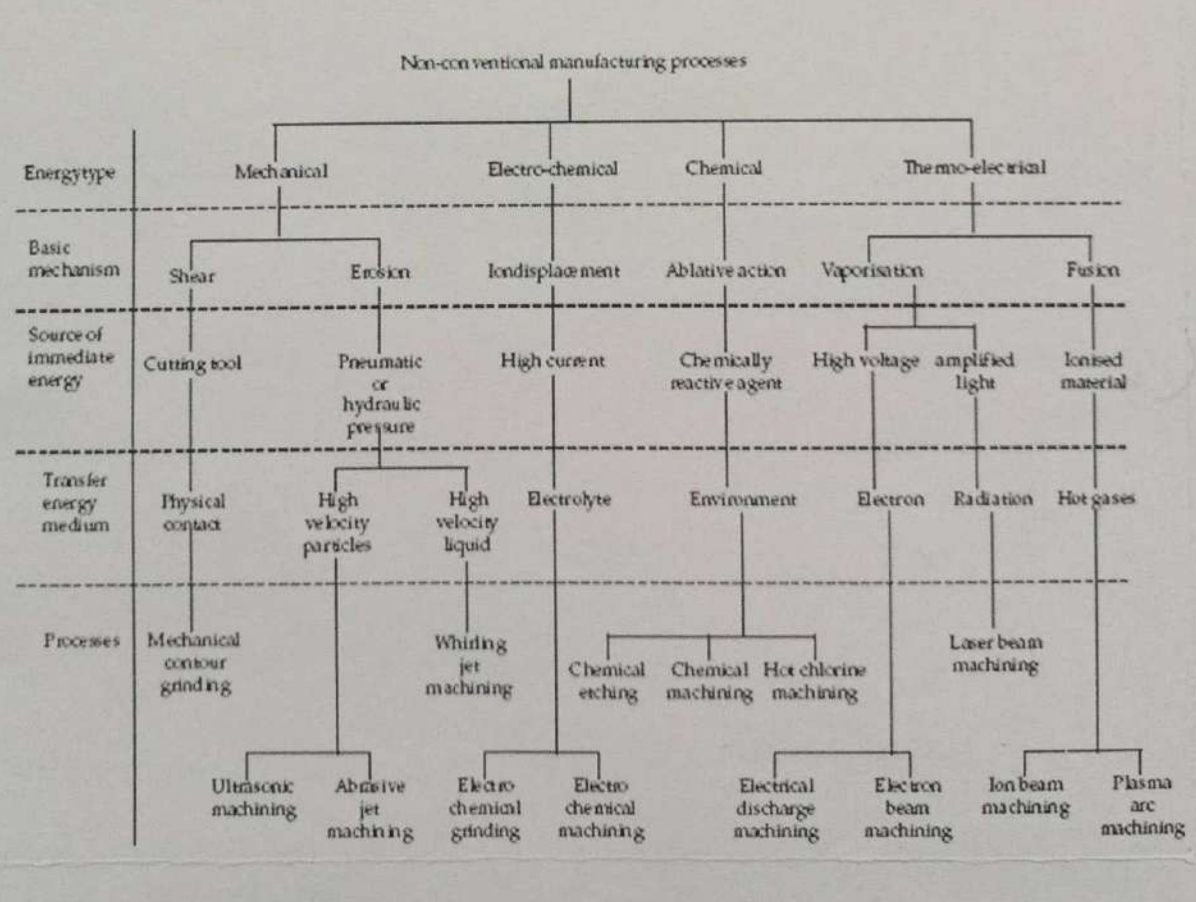
.) The non conventional Machining processes may be classified on the basices of energy namely,

- .) Mechanical
- .) Electrical
- .) Chemical
- .) Thermal
- .) Magnetic.

.) Thus, these non conventional processes can be classified into the various groups according to the

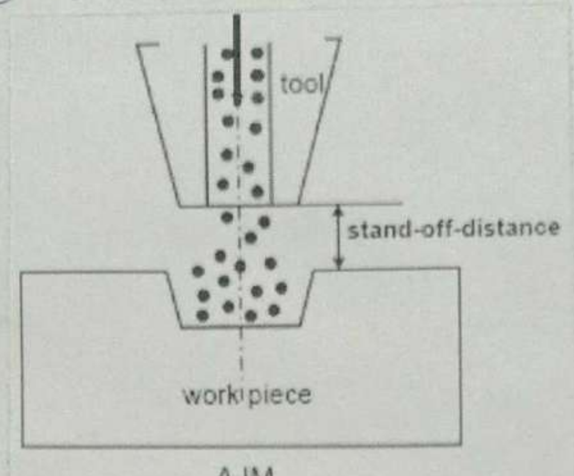
basic requirements as follows.
(i.) Type of energy required namely, mechanical, electrical, chemical etc.
(ii) Basic mechanism involved in the processes like erosion, ionic, dissolution, vapourisation etc.
(iii) Source of Immediate energy required for material removal, namely, hydrostatic pressure, high current density, high voltage, Ionized materials etc.
(iv.) Medium for transfer of those energies like high velocity particles, electrolyte, electron, hotgases etc.

Classification of Non-conventional Manufacturing Processes



Overview of Basic UCMP's:-

◦) Abrasive Jet Machining (AJM)



AJM

Principle:- In AJM, the KE of abrasive particles is used to cut/ Machine brittle and/or hard materials. In this case; abrasive particles suspended in the air stream are made to strike the work surface at high velocity.

On impacting, the KE in the Abrasive Jet induces mechanical stress into the surface to be machined which is responsible for erosion of surface and material removal.

Merits:-

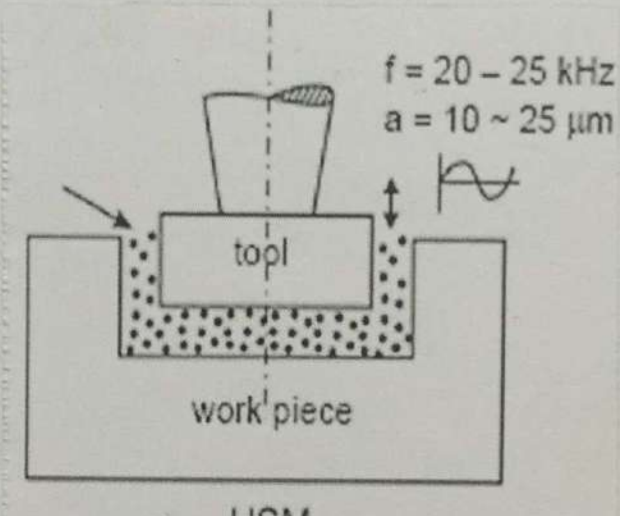
i.) flexibility (ii) low heat production

iii.) Ability to machine hard & brittle materials

iv.) Initial cost is low.

Demerits:
i.) Slow MRR.
ii.) The process produces a tapered cut resulting in poor accuracy.
(iii.) Soft materials can't be Machined.

·) Ultrasonic Machining (USM):-



USM

Principle:- In USM, a tool vibrating at Ultrasonic frequency agitates the abrasive particles suspended in a liquid carrier.
The high velocity abrasive particles are directed towards the w/p, resulting in removal of work Material by erosion even in case of hard materials like ceramics.

Merits:-

i.) Machining of any Materials regardless of conductivity & precision of machining of brittle hard Materials

ii.) Doesn't produce any electrical, chemical or thermal defects on the Surface.

iii.) less stress becaus of its non thermal nature.

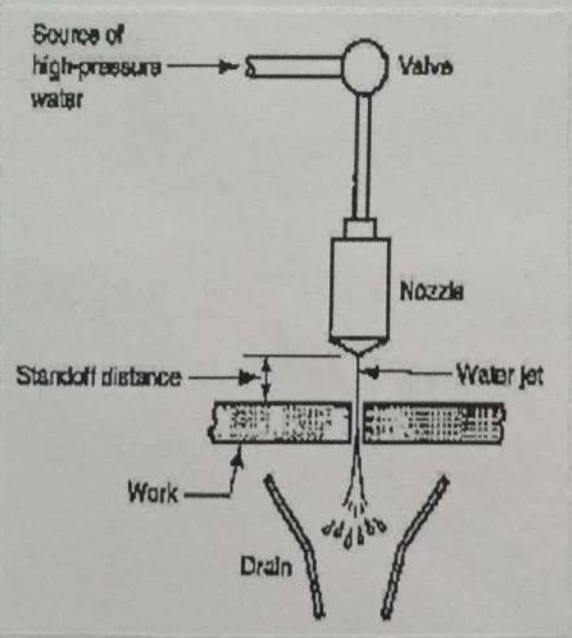
Demerits:

i.) Low MRR.

ii.) Faster toolwear.

iii.) Machining area & depth are restricted

•) Water Jet Machining (WJM):

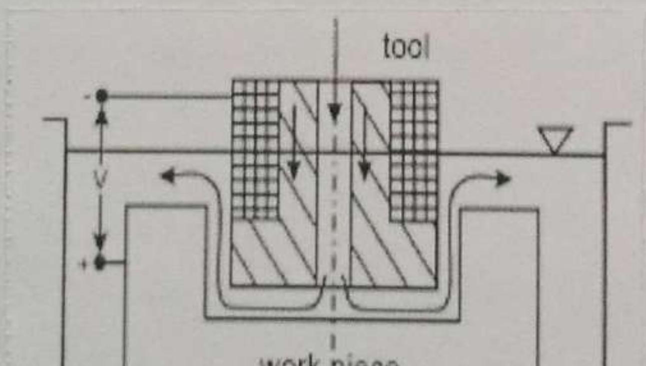


Principle :- This employs a fine high pressure, high velocity jet of water, when bombard on W/P erodes the Material.

Merits :-
i.) No crushing or burning of work surface.
ii.) Minimum material loss because of narrow cut slit.
iii.) No environmental pollution.
iv.) Easy automating processes.

Demerits :-
Not suitable to cut brittle material because of their tendency to crack during cutting.

•) Electro chemical Machining (ECM).

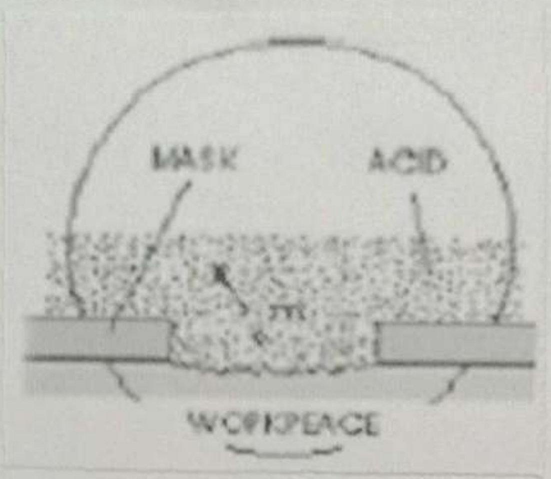


Principle:- It removes metal from an electrically conductive w/p by anodic dissolution; in which the shape of w/p is obtained by a formed electrode tool in close proximity to, but separated from the work by a rapidly flowing electrolyte.
The Underlying principle is material is deplated from the anode and deposited onto the cathode in the presence of an electrolyte bath.

Merits:-
i.) Little surface damage to the work part.
ii.) No burrs as in conventional machining
iii.) Low tool wea
iv.) Relatively high MRR.

Demerits:-
i.) Significant cost of electrical power to drive the operation
ii.) Problems of disposing of the electrolyte ~~surge~~ sludge.

•) Chemical Machining (CHM).

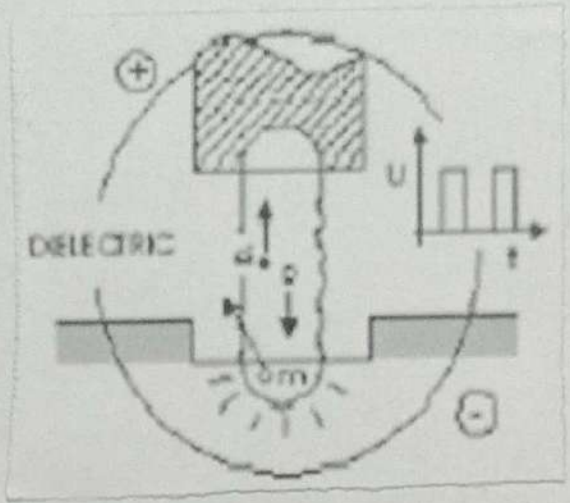


Principle:- The Material is removed from the w/p by controlled dissolution when in contact with strong chemical reagent.

Merits:-
i.) Production of burr free surface.
ii.) Production of stress and crack free surface.
iii.) Less skill of operator are required
iv.) Tooling cost are small.

Demerits:-
i.) Low MRR.
ii.) Difficulty in finding a suitable etchant for the given work Material.

·) Electric discharge Machining (EDM).



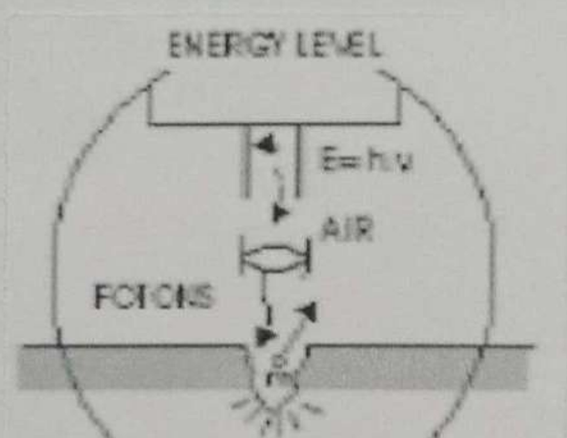
Principle:. In EDM, the electrical energy of the electric spark created between closely spaced anode & Cathode is ultilized for Material removal by Therm al erosion.
Discharge region heated to extremely high temperature so that a small portion of the work surface is Melted and removed.
·) Individual discharges occur 100's or 1000's of times per second to give a gradual erosion of the entire Surface.

Merits:
i.) Complex Shapes can be done
ii.) Very close Tolerances.

iii.) Very small work pieces where conventional cutting tools may damage the part from excess cutting tool pressure.
iv.) No direct between tool & w/p
v.) Good Surface finish obtained
vi.) Very fine holes can be easily drilled.

Demerits:-
i.) Slow MRR.
ii.) Additional time & cost used for creating electrodes for ram/sinker EDM.
iii.) Power consumption high.
iv.) Excessive Tool wear.

•) Laser beam Machining (LBM)



Principle: Uses light energy from a laser for machining materials. Light beam pulsed so that the released energy results in an impulse against the work surface, producing evaporation and melting.

Merits:

i) No physical contact between work-tool

ii) No possibility on wear of tool.

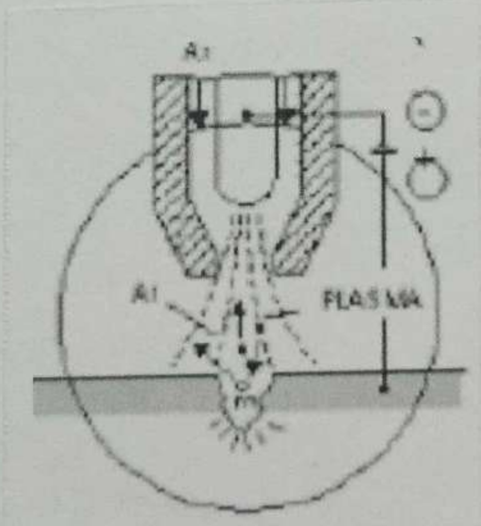
iii.) Precise cut and narrow HAZ.

Demerits:

i.) Overall efficiency is low.

ii) Process is limited to thin sheet plates.

.) Plasma Arc Machining (PAM).



Principle: Plasma ~ a superheated, electrically ionized gas. PAM uses a plasma stream operating at very high temperatures to cut metal. The high velocity plasma stream is directed at the w/p, melting it and blowing the molten metal.

Merits:-

i.) Leaves a narrow kerf

ii.) High temperature process

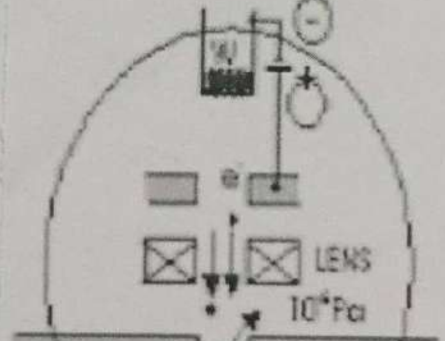
iii.) Energy seems to be unlimited.

Demerits:

i.) Initial cost is high

ii.) Rough cut surface, Metallurgical damage.

.) Electron Beam Machining [EBM]:



Principle :- A high velocity beam of electrons strike the w/p. The K.E of electron converts into heat which is responsible for melting & vapourization of w/p.

Merits :-

i.) Less HAZ.

ii.) Provides high drilling rates when small holes with large aspect ratio are to be drilled.

Demerits :-

i.) High capital cost.

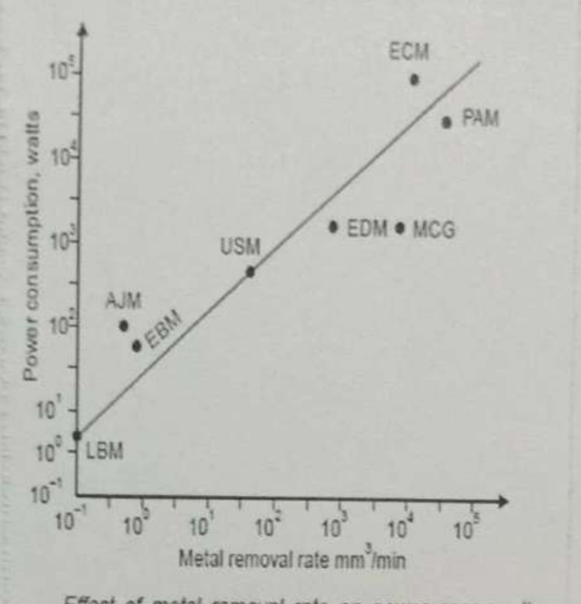
ii.) Non production period for attaining desired vaccum is high.

.) Physical Parameters :-

Physical Parameters of the Non-conventional Processes

Parameters	*USM*	*AJM*	*ECM*	*CHM*	*EDM*	*EBM*	*LBM*	*PAM*
Potential (V)	220	220	10	—	45	150000	4500	100
Current (Amp)	12 (A.C.)	1.0	10000 (D.C.)	—	50 (Pulsed D.C.)	0.001 (Pulsed D.C.)	2 (Average 200 Peak)	500 (D.C.)
Power (W)	2400	220	100000	—	2700	150	—	50000
Gap (m.m.)	0.25	0.75	0.20	—	0.025	100	150	7.5
Medium	Abrasive in water	Abrasive in gas	Electrolyte	Liquid chemical	Liquid dielectric	Vaccum	Air	Argon or hydrogen

From Comparative study of the effect of MRR on the power consumed by various non conventional machining process is shown in the figure.



. Effect of metal removal rate on power consumption.

Capability to shape.

Shape Application of Non-conventional Processes

Process	*Holes*				*Trough cavities*		*Surfacing*		*Trough cutting*	
	Precision small holes		*Standard*		*Precision*	*standard*	*Double contouring*	*Surface of revolution*	*Shallow*	*deep*
	Dia < .025 mm	*Dia > .025 mm*	*Length < 20 mm*	*Length > 20 mm*						
USM	—	—	good	poor	good	good	poor	—	poor	—
AJM	—	—	fair	poor	poor	fair	—	—	good	—
ECM	—	—	good	good	fair	good	good	fair	good	good
CHM	fair	fair	—	—	poor	fair	—	—	good	—
EDM	—	—	good	fair	good	good	fair	—	poor	—
LBM	good	good	fair	poor	poor	poor	—	—	good	fair
PAM	—	—	fair	—	poor	poor	—	poor	good	good

The capability of different process can be analysed on the basis of various machining operation point of view such as Micro drilling, drilling, cavity sinking, pocketing, contouring a surface, through cutting, etc

Applicability to materials:

	Metals Alloys					Non-Metals		
Process	Aluminium	Steel	Super alloy	Titanium	Refractory material	Ceramics	Plastic	Glass
USM	Poor	Fair	Poor	Fair	Good	Good	Fair	Good
AJM	Fair	Fair	Good	Fair	Good	Good	Fair	Good
ECM	Fair	Good	Good	Fair	Fair	—	—	—
CHM	Good	Good	Fair	Fair	Poor	Poor	Poor	Fair
EDM	Fair	Good	Good	Good	Good	—	—	—
EBM	Fair	Fair	Fair	Fair	Good	Good	Fair	Fair
LBM	Fair	Fair	Fair	Fair	Poor	Good	Fair	Fair
PAM	Good	Good	Good	Fair	Poor	—	Poor	—

For the machining of electrically non conducting materials both ECM and EDM are unsuitable, whereas the mechanical methods can achieve the desired results. USM is suitable for Machining of refractory type of Material while AJM are for Super alloys and refractory Materials.

Machining Characteristics:-

Process	MRR (mm^3/min)	Tolerance (μ)	Surface (μ) CLA	Depth of surface damage (μ)	Power (watts)
USM	300	7.5	0.2–0.5	25	2400
AJM	0.8	50	0.5–1.2	2.5	250
ECM	15000	50	0.1–2.5	5.0	100000
CHM	15	50	0.5–2.5	50	—
EDM	800	15	0.2–1.2	125	2700
EBM	1.6	25	0.5–2.5	250	150 (average) 2000 (peak)
LBM	0.1	25	0.5–1.2	125	2 (average)
PAM	75000	125	Rough	500	50000
Conventional machining	50000	50	0.5–5.0	25	3000

.) The MRR of ECM and PAM are resp. 1/4 and 1.25 times that of conventional whereas are only a small fractions of it.

.) The surface finish and tolerance obtained by various parameters except PAM is satisfactory.

.) ECM has very low tool wear rate

.) Power requirement of ECM and PAM are very high when compared to other non conventional machining processes. This involves high capital costs.

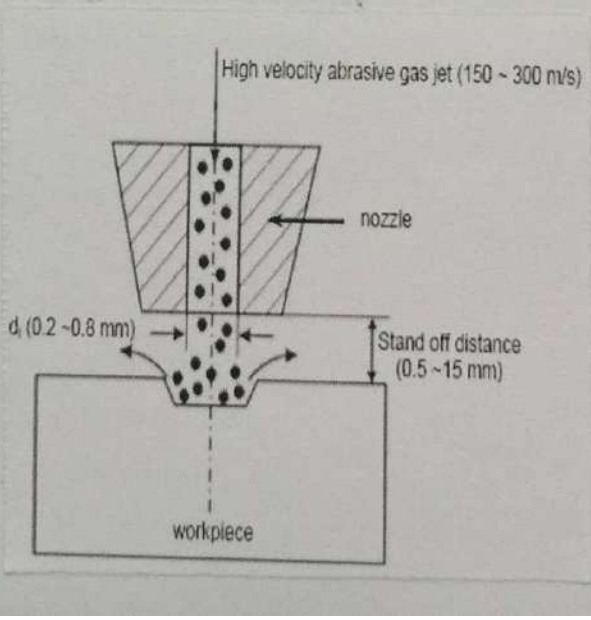
Economics of Processes:-

Process	Capital cost	Tooling cost	Power consumption cost	Material removal rate efficiency	Tool wear
USM	L	L	L	H	M
AJM	VL	L	L	H	L
ECM	VH	M	M	L	VL
CHM	M	L	H*	M	VL
EDM	M	H	L	H	H
EBM	H	L	L	VH	VL
LBM	L	L	VL	VH	VL
PAM	VL	L	VL	VL	VL
MCG	L	L	L	VL	L

* indicates cost of chemicals.

In Conclusion, the Sustainability of application of any of the processes is dependent upon Various factors and must be considered all or some of them before applying unconventional processes.

Abrasive Jet Machining (AJM):-



Principle :-

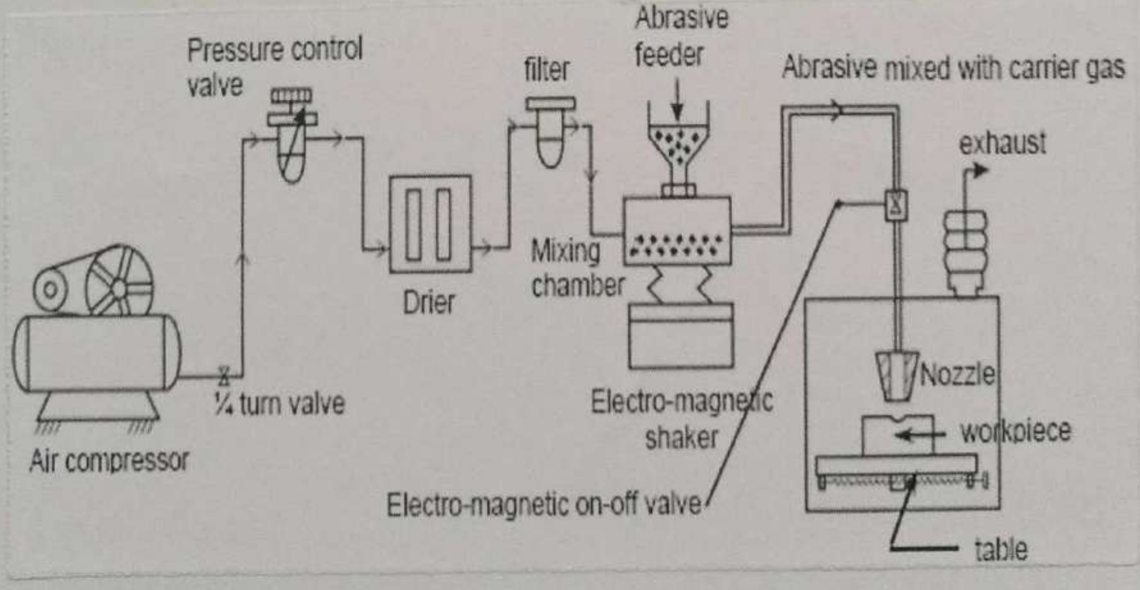
.) In AJM, the abrasive particles are made to impinge on the work material at a high Velocity. The jet of abrasive particles is carried by carrier gas.

.) The high Velocity stream of abrasive is generated by converting the pressure energy of the carrier gas to its KE and high velocity jet.

.) The nozzle directs the abrasive jet in a controlled manner onto the work material, so that the distance between the nozzle and W/P and the impingement angle can be set desirably.

.) The high velocity abrasive particles remove the Material by micro cutting action.

Equipment Used :-



Machining Characteristics :-

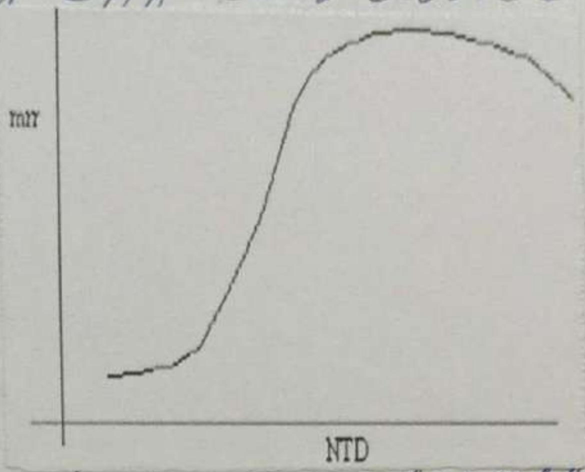
.) MRR — mm^3/min.

.) Machining accuracy

.) Life of Nozzle.

Parametric analysis

i.) Stand off distance (SOD)

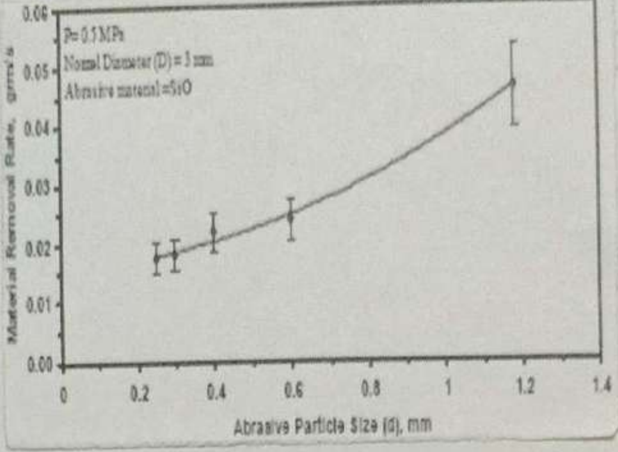


.) Cross section of actually machined profiles show that the shape of the machined cavity changes with a change of SOD.

.) Decrease in SOD improves accuracy decreases the kerf width and reduces taper in the machined groove.

.) The range of SOD varies from 0.75 to 1 mm.

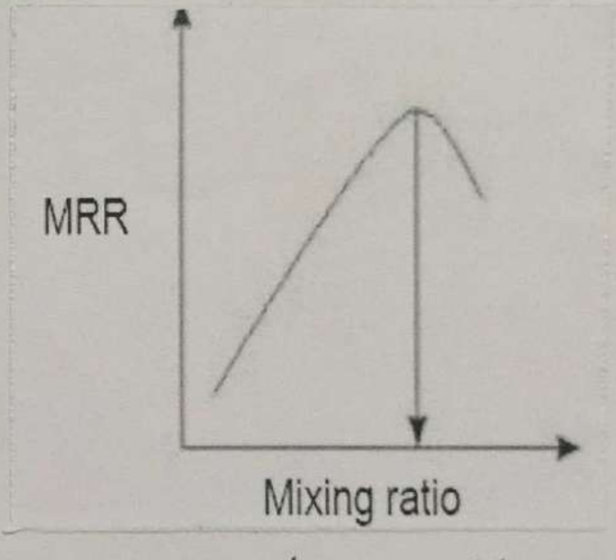
ii.) Size of abrasive particles:-



.) The increase of the abrasive size (d) increases the MRR.

.) Fine grains are less irregular in shape, hence their cutting ability is poor.

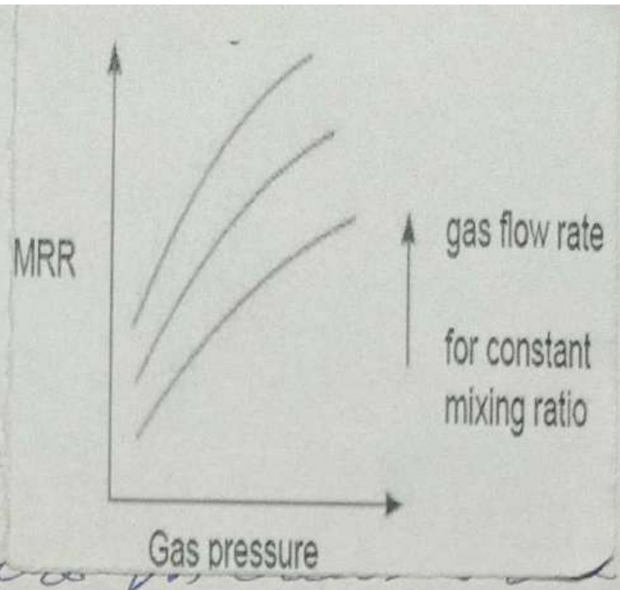
iii.) Mixing ratio:-



.) Mixing ratio is equal to the ratio of volume flow rate of abrasive particles to the volume flow rate of carrier gas.

.) The optimum value of mixing ratio has been observed that gives maximum MRR.

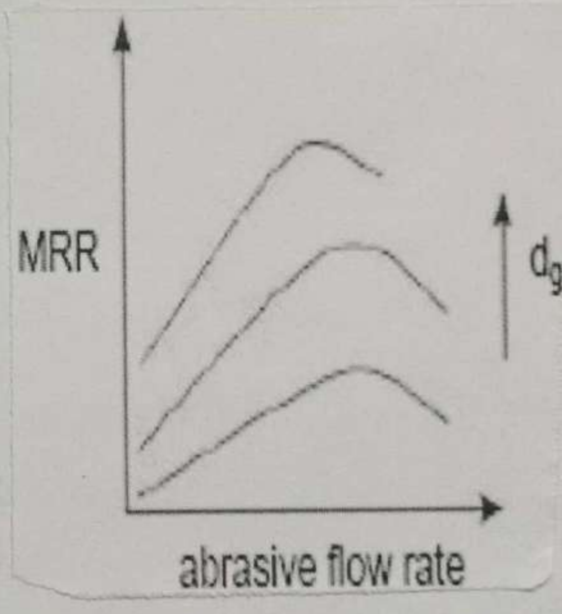
iv.) Gas pressure:-



.) When gas pressure increases MRR increases.

.) The reason may be the increase in gas pressure the KE of abrasive particles which is responsible for the removal of material by erosion.

v.) Abrasive flow rate

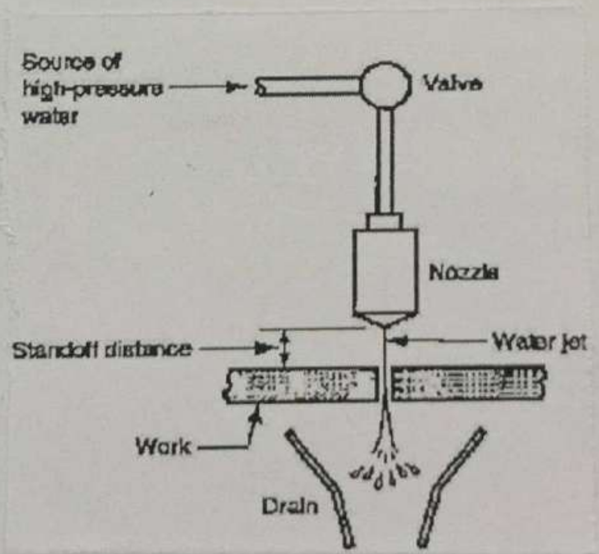


.) MRR increases only up to a certain value of abrasive flow rate beyond which it starts to decreasing.

Applications:-
i.) For drilling holes of Intricate shapes.
ii.) For Machining fragile, brittle and heat Sensitive Materials.
iii.) Micro machining of brittle Materials

Limitations:
i.) MRR is low.
ii.) Abrasive particles tend to get embedded particularly if the work Material is ductile
iii.) Tapering occurs due to flaring of jet.

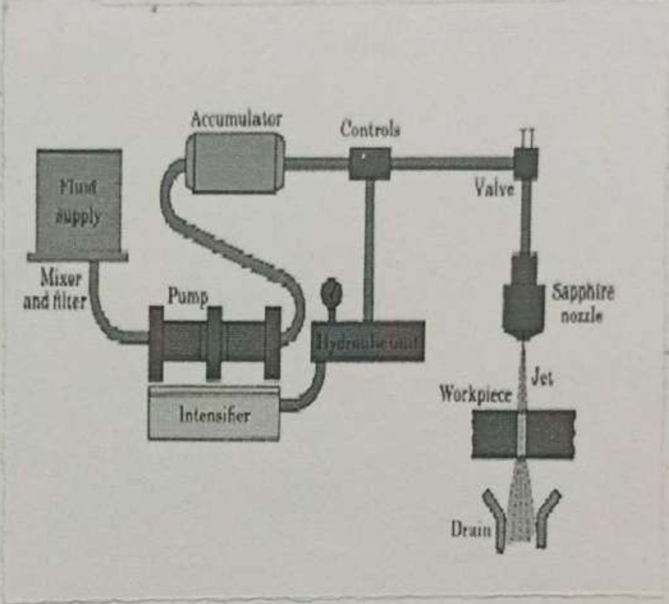
Water Jet Machining (WJM)



Principle:
.) The WJM, works on the principle of erosion effect of a high Velocity, small diameter jet of Water.

·) The velocity of jet may be as high as 900m/s.
·) As the high velocity water jet is discharged from the orifice, the jet tends to entrain atmospheric air and flares out decreasing its cutting ability.

Equipments used:-



Process parameters:-

i.) Pressure
ii.) Diameter of Nozzle
iii.) Traverse rate
iv.) Stand off distance.

Process Capabilities.
·) This process doesn't require predrilled hole to start cutting in any direction and location provided

Abrasive Water jet Machining (AWJM)

Principle:-

.) Abrasives such as garnet, diamond or powders can be mixed into the water to make a slurry with better cutting properties than straight water. In principle, this process is similar to AJM except that in this case water is used as carrier fluid in place of gas.

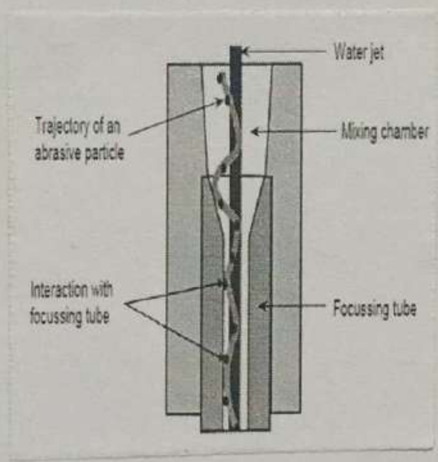
.) Water jet and a stream of abrasives coming from two different directions mix up and pass through abrasive jet nozzle. Here a part of the momentum

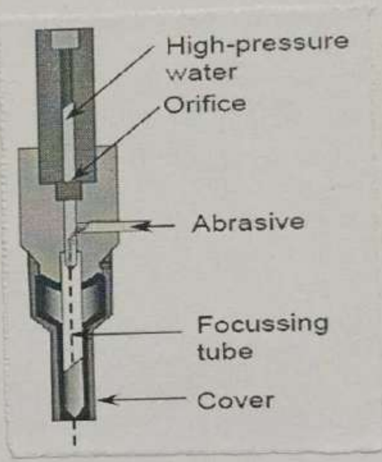
is accessible for the water jet.
·) Too thick materials can be cut in more than one pass.
·) Second and subsequent passes are used to make the cut deeper rather than wider.
·) Ultra high pressure water jets can cut to the accuracy of +/- 0.25mm.
·) This process doesn't produce airborne dust.
·) Low level of mechanical stress placed on the surface thus preventing damage and deformation.

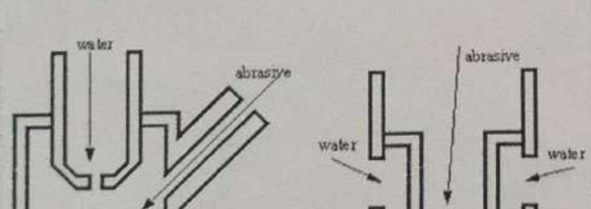
Applications:
·) This process is good for cutting and slitting of porous non metals like wood, leather, foam, asbestos, corrugated cardboards.

of water jet is transferred to the abrasives. As a result velocity of abrasives rises rapidly. Thus a high Velocity stream of mixtures of abrasives and water impinges on the w/p and removes material

Equipment Used:-
i.) Pumping System.
ii.) Abrasive feed System
iii.) Abrasive water jet nozzle
iv.) Catcher.

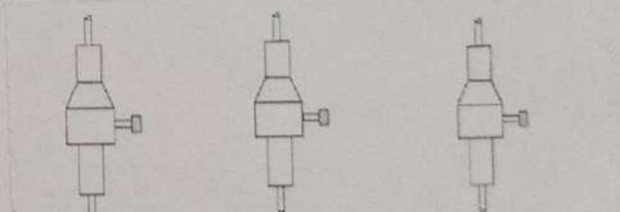






Single Jet, side feed

Multiple jet, central feed

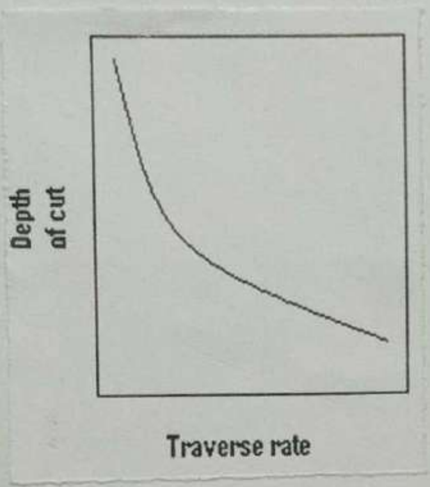

(a) water basin (b) steel/WC/ceramic balls (c) catcher plates (TiB_2)

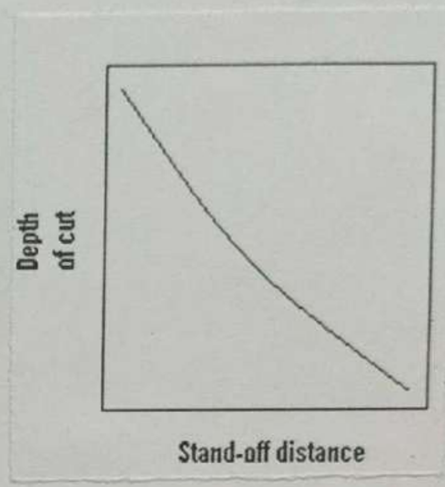
Process Variables:

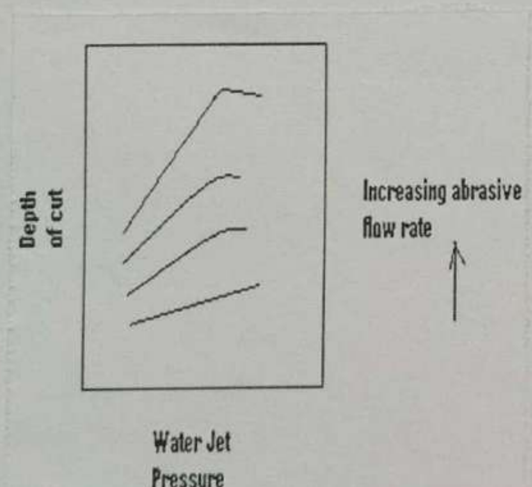
i.) Water → Pressure, flow rate

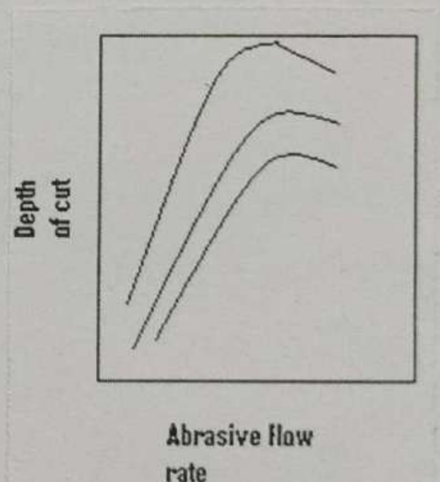
ii.) Abrasives → Type, size, flow rate

iii.) Cutting parameters → feed rate & stand off distance.









Process Capabilities:-

-) Tolerance +/- 0.005 inch
-) Cut thin stuff
-) Omni directional cutting having no burrs.
-) No heat generated.
-) Leaves a satin smooth finish.

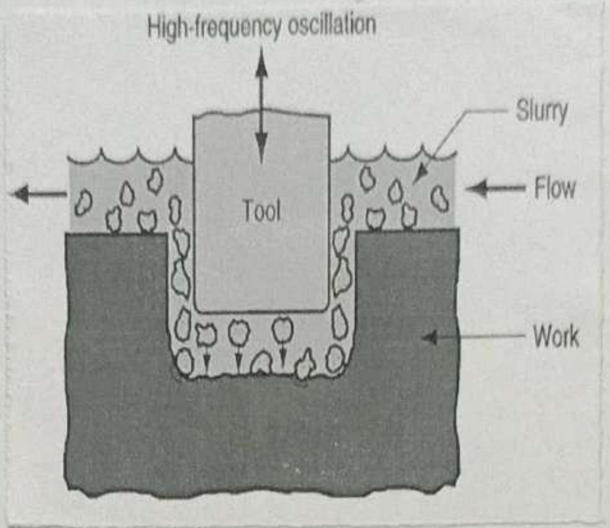
Application:-

i.) The process has been employed to cut a wide range of materials including both metals & non metals.
ii.) Aerospace Industries [sandwiched honeycomb]
iii.) Various steels have been cut into different shapes like plate, tube etc

Limitations:-

i.) Limited to number of Materials.
ii.) Taper is a problem with water jet cutting in very thick Materials.
iii.) Very thick parts can't be cut with waterjet cutting.

Ultrasonic Machining (USM):-



Principle:- In USM, a tool of desired shape vibrates at an Ultrasonic frequency over the w/p. The word ultrasonic describe a vibratory wave having frequency larger than the upper frequency limit of human ear.

Between the tool and w/p, the machining zone is flooded with hard abrasive particles generally in the form of water based slurry.

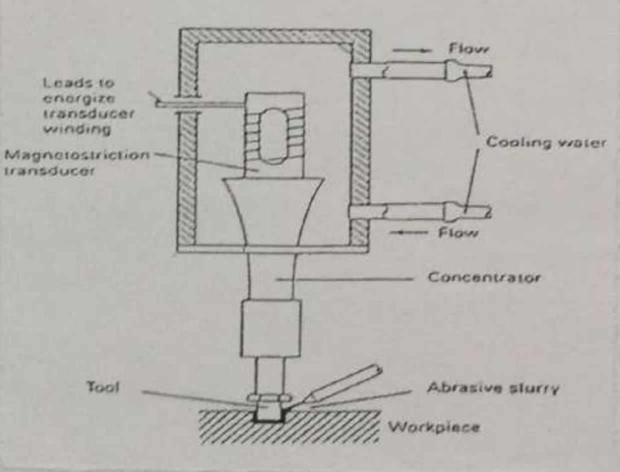
Abrasives contained in a slurry are driven at high velocity against the work by the vibrating tool.

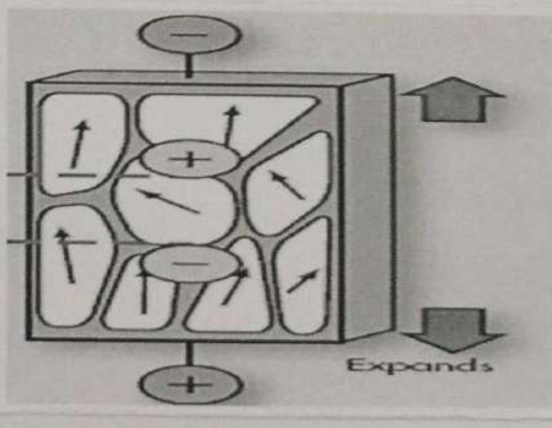
As the tool vibrates over the w/p, the abrasive particles act as the indenters and indent both the work material and the tool.

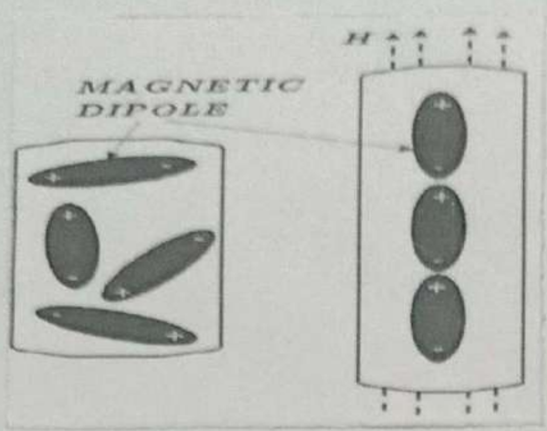
The abrasive particles as they indent, the work material, would remove the same.

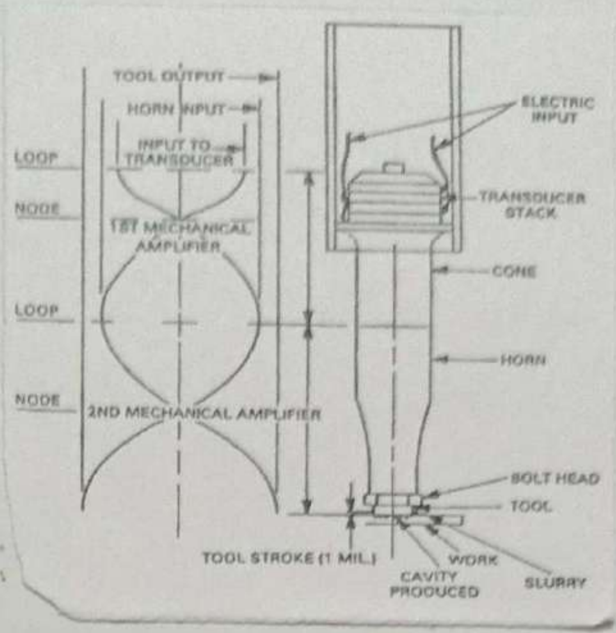
Tool oscillates in a direction ⊥ to the w/p surface and is feed slowly into the w/p so that the shape of the tool is formed in the part.

Equipment Used:
- i.) Transducer → Piezoelectricity / → Magnetostriction.
- ii.) Toolholder
- iii.) Tools
- iv.) Abrasive
- v.) Power Supply.









- Selection of Abrasives:-

.) Hardness, Usable life, cost and particle size.

.) Boron carbide is economical and yields good machining rates.

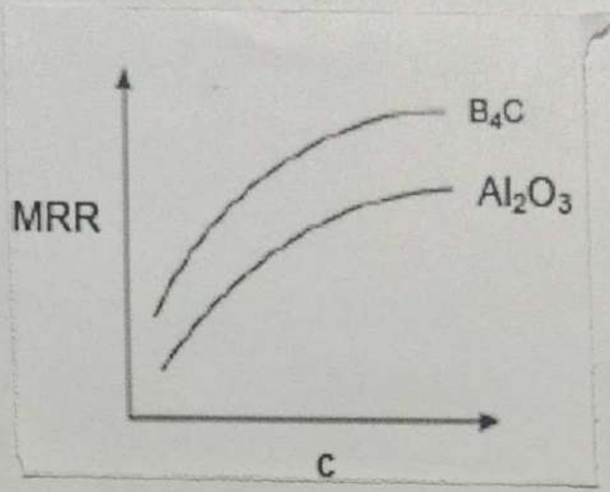
.) SiC and Al_2O_3 are also used.

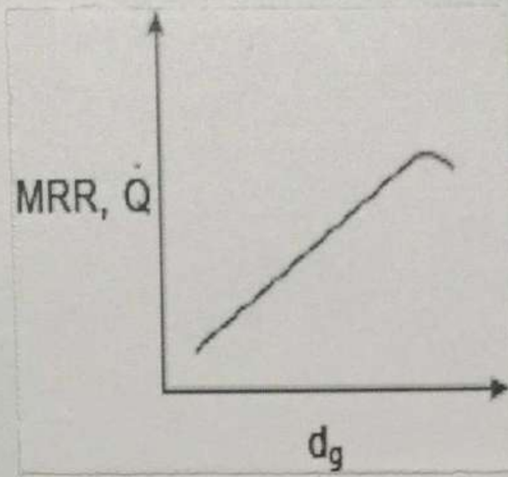
.) Fine grains results in lower MRR and better Surface finish.

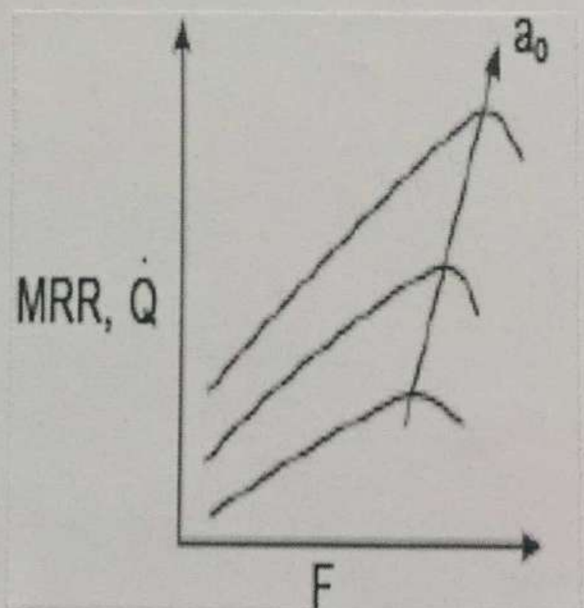
.) Abrasive and Water ratio in the slurry is normally 1:1.

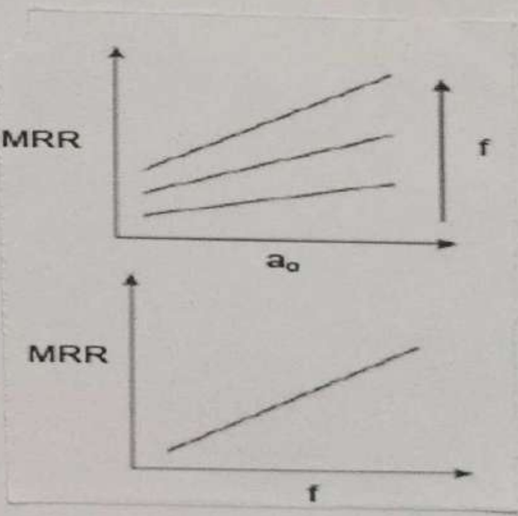
Process Parameters:

- Abrasive → Size, Shape, concentration
- Tool and Tool holder.
- W/p → Mechanical properties.

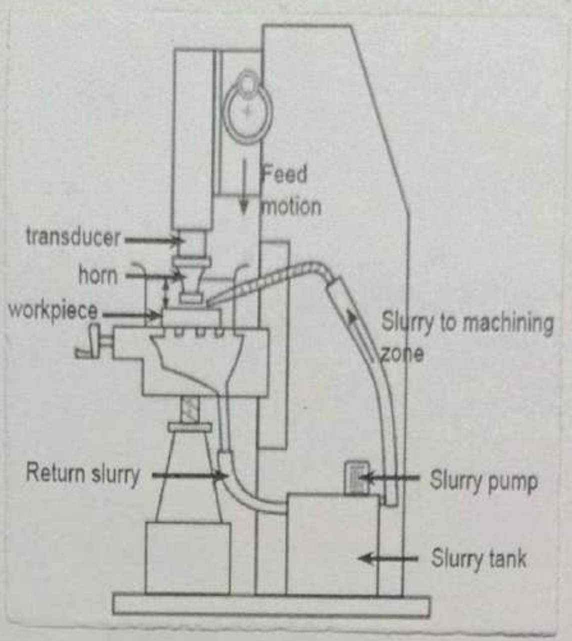




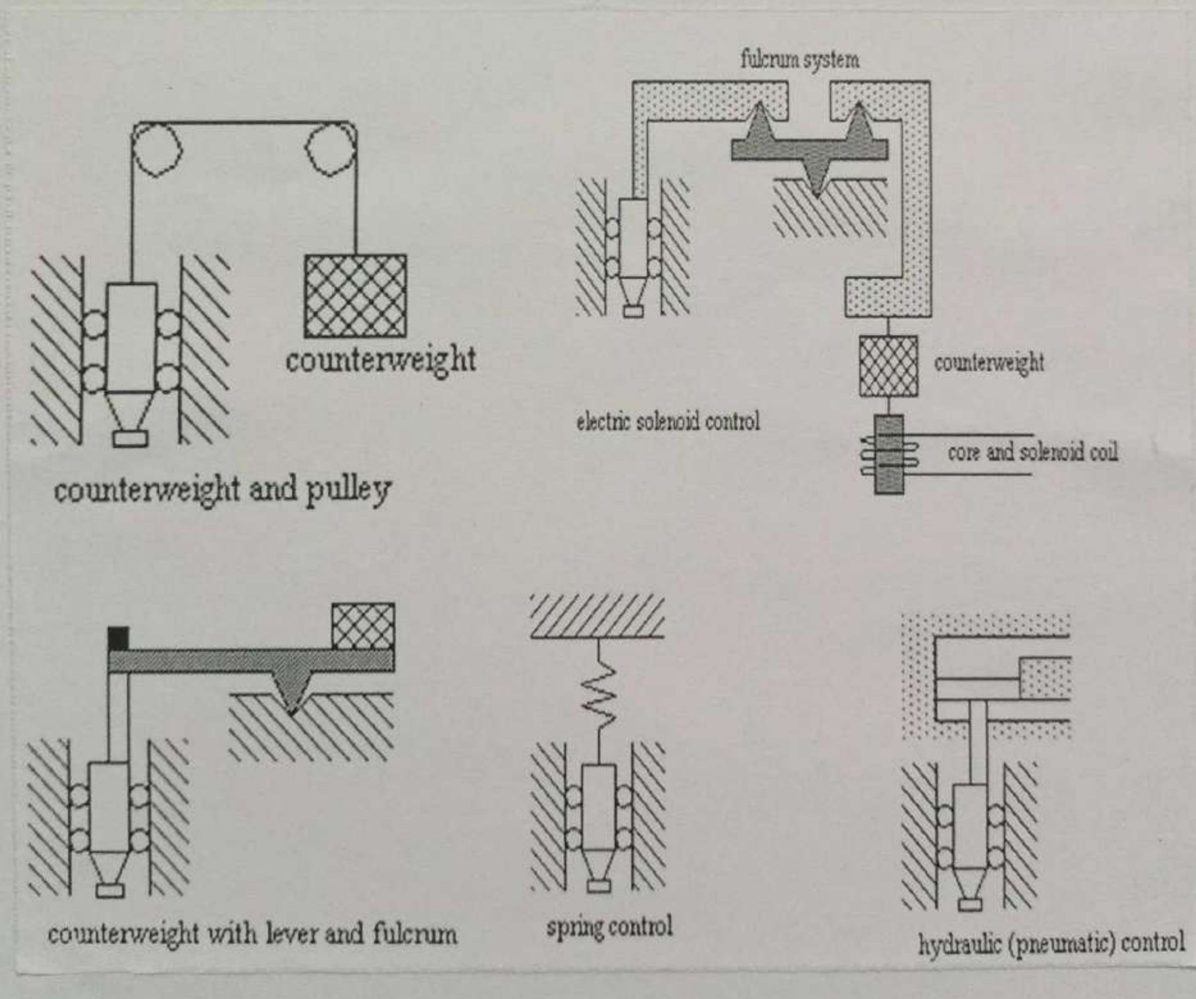




USM Machine.



Feed Mechanism.



Process Capabilities:-

·) USM works satisfactorily only when w/p hardness is greater than 40HRC. It works very well if w/p hardness is greater than 60.

·) Tolerance that can be achieved by this process range between 7 µm and 25 µm.

·) MRR achieved during USM ranges from 0.025 to 25 mm³/min.

Applications:-

·) Used for machining hard & brittle metallic alloys, semiconductors, glass, ceramics, carbides etc.

·) Used for machining round, square irregular shaped holes and surface impressions.

·) Machining, wiredrawing, punching or small blanking die.

Limitations:-

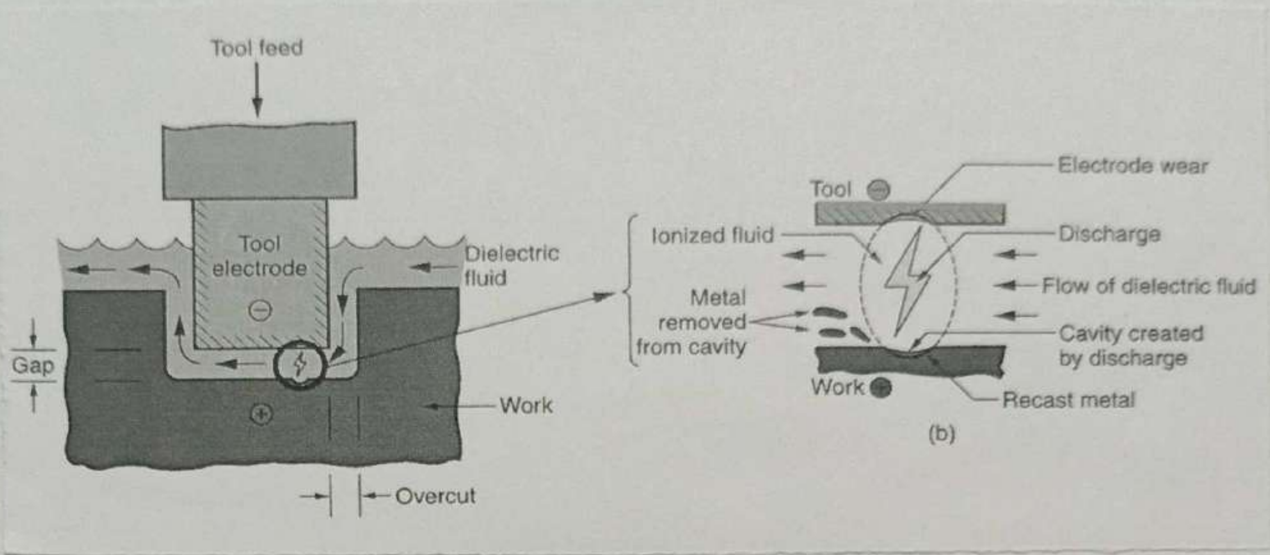
·) Low MRR.

·) Faster toolwear.

·) Machining area and depth are restricted.

Unit-2

Electro discharge Machining (EDM).



Working principle:

·) During EDM, pulsed DC of 80-100V at approx. 5KHz is passed through the electrodes.

·) Depending upon the applied potential difference and the gap between the tool and w/p, an intense electric field would be established.

·) As the electric field is established between the tool & the job, the free electrons on the tool are subjected to electrostatic forces.

·) If the bonding energy of electrons is less, electrons would be emitted from the tool. Such emission of electrons

are called cold emission.
.) The cold emitted electrons are accelerated towards the job during the dielectric medium.
.) As they gain velocity and energy, and start moving towards the job, there would be collisions between the electrons & dielectric molecules.
.) Such collisions may result in ionisation of dielectric molecules depending upon the ionisation energy of the dielectric molecule and the energy of the electron. Thus as the electrons get accelerated, more +ve ions and electrons from the dielectric would get generated due to collisions
.) Ionisation becomes so intense that a very narrow column of continuous conductivity is established.
.) In this column, there is a flow of considerable no of electrons towards anod and ion towards cathode.
.) KE → heat energy, heating of anode due to the bombardment of electrons and heating of cathode due to the bombardment of ion takes place.

·) Finally a spark generated, spark energy raises the localised temp of the tool and w/p to 10000°c that results in either melting / vapourisation of Small amt of Materials from the Surface of both electrodes at the point of spark Contact.

.) As the potential difference is withdrawn the plasma channel is no longer Sustained. As the plasma channel Collapse, it generates pressure / shock waves, which evacuates the Molten material forming a crater of removed materials around the Site of spark.

Equipment Used :-

·) Dielectric System

·) Tool

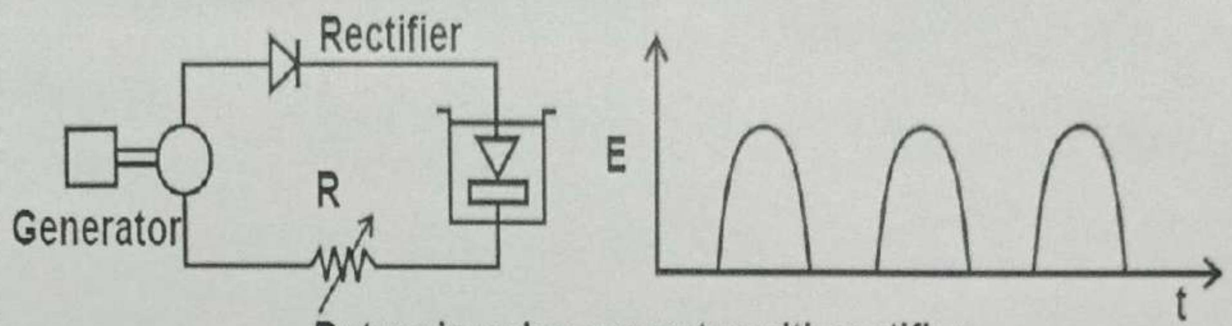
·) Work Piece

·) Servo System.

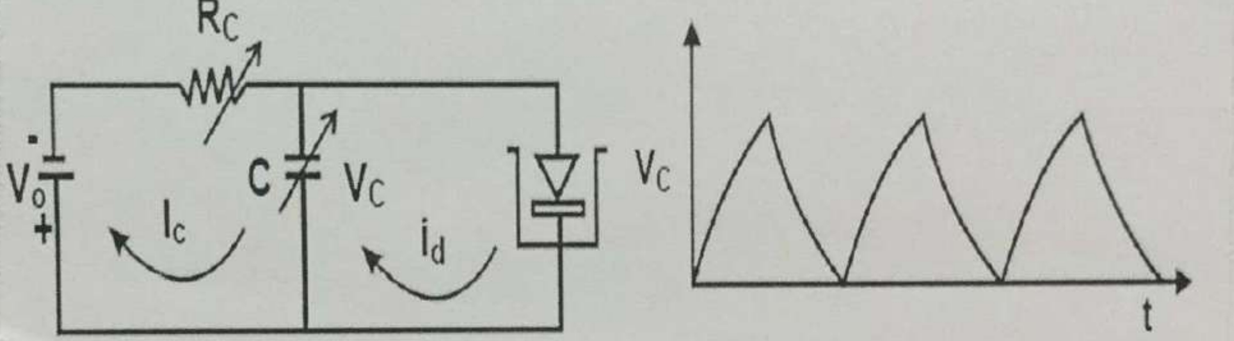
·) Power Supply. → Converts AC → DC.

- → Rotary Impluse type generator.
- → RC type Relaxation generator
- → Electronic pulse generator.

Power Supply.



Rotary impulse generator with rectifier



Dielectric :-

A dielectric is an electrical Insulator that can be polarized by an applied electric field.

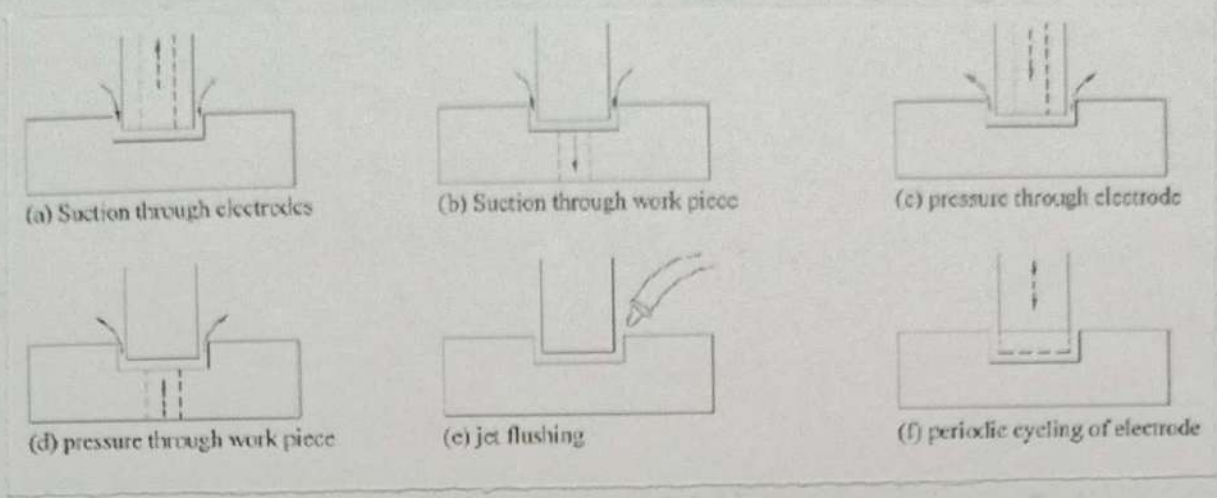
Dielectric Systems

- → dielectric fluid
- → reservoir
- → Filters
- → Pump
- → Delivery device.

Functions of dielectric fluid:
- Dielectric oil acts as a medium through which controlled electrical discharges occur.
- Dielectric oil acts as a quenching medium to cool and solidify the gasous EDM debris resulting from the discharge.

Types of Dielectric fluids:
- Deionised Water
- Mineral oils
- Synthetic oils
- Silicone oils.

Purpose of flushing:
- The concentration of the debris particles in the gap increases rapidly as the machining progresses. These wear particles should be removed from the gap so that fresh dielectric enters the gap for spark discharges.
- Ineffective flushing results in low MRR and poor surface finish.



Electrodes:-

.) Both tool and W/P are electrodes in EDM. But the word electrode is generally used for tool.

- Easily Machinaple.
- Low Wear rate
- Good Conductor of heat & Electricity
- Readily available.
- cheap.

Electrode Materials

.) Copper.
.) Brase
.) Copper Tungsten (Cuw).
.) Silver Tungsten
.) Graphite (90% applications).

Electrode degeneration:

- Electrode shape degeneration due to uncontrolled wear of tool is a serious problem in EDM.
- Electrode wear is more at corners/ edges than the rest of the tool.
- The tool gets trapped and its corners rounded off due to shape degeneration.

Electrode Refeeding:-

- Toolwear during EDM also reduces length of tool. For accurate machining the reduced length must be compensated otherwise the lengths of each successive hole to be drilled will be shorter than desired one.
- Increase in feed by each time can be a simple way to overcome this problem.
- Electrode re feeding can be done manually as well as automatically

Servo System:

- ↳ Electrical servo system
- ↳ Hydraulic Servo System.

Process Variables.

i.) Mean Current

ii.) Inter electrode gap

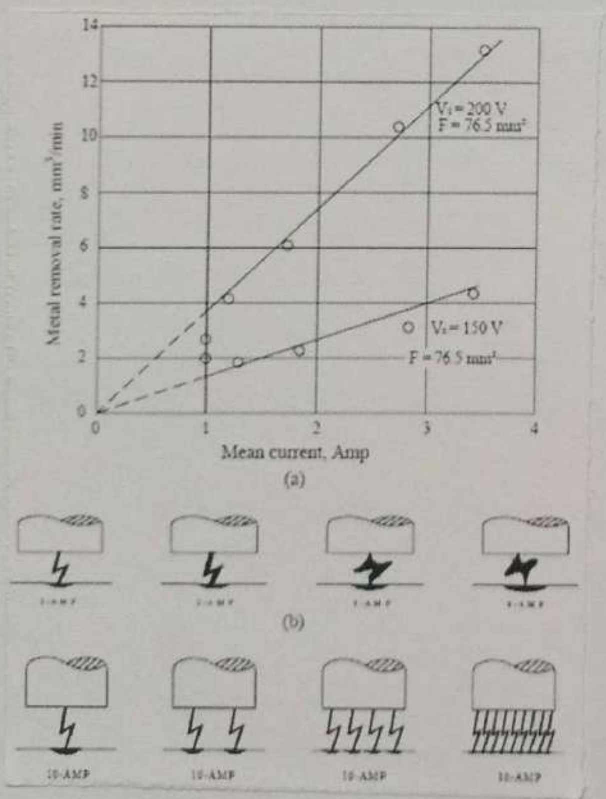
iii.) Pulse Duration

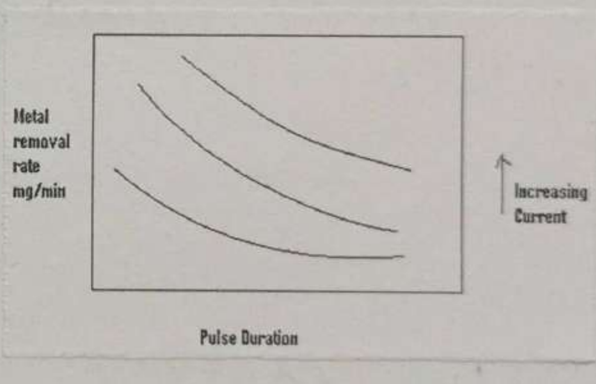
Responses:

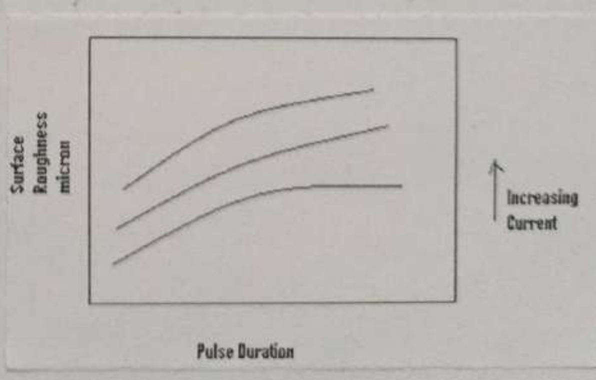
i.) MRR

ii.) Surface Roughness

iii.) Relative electrode Wear.





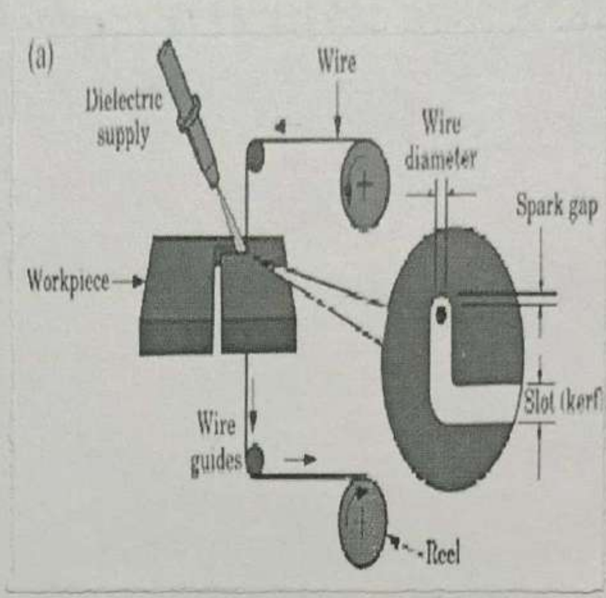


Applications:
i.) Die and Mould engineering
ii.) Use of die materials viz Carbide, hardened steel etc.
iii.) Can be employed to machine any material provided it has minimum electrical Conductivity.

Advantages:-
i.) Complex shapes can be machined
ii.) Hard materials to very close tolerance
iii.) No direct Contact between tool and W/P
iv.) Good surface finish

Dis advantages:
i.) Slow rate of Material removal.
ii.) Power Consumption is very high.
iii.) Out Cut is formed
iv.) Excessive tool Wear.
v.) Electrically non-Conductive materials can not be machined.

Wire EDM.



Principle:

.) Special form of EDM uses a wire as the electrode.

wire 0.05mm to 0.30mm in diameter

.) The wire unwinds from a spool feeds through the w/p and is taken up on a second spool.

.) DC power delivers high freq. pulses of electricity to the wire and the w/p.

.) The gap between the wire and w/p is flooded with dielectric. Unlike conventional EDM, the w/p in wire EDM is never submerged in Dielectric fluid, a localised stream is used.

.) Cutting action is achieved by thermal energy from electric discharges between the electrode wire and the W/P.

.) The Wire - W/P gap usually ranges from 0.025 mm to 0.05 mm.

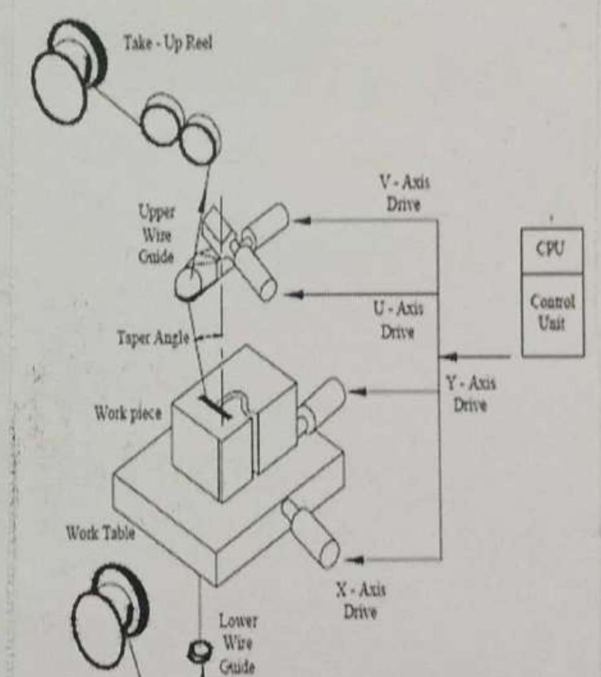
Equipments:-

i.) Positioning System.

ii.) Wire drive System

iii.) Power Supply System

iv.) Dielectric System.



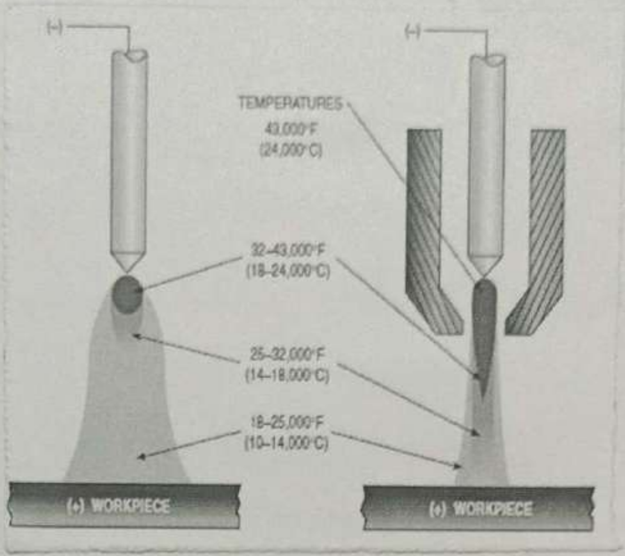
Applications:-

i.) Ideal for Stamp & die components

ii.) Possible to fabricate punch & die in a single cut

iii.) Lathe form tools, extrusion dies.

Plasma Arc Machining (PAM):-



Principle:-

- Plasma is the glowing, ionized gas that results from the heating of material to extremely high temperature.
- It is composed of free electrons dissociated from the Main gas atoms, +ve ions and neutral ions.
- While in plasma state, a gas becomes electrically conductive as well as responsive to Magnetism.
- The Source of heat generation in plasma is the recombination of electrons and ions into atoms or recombination of atoms into molecules.

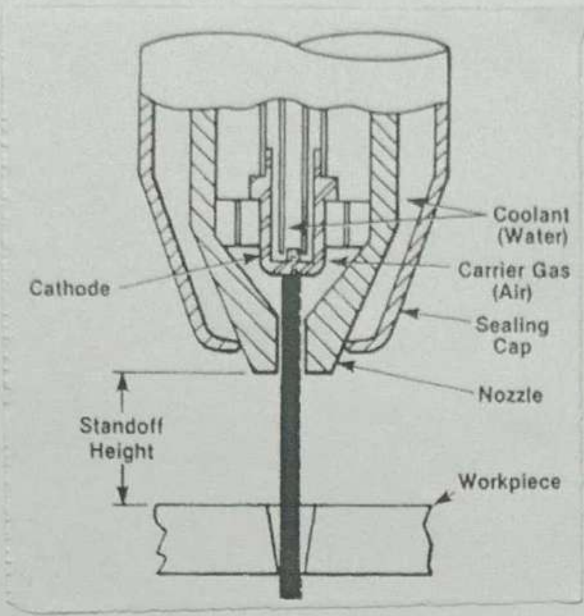
.) This liberated bonding energy is responseble for increase KE of the atoms or molecules formed by recombination.

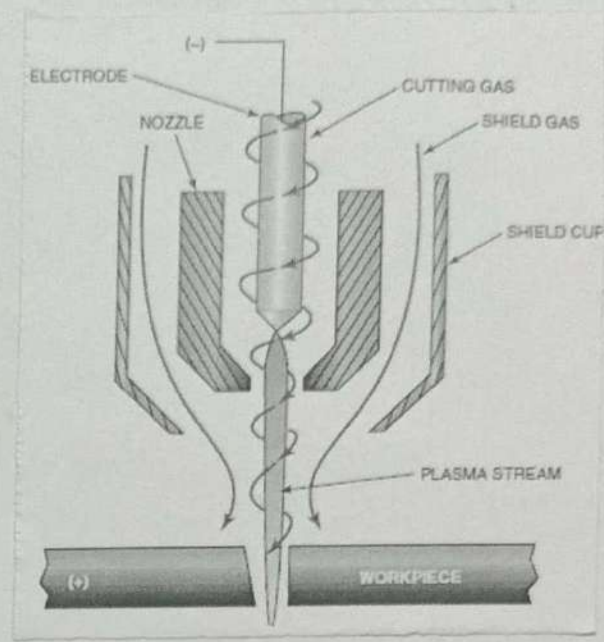
.) The temperature of plasma can be that of order 33000°c which means that literally all metals can be rapidly cut.

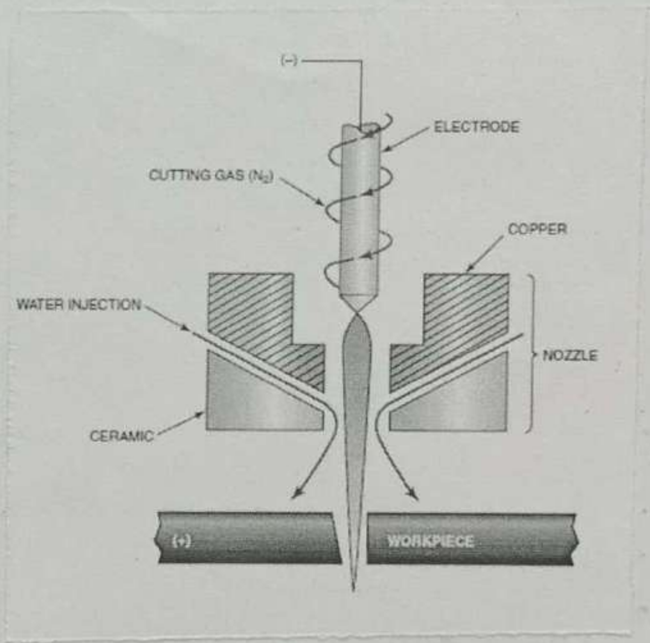
.) When plasma reacts with work material, the work material melts out or may even vaporise and finally is cut into pieces.

Equipment:-

.) Power supply.
.) Gas supply
.) Cooling water system.
.) Control console
.) Plasma torch.
  - Air plasma torch.
  - Oxygen plasma torch.
  - Water injected torch
  - Dual Gas Torch System.







Process Parameters

.) Surface Speed → $S = \frac{25.4}{t}$

.) Stand off Distance → distance between nozzle tip to the work.

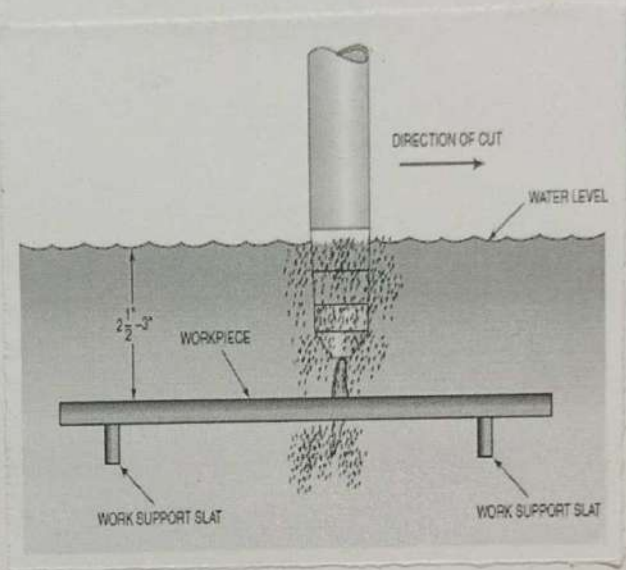
.) Gases

Application:-

Plasma arc cutting ~~fluids~~ finds its application in metal fabrication and metal plate industries for shape cutting.

Pipe industries.

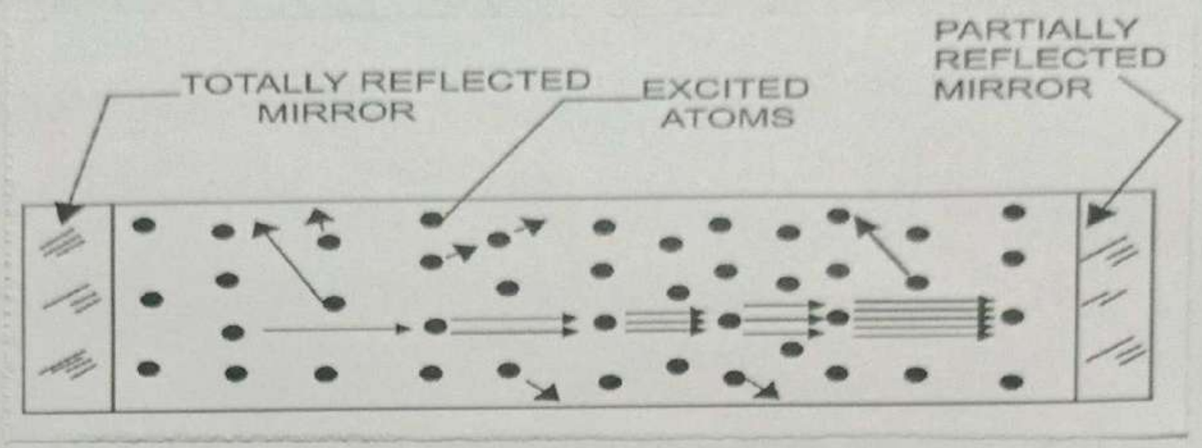
Underwater Plasma Cutting.-



For Underwater plasma cutting, the w/p is immersed about 2 to 3 inches under water and plasma torch cut while immersed in water.

·) Finally when cutting in water, some water surrounding the cut zone is dis associated into O_2 and H_2 and freed oxygen has a tendency to combine with the molten metal from the cut to form metal oxide, which leaves free H_2 gas in the water.

Laser beam Machining (LBM).



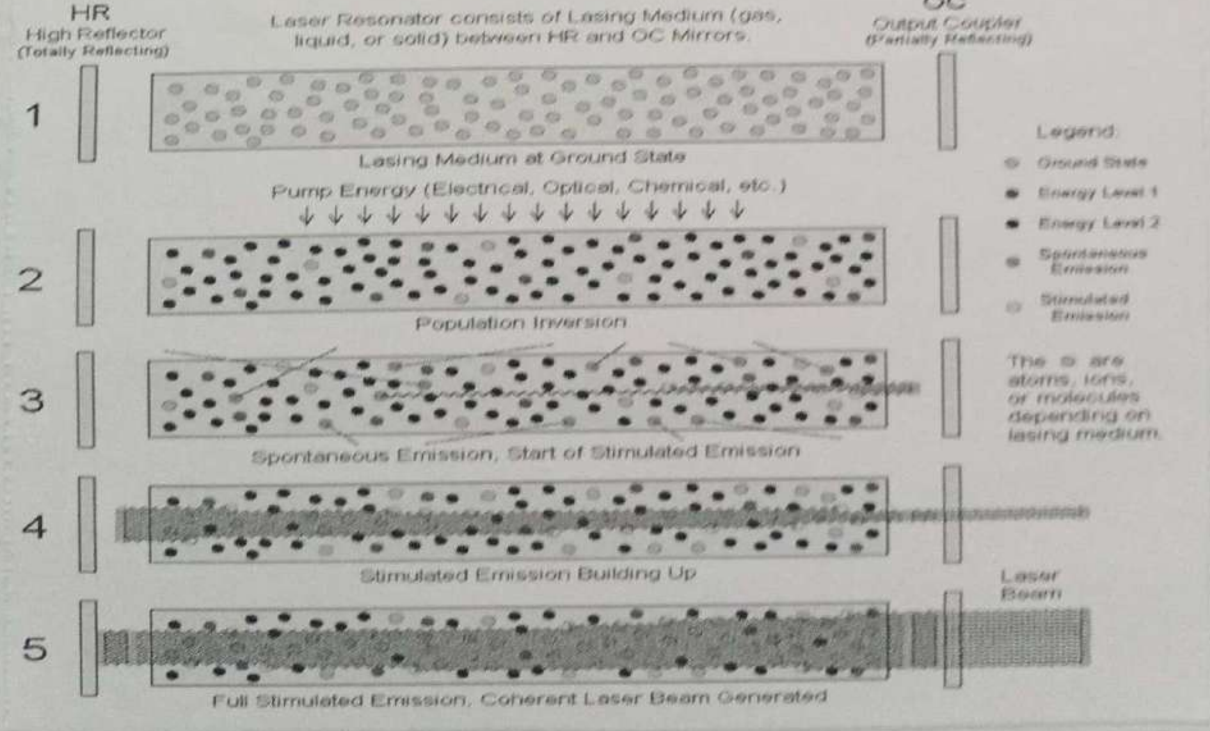
Working principle of Laser.

·) The three imp. elements of laser devices are (i.) Laser Medium
(ii.) pumping energy source
(iii.) Optical feedback System

·) Considering a gas laser consisting of a thin tube filled with gas at low pressure. There are electrodes at both ends of the tube. Electric current when passed through provides sufficient energy to simulate the atoms of gas in tube. This causes population inversion.

·) The Stimulated emission would initiate lasing action, Stimulated emission of photons could be in all directions. Most of simulated photons, not along the longitudinal direction would be lost and generate waste heat. The photons in the longitudinal direction would form coherent, highly directional, intense laser beam.

-) The feedback mechanism for laser consists of ll mirror kept at ends of tube. One of these mirrors is fully reflective while the other is partially transparent to provide the laser output. It allows a beam of radiation to either pass through, or bounce back and forth repeatedly through a laser medium.



Properties of laser:-

.) Mono chromatic:.
↓
wavelength occupies very narrow portion of the spectrum.

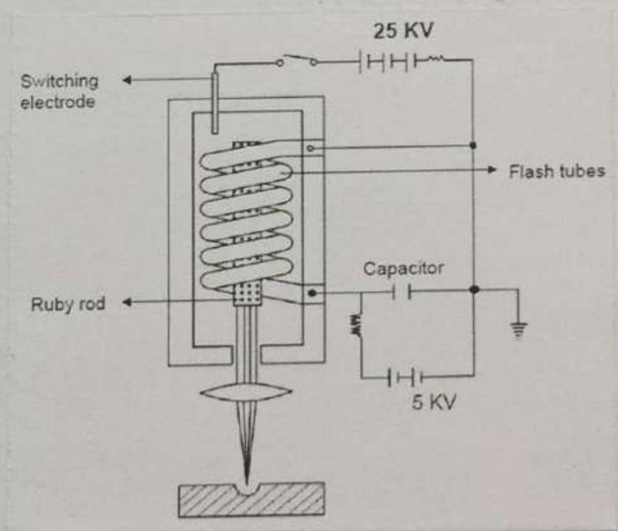
.) Coherence

.) Divergence

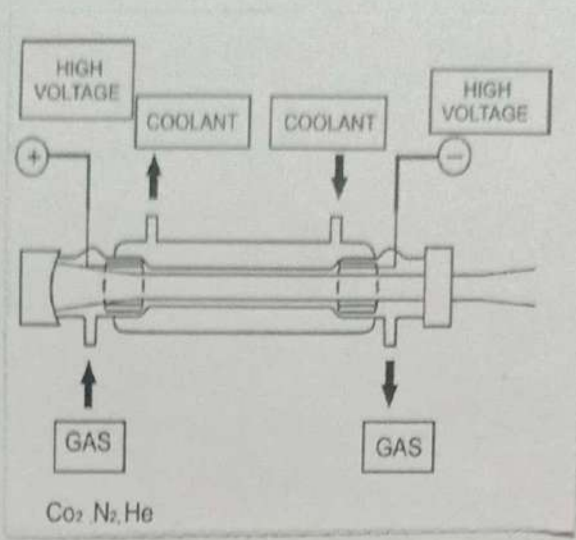
.) Brightness.

Equipments:.

.) Solid state lasers
↳ Ruby, Nd glass, Nd-YAG.
↓
Yttrium Al-garnet.



.) Gas lasers:. (CO_2 lasers).
construction of gas lasers is very similar to that of solid state lasers.

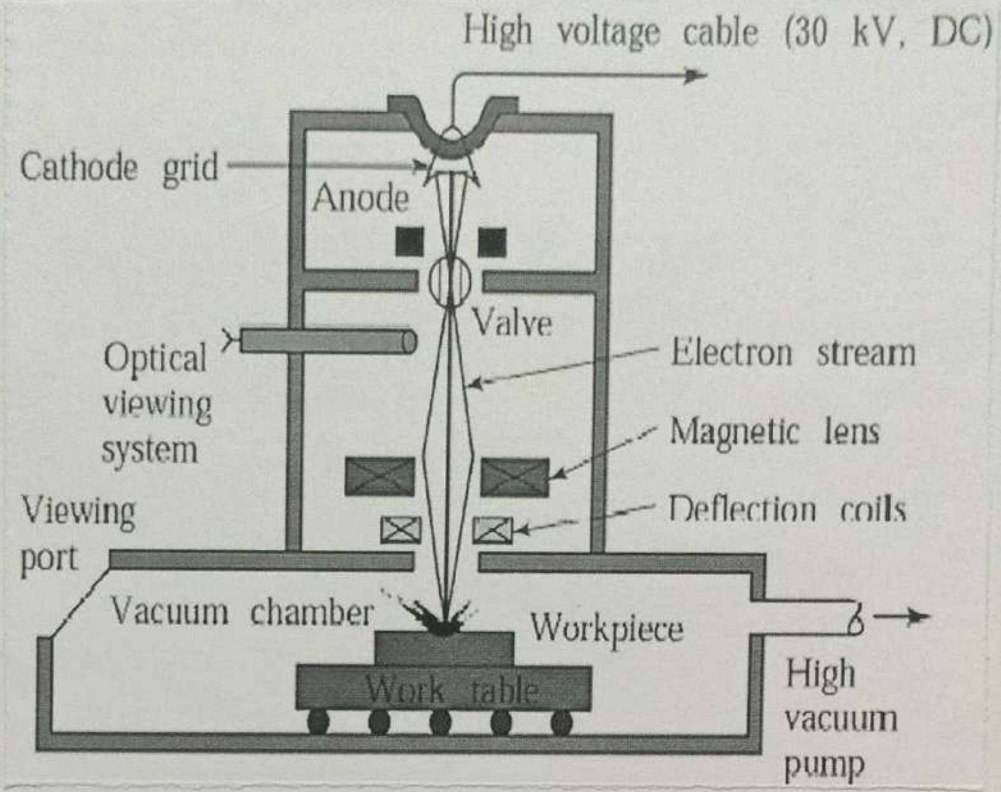


Applications :-
- Laser heat treating
- Laser cladding
- Laser Welding
- Laser Machining
- Laser Beam drilling.
- Laser Cutting, Marking.

Advantages:-
- No physical tool required.
- No ~~tool~~ wear.
- Micro holes can be drilled.

Limitations:-
- High initial Capital Cost
- High Maintenance cost
- Not very efficient process.

Electron beam Machining (EBM):



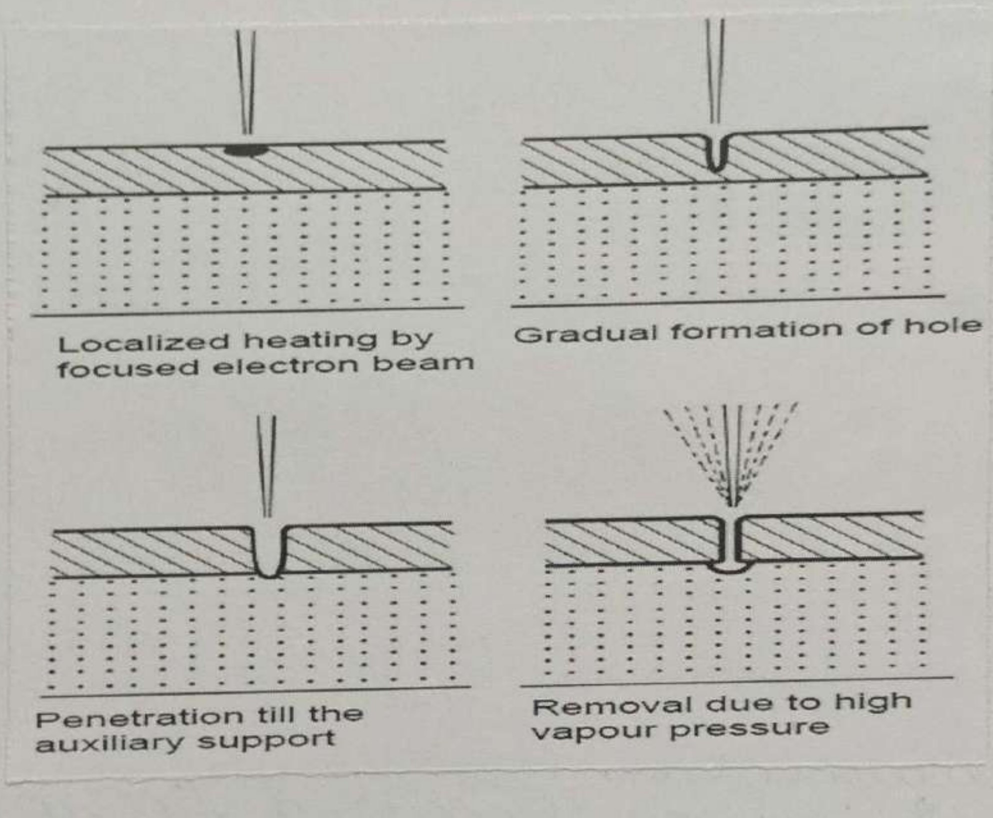
Principle:-

.) Electron Beam Machining is a thermal material removal process that utilises a focussed beam of high velocity ~~process~~ electrons.

.) A thermoelectric cathode is heated to a high temperature that the electrons acquire sufficient speed to escape out to the space around the cathode.

.) The stream of large no of electrons move as a small diameter beam of electrons towards the anode.

·) The high velocity beam of electrons strikes the w/p.
·) Upon striking, the KE of electrons converts into heat which is responsible for melting & vapourisation of w/p.
·) Material removal process is represente below.



Elements in EBM:-
·) Electron beam gun
·) Vaccum System.
·) Power Supply.

Process Parameter:-

.) Beam Current.

.) Duration of pulse

.) Lens Current

⇒) Beam Current [100 μA to 1A].

⇒) Pulse duration [50 μs to 10 ms].

⇒) Lens current [distance between the electron beam gun an focal point].

Application:-

.) Used to make fine gas orifices in space nuclear reactors.

.) Holes in wire drawing dies.

.) Cooling holes in Turbine blades.

Advantages:-

.) Very high drilling rate when small holes with large aspect ratio are to be drilled.

.) Fixture Cost is less.

.) HAZ is shorter

Limitation:-

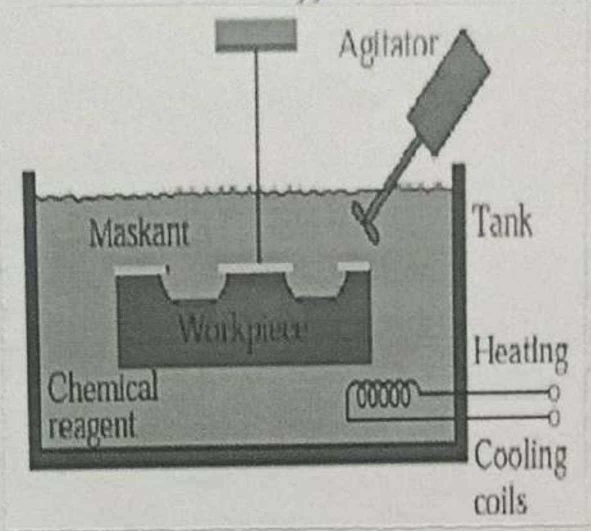
.) High Capital Cost.

.) Non production pump down period
↓
production of vaccum

.) Formation of Recast layer.

Unit-3

Chemical Machining (CHM).



•Chemical Machining is a process used to remove materials by dissolution in controlled manner from w/p by application of acidic/alkaline solution.

•) Maskants are the materials that don't allow etchants to penetrate through to reach the work material to dissolve.

•) This selective etching process is popular for the production of delicate parts that could easily be damaged by the forces of conventional cutting tools.

Types of CHM:-

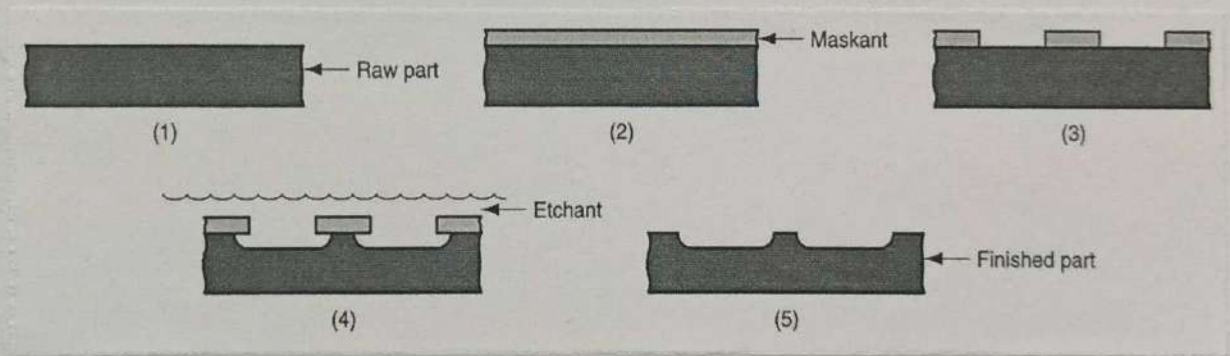
-) Chemical Milling]

defined as the process of chemically eroding material to produce 'blend' details etc or to remove materials from all surfaces of a part for the purpose of weight reduction.

-) Chemical blanking]

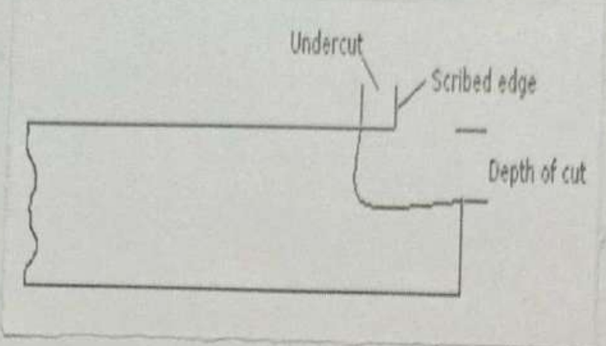
Process for producing details that penetrate the material entirely.

Steps in CHM.



① Preparing → precleaning
② Masking → Applying a thin coating of Maskant.
③ Etching.
④ Remove Maskant
⑤ Finish → Inspection & post processing.

Etch factor:-



.) The Material removal takes place both downward & laterally from the exposed Surface. First one is known as depth of cut while the latter is known as under cut.

.) The extent of undercut depends upon the factors like depth of cut, the type & strength of the etchant and w/P.

.) The qualification of undercut is known as etch factor.

$$\text{Etch factor} = \frac{\text{Undercut}}{\text{Machined depth}}$$

Application:-

.) Missile Skin panel section

.) Weight reduction of space launch vehicle by CHM aluminium alloy plates.

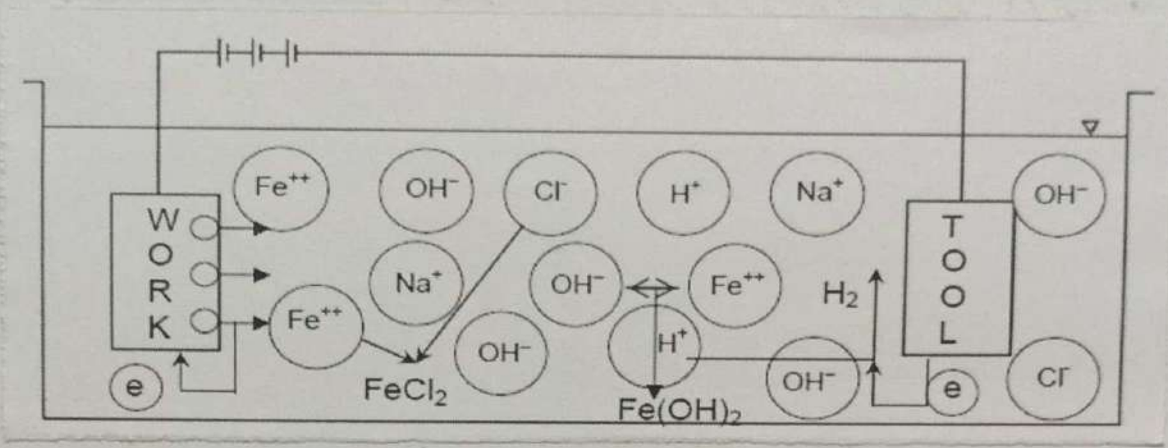
Advantages:
- Easy weight reduction.
- No effect of W/P material properties such as hardness.
- No burr formation
- No stress induction to W/P.
- Low Capital cost for the equipment
- Easy & quick design changes.
- Low tooling Costs.
- Good quality Surface
- Requirement of less skilled Workers
- Low Scrap rates (3%).

Limitations:
- Difficult to get sharp corners
- Difficult to chemically Machine thick materials
- Scribbing accuracy is limited, causes less dimensional accuracy.
- Etchants are very dangerous for Workers.
- Etchant disposals are very expensive.

Electro chemical Machining [ECM]:

·) Electrochemical Machining [ECM] is a process that relies on the principle of electrolysis

·) ECM is opposite of electrochemical deposition.



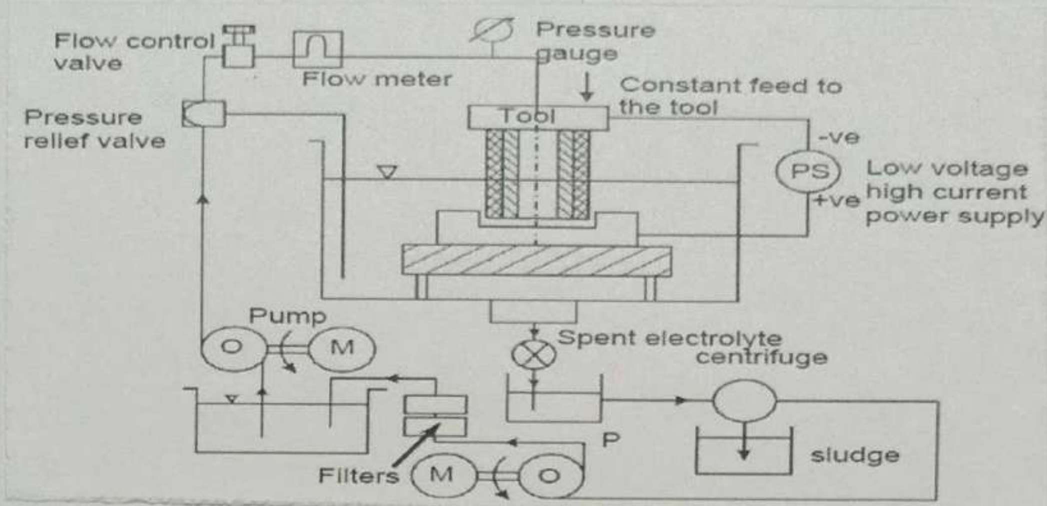
·) ECM can be thought of a controlled anodic dissolution at atomic level of w/p that is electrically conductive by shaped tool due to flow of high current at relatively low potential difference through an electrolyte.

·) A deplating action between a conductive w/p and shaped tool produces a predictable erosion of w/p.

Process:-

- This process works on the principle of Faraday's law of electrolysis.
- In ECM, a high current low voltage DC power supply is connected between an electrically conductive tool and w/p
- The shaped tool is cathode and w/p is anode. A conductive electrolyte flows through a small gap that is maintained between the tool & w/p.
- The transfer of ions & electrons between the electrodes completes the electrical circuit.
- The metals detached atom by atom, from the anode surface and appears in the electrolyte as +ve ions. The detached metal appears as precipitated solid.
- During this time, the electrolyte flows through a gap at a high velocity removing the deplated work piece material.

ECM machine tool:-

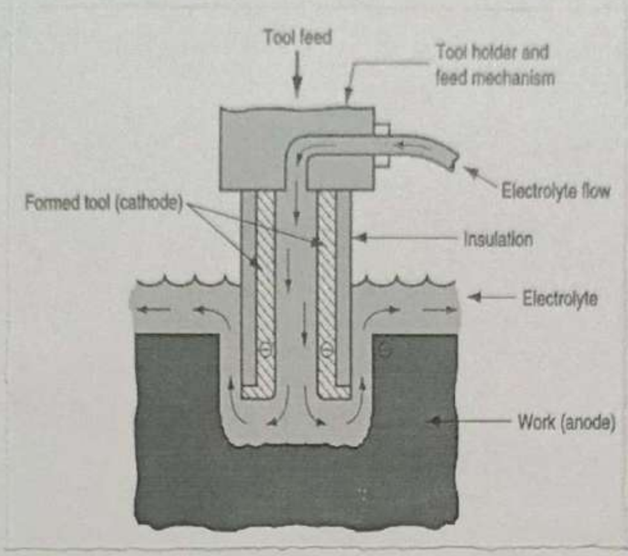


- .) Electro lyte supply & cleaning System.
- .) Tool & Tool feed
- .) Workpiece
- .) Work holding
- .) Power supply.

Electrolyte supply & cleaning System

The Electrolyte supply & cleaning System consists of a pump, filters, pipings, control valves, heating & cooling coils, pressures gauges and a Storage tanks.

Tools:-



The Criteria for a good ECM tool material is that it be a good electrical & thermal Conductor, be easily machinable, resist chemicals exhibit good stiffness. and be easily obtained.

- Al
- Brass
- Bronze
- Carbon
- Copper.
- Stainless steel
- Ti (99% pure).

Process Parameters.

- Current density.
- Inter electrolyte gap
- Electrolyte properties
- Electrolyte Velocity
- Electrolyte velocity
- Electrolyte temperature
- Feedrate.

Applications:-

- Turbin blade (Ni alloy).
- Thin slots.
- Integral airfoils on a Compressor disk.
- Two total knee replacement systems
  ↓ Metal implants

Advantages:-

- Can Machine high Complicated & curved shapes in a single pass.
- Single tool can be used to machine a large no of pieces without any loss in its shape & size.
- Burr free surface.

Limitations:

.) Used only for electrically conductive work materials.

.) The accuracy of machined components depends upon the factors like tool design, process control.

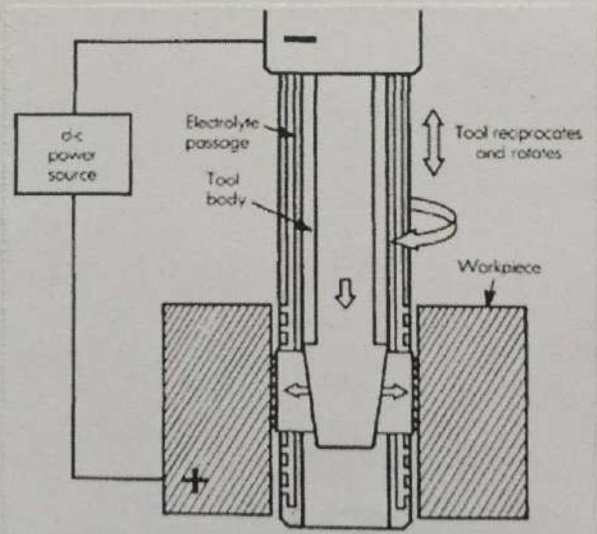
.) Can't produce sharp corners & edges

Electrochemical Honing:

.) Electrochemical Honing is a modification of conventional honing technique using ECM principle.

.) The Material is removed through a combination of anodic dissolution and mechanical abrasion.

.) W/P ⇒ anode
Stainless steel → cathode.



Process Capabilities:-

- Surface finish is 0.05 mic.
- Dimensional accuracy of ± 0.012mm
- Bore length upto 600mm.

Bore diameters from 9.5-150mm.

Advantages:-

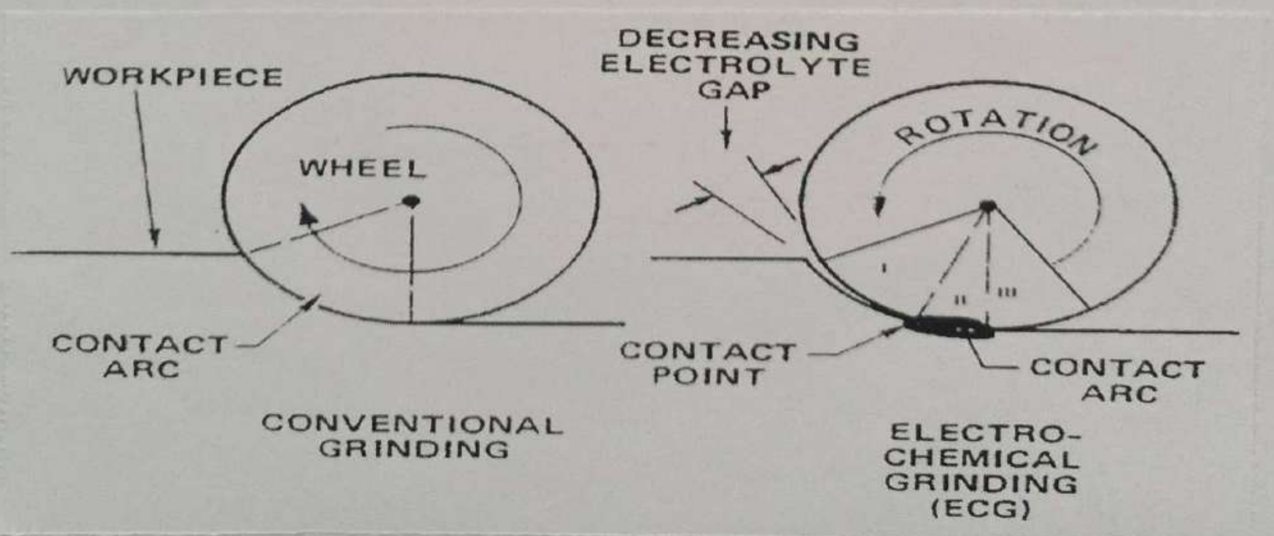
i.) Material of any Hardness can be machined by ECH as long as it is electrically conductive.

ii.) Process can remove material at rates upto 100% faster than conventional honing.

iii.) Because most of the material is removed electrolytically, honing stone life is greatly extended.

iv.) ECH imparts no residual stresses in the W/P.

Electro chemical grinding [ECG].

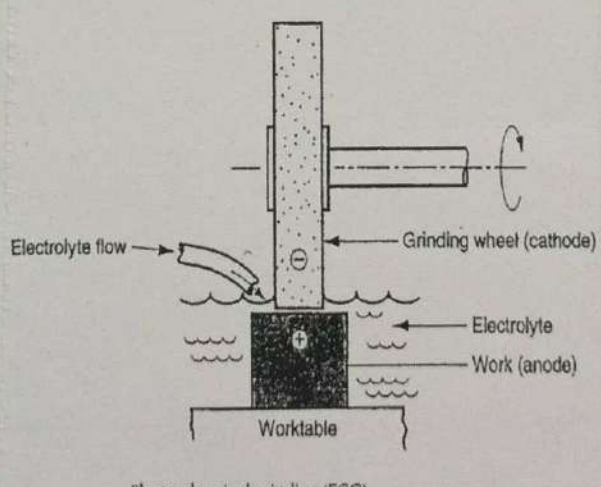


Process:-

·) In ECG, there is a grinding wheel similar to a conventional grinding wheel except that the bonding material is electrically conductive.

·) Electrolyte is supplied through inter electrode gap (IEG) between the wheel and the W/P.

·) The height of abrasive particles protruding outside bonding material of the wheel helps in maintaining a constant IEG because the abrasive particles acts as spacers. Life of ECG wheel is about 10 times more than the conventional grinding wheel.



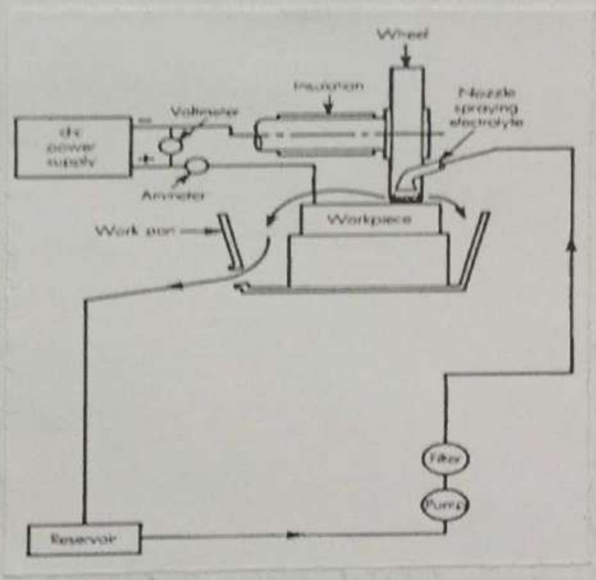
Electrochemical grinding (ECG).

The Mechanical contact arc of an ECG wheel is smaller than that of a conventional grinding wheel.

because ECG material removal occurs in three phases corresponding to three zones on the wheel.

- Entirely electrochemical
- Material removal phase
- Material removal → Totally electrochemically.

Equipment :-



- Power is supplied through spindle either with the help of brushes or mercury couplings.
- ECG wheels consists of an abrassive in an electrically conductive bonding agent. Cu, Brass, Ni are most Commonly used material for

metal bonding wheels.
·) The commonly used abrasive is alumina.

Applications:-
·) Electrochemical grinding is economical for grinding carbide cutting tool inserts.
·) Reprofile worn locomotive traction motor gears.
·) Grinding super alloy turbine blade and fragile aerospace honeycomb metals.

Advantages:
·) High MRR.
·) Surface finish good.
·) Cost is lower than Conventional
·) Risk of thermal damage is reduced.

Limitations:-
·) Although removal rates are high, ECG can't obtain conventional grinding tolerances.
·) More investment initially.

Unit-4

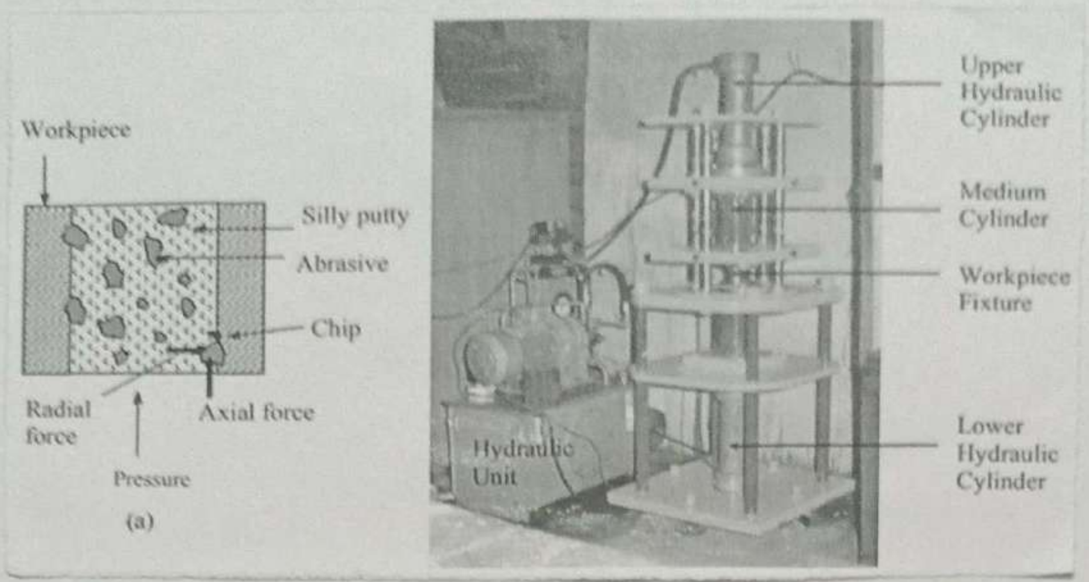
There are many advances taking place in the finishing of materials with fine abrasives, including the processes, the abrasives and their bonding, making them capable of obtaining nm order surface finish.

Abrasive flow Machining (AFM):-

.) AFM is a method to deburr, polish and radius difficult to reach surfaces and edges by flowing an abrasive laden viscoplastic polyer over them.

.) It uses 2 vertically opposed cylinders, which extrude an abrasive medium back & forth through passage formed by the w/p and tooling.

.) Abrasion occurs whenever the medium passes through the restrictive passages.



.) Abrasive action accelerates by change in rheological properties of medium when it enters and passes through restrictive passages

.) The Viscosity of polymeric medium plays an Imp. role in finishing operation. This allows it to selectively and controllably abrade surfaces that it flows across.

.) The W/P held by fixture is placed between two medium cylinders which are clamped together to seal so that Medium doesn't leak during finishing process.

.) The 3 major elements are:-

.) Tooling
.) Machine
.) Polymeric Medium]

whose rheological properties determine the pattern and aggressiveness of the abrasive action.

Process Parameters:-

.) Extrusion pressure
.) No of cycles.
.) Grit Composition
.) Fixture design.

Applications:-

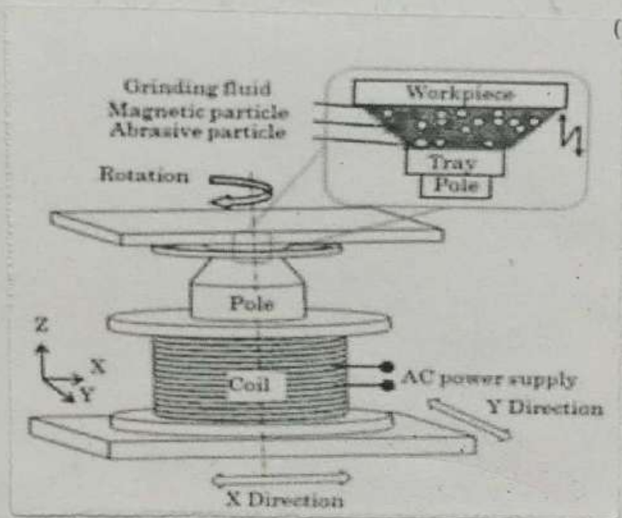
.) Aerospace, aircraft Components
.) Medial Components.
.) Electronics & automotive Components
.) Precision dies & Moulds.

Advantages:-

.) AFM process can polish anywhere the air, liquid or fuel flows.
.) Wide range of surface finish can be obtained.
.) No thermal damage.
.) Low capital Investment.

Limitations:
- Not suitable for soft and ductile Materials.
- Abrasives are not reusable.
- Abrasive Collection & disposal are problematic.
- Limited nozzle life.

Magnetic Abrasive Finishing (MAF):



- MAF is a process in which mixture of non ferro magnetic abrasive and ferro magnetic iron particle is taken and magnetically energized using a magnetic field.
- The w/p is kept between two poles of a Magnet.

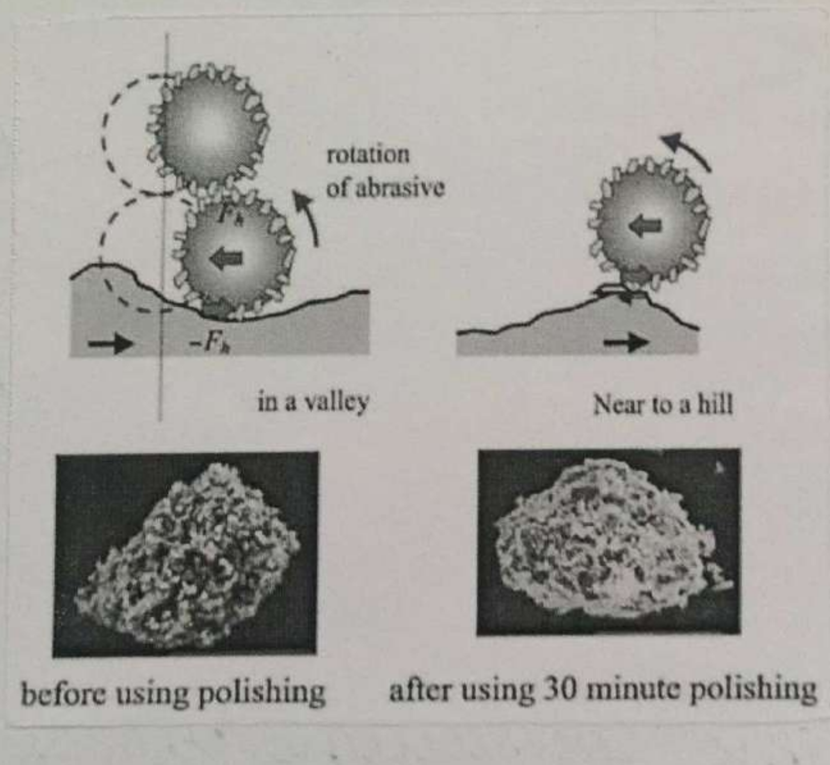
.) The working gap between w/p and magnet is filled with magnetic Abrasive particles. (MAP)

.) MAP can be used as bonded or unbonded

.) The magnetic abrasive particles join each other along lines of magnetic force and forms a flexible magnetic abrasive brush (FMAB)

.) This brush behaves like a multipoint cutting tool for finishing operation

Mechanism of MAP.



Application:
- Internal finishing of capillary tube
- Cutting tools, Air foils
- Optics, Sanitary pipes
- Curved pipes.

Advantages:
- Able to attain wide range of surface characteristics.
- Enhances surface characteristics such as wetability or reducing friction.
- Capability to accessing hard to reach areas.
- Setup is independent of w/p Material

Limitations:
- Difficult to Implement Magnetic abrasive finishing in Mass production operations.
- Not applicable for some ordinary finishing task where conventional finishing technique can be easily implemented.
- Time consuming process.
- The cost of process is high.

Magnetorheological Finishing (MRF)

- Magnetorheological finishing is a fine finishing process that has been applied to a large variety of brittle materials, ranging from optical glasses to hard crystals.
- Under the influence of a magnetic field, the carbonyl iron particles (CIPs) and non-magnetic polishing abrasive particles remove material from the surface being polished.

Magnetorheological fluid:

Magnetorheological finishing process relies for its performance on magnetorheological effect exhibited by carbonyl iron particles along with abrasive particles in non-magnetic carrier Medium.

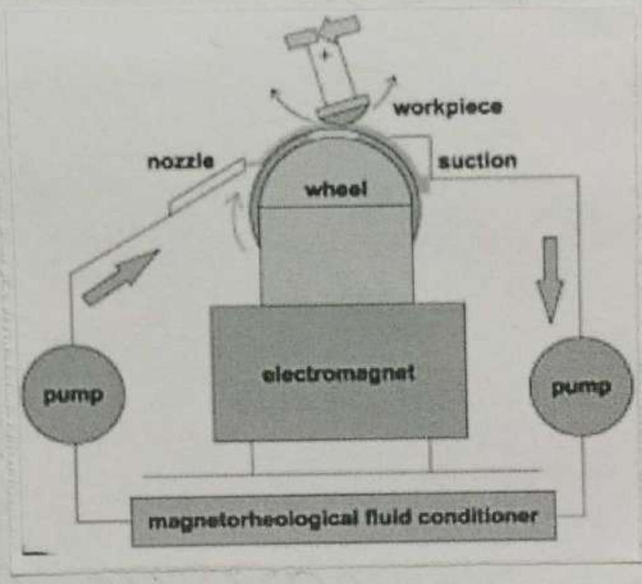
4 components of MR fluid:

- Base fluid → water, hydrocarbon oils.
- Metal particles → Carbonyl iron, Powder iron
- Abrasive particles → Silicone Carbide, Al_2O_3.
- Stabilizing additives. → Glycerol, Ferrous Oleate.

·) A convex lens installed at a fixed distance from a moving wall, so that lens surface and wall form a converging gap.

·) An electromagnet is placed below the moving wall, generates magnetic field in the area of gap.

·) MR fluid is delivered to the moving wall just above the electromagnet pole pieces to form a polishing ribbon.



·) The ribbon moves in the magnetic field it acquires plastic Bingham's property.

·) Then the ribbon pulled against the moving wall by magnetic field gradient and is dragged through the gap. resulting in material removal over lens contact zone.

·) The area designated by polishing spot.

Process Parameters:-

·) Concentration of CIP's.

·) Working gap.

·) Abrasives Concentration.

·) Wheel rotation.

Applications:-

·) High precision surfaces.

·) Optical glasses, single crystals and ceramics.

·) High aspect ratio optics and Substrates.

Advantages:-

·) High accuracy.

·) Stable in nature.

·) Increased production rate.

·) No subsurface damage.

·) Polishing tool is easily adjusted.

Limitations:-

·) High quality fluids are expensive.

·) Fluids are subject to thickening after prolonged use and need replacing.

·) No suitable Internal & external Surface finishing.

Magnetorheological Abrasive flow finishing [MRAFF]:-

- MRAFF process provides better control over rheological properties of abrasive magnetorheological finishing medium.
- MR polishing fluid Comprises of carbonyl iron powder and silicon carbide abrasives dispersed in the viscoplastic base of grease and mineral oil, it exhibits change in rheological behaviour in presence of external magnetic field.
- This smart behaviour of MR-polishing fluid is utilized to precisely control the finishing forces, hence final surface finish.

Experimental Setup:

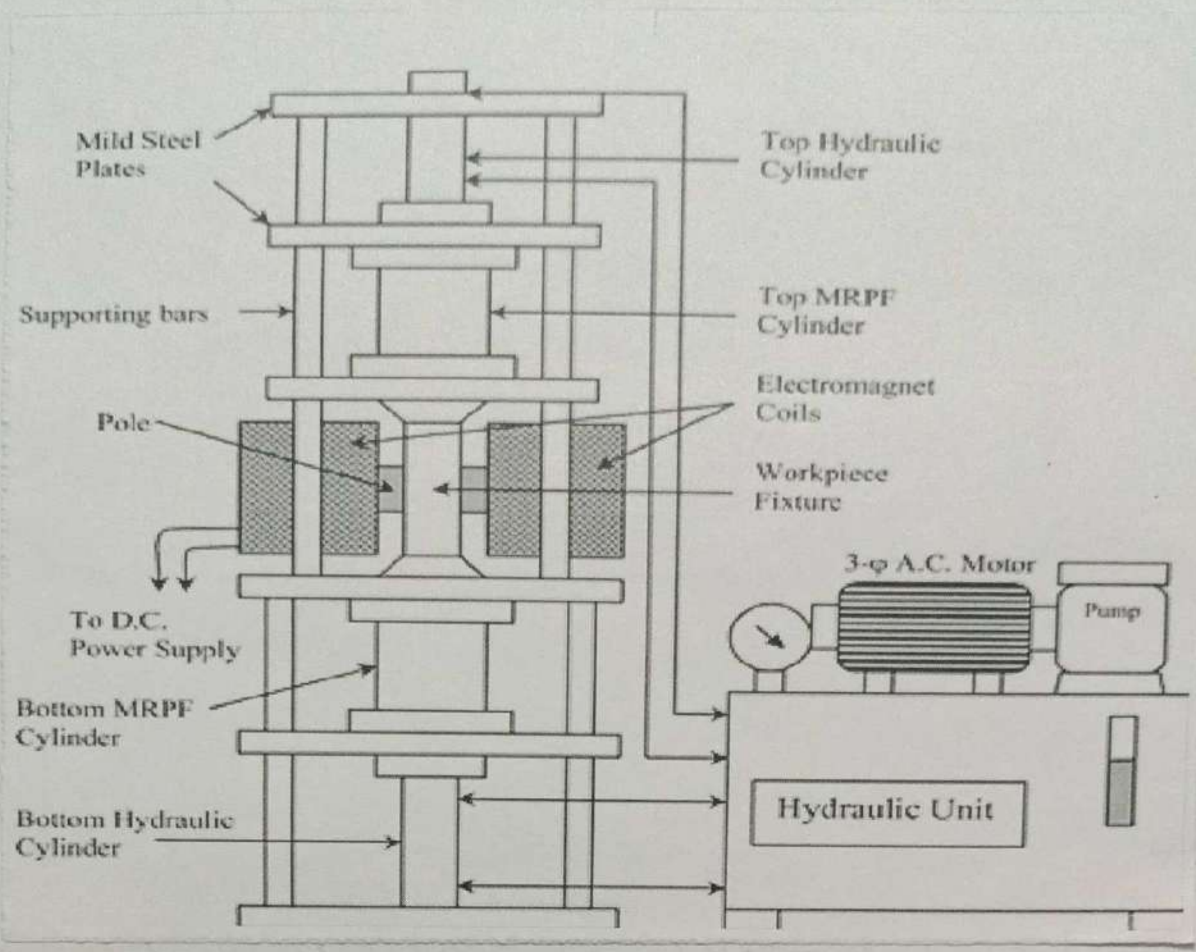
.) A hydraulically powdered experimental setup is designed to study the process characteristics and performance.

.) The setup consists of two MR-polishing fluid cylinders, two hydraulic actuators, electromagnet, fixture and supporting frame.

.) In MRAFF process, MRPF is extruded through the w/p passage to be finished utilizing two opposed cast iron cylinders under the presence of external magnetic field.

.) The viscosity of smart magneto-rheological polishing fluid (MRPF) is a function of applied magnetic field strength, and it is varied according to the desire finishing characteristics.

.) The shearing of Bingham plastic polishing fluid near the w/p surface contributes to the material removal & hence finishing.



characteristics:-

·) In MRAFF process, a magnetically stiffened slug of MRP fluid is extruded back and forth through or across the passage formed by w/p and fixture.

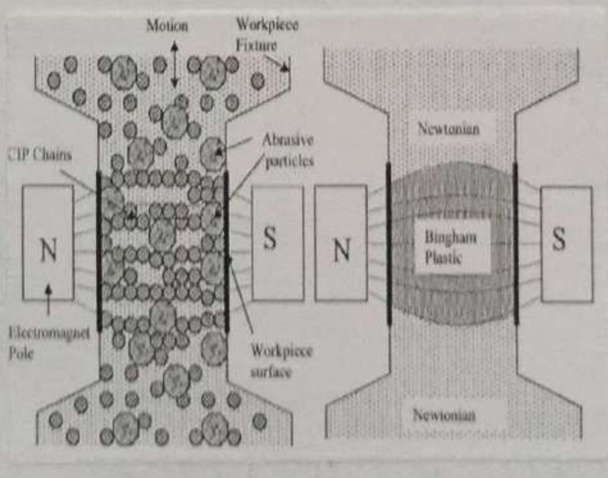
·) Abrasion occurs selectively only where the magnetic field is applied across the w/p surface, keeping the other areas unaffected.

·) The Rheological behaviour of polishing fluid changes from nearly Newtonian to Bingham plastic and Vice versa upon entering and exiting the finishing zone respectively.

·) The abrasive held by carbonyl iron chain rub the w/p surface and shear the peaks from it.

·) The amount of material sheared from the peaks of the w/p surface by abrasive grains depends on the bonding strength provided by field induced structure of MR polishing fluid and the extrusion pressure applied through piston.

·) In this way magnetic field strength controls the extent of abrasion of peaks by abrasives.



Advantages:-
- ·) High machining versatility.
- ·) Surface finish improvement
- ·) Cutting activity can be easily controlled.
- ·) Process is sample.
- ·) complex structures can be easily machined.

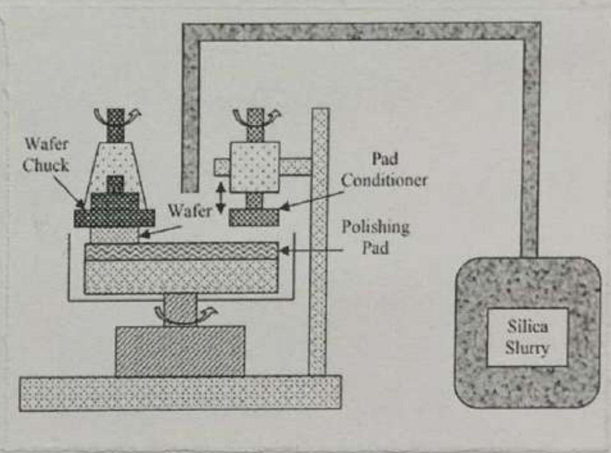
Disadvantages:
- ·) Machining setup is complex.
- ·) Cost is high.

Applications:-
- ·) Automotive
- ·) Aerospace
- ·) Robotics
- ·) Medical field.
- ·) Optical instruments
- ·) Metrology.

Chemical Mechanical Polishing

CMP is the fastest growing process technology in the semi-conductor manufacturing. CMP is a planarization process which involves a combination of chemical and Mechanical actions. The importance of each contribution depends on polished material.

.) It was developed at IBM in the mid 1980's as an enabling technology to planarize SiO_2 interlevel dielectric (ILD) layers so that 3 or more layers/levels of metal could be integrated into high density interconnection process.



Advantages:-

.) The Substrative nature of CMP helps in reducing surface defects

.) Environmental friendly.

Disadvantages:

.) Several potential defects including stress cracking, delaminating at weak interface & corrosive attacks

Unit-5

Recent trends in non traditional machining processes are micro-machining and hybrid processes.

The hybrid process is a combination of two or more non traditional machining processes. This process was developed by combination of the merits of those processes and eliminating their defects.

The Various types of hybrid processes are

- Electric discharge diamond grinding [EDDG].
- Electro chemical spark machining [ECSM].
- Magneto rheological abrasive flow finishing [MRAFF].

Electric discharge diamond grinding [EDDG]:

EDDG is a spark erosion process used for precision grinding. Spark is produced metal bonded grinding wheel and w/p. Hence heat generated during sparking softens the w/p.

surface and material surface is easily abraded using diamond abrasive particles

working:-

·) An electrically conductive rotating grinding wheel is used as the electrode and W/p is used as the anode

·) The wheel and the w/p are connected to -ve and +ve terminal of pulse power generator.

·) This pulse power generator is in turn connected to CNC computer

·) The arrangement is submerged in a big tank filled with dielectric fluid.

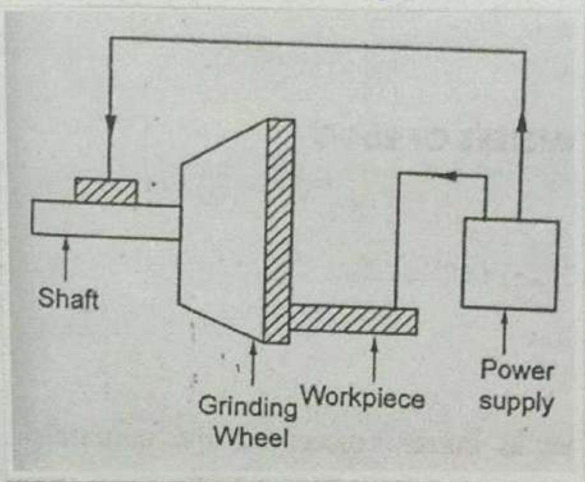
·) The pulse power generator generate pulse electrical energy at rates upto 250000 pulses/second.

·) The dielectric fluid flows through a small gap that is maintained continously and uniformly at the rotational motion of grinding wheel.

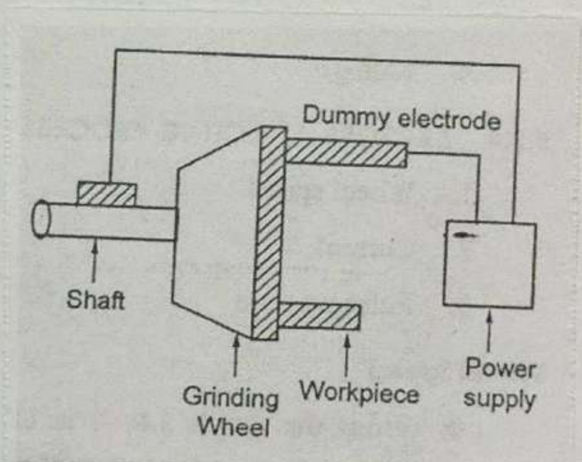
·) When the power supply discharge DC pulse power to the wheel and w/p, the insulative property of dielectric fluid is broken down and a spark is

produced between the gap.
·) Due to this, heat is generated between the gap and the material removal takes place.

Configuration of EDDG:-
i.) W/P is electrically conductive:-



ii.) W/P is electrically nonconductive:-



Parameters:-
·) Wheel speed
·) Current
·) Pulse on time.

Advantages:

.) It can grind any conductive and non-conductive materials

.) Less corrosive effect is produced.

.) High MRR.

.) Lower operating cost.

.) Produces higher accuracy.

Disadvantages:-

.) Recast layer is formed after grinding.

.) Possibilities of oil fires.

.) Wheels are fragile.

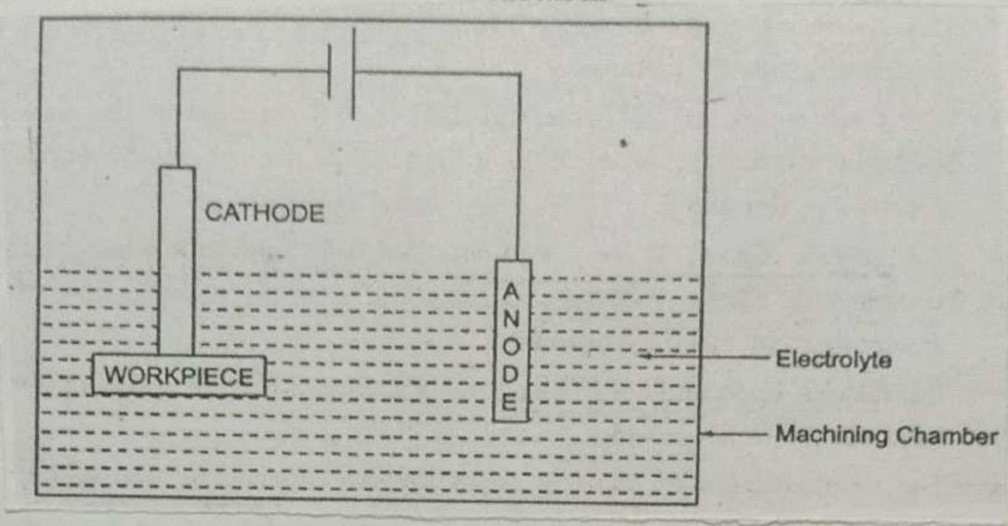
Applications:-

.) It is used in grinding thin sections

.) Grinding of high hardness materials such as ceramics, super alloys and MMC's.

.) Electro chemical spark Machining [ECSM]:

.) The anodes and cathodes are immersed inside the electrolyte. Due to potential difference developed the hydrogen bubbles are generated and thus spark is created between the cathode and w/p. This produces high energy that helps in material removal or vapourization of material.



Working:-
.) Setup is immersed inside the electrolyte.
.) Supply → ON, potential difference is created in the area and hydrogen bubbles are produced near the cathode in between the w/p.
.) Cathode → high potential → generates high no. of electrons → accerates to w/p surface.
.) The flow of huge no of electrons is seen as a current spike for a short duration of a milli seconds.

.) The bombardment of electron rises the temperature of the w/p giving rise to a sharp temperature pulse. This removes the material and vapourise it.

Cathode:-

$$2H_2O + 2e^- \rightarrow H_2\uparrow + 2OH^-$$

Anode

$$4OH^- \rightarrow 2H_2O + O_2\uparrow + 4e^-$$

Process Parameters:-

.) Cutting tool diameter
.) Voltage supply.
.) Table Speed.
.) W/p material.

Advantages:-

.) No need for Vacuum
.) Cost effective
.) Material removal in the form of circular pits

~~Disadvantages:~~
~~.) No need for vacuum.~~
~~.) Cost~~

Disadvantages:
.) The fumes produced due to chemical reaction is harmful to operator.
.) The fumes are more corrosive in nature.

Application:-
.) Used in machining materials like Alumina, Quartz and composities
.) Perparation of blind holes in quartz materials.
.) Automobile, electrical and manufacturing fields.