CBCS SCHEME

USN | | | | | | | | | | |

17ME554

Fifth Semester B.E. Degree Examination, Dec.2019/Jan.2020
Non-Traditional Machining

Time: 3 hrs. Max. Marks: 100

Note: *Answer any FIVE full questions, choosing ONE full question from each module.*

Module-1

1 a. Define Non-Traditional Machining. What are the need for N.T.M process. Explain briefly. **(06 Marks)**

b. What are the comparison between conventional and non-conventional machining. **(06 Marks)**

c. What are the various aspects to be considered before selecting a N.T.M process? Discuss briefly. **(08 Marks)**

OR

2 a. Give classification of N.T.M process. **(06 Marks)**

b. What are the specific advantages, limitations and applications of non-traditional machining processes? **(10 Marks)**

c. Enumerate the physical parameters of the Non-traditional machining process. **(04 Marks)**

Module-2

3 a. With the help of neat sketch, explain working principle of ultrasonic machining process. **(10 Marks)**

b. Explain with neat diagrams, process parameters in USM. **(06 Marks)**

c. What are the process characteristics of USM? Explain briefly. **(04 Marks)**

OR

4 a. Explain with neat sketch, working principle of Abrasive Jet machining and also give advantages and applications of A.J.M process. **(10 Marks)**

b. With the help of neat sketch, explain water jet machining process and also give advantages and disadvantages of W.J.M. **(10 Marks)**

Module-3

5 a. With a neat sketch, explain the working principle of ECM process. **(10 Marks)**

b. Explain with a neat sketch, Electro Chemical Grinding (ECG). **(06 Marks)**

c. What are the process parameters of ECM? Explain briefly. **(04 Marks)**

OR

6 a. Explain the following in Chemical Machining Process :
i) Maskants ii) Etchants. **(06 Marks)**

b. Sketch and explain Electro Chemical Honing (ECH). **(06 Marks)**

c. Explain with neat sketches of chemical blanking and Chemical Milling process. **(08 Marks)**

Module-4

7 a. With the help of a neat diagram, working principle of Electrical Discharge Machining process. **(08 Marks)**

b. Explain with neat sketch, the travelling wire EDM process. **(06 Marks)**

c. Mention various dielectric flow pattern of EDM process. Explain any two with sketches. **(06 Marks)**

OR

8 a. Explain with neat diagram, construction and working principle of Plasma Arc Machining (PAM). **(10 Marks)**

b. What are the process parameters of PAM? Explain briefly. **(05 Marks)**

c. What are the safety precautions in PAM? Explain. **(05 Marks)**

Module-5

9 a. Explain with neat sketch, working principle of Laser Beam Machining process (LBM). **(08 Marks)**

b. What are the advantages, limitations and applications of LBM? **(06 Marks)**

c. What are the process parameters and characteristics of LBM? **(06 Marks)**

OR

10 a. Explain with the help of a neat diagram, Operation Principle of Electron Beam Machining (EBM). **(10 Marks)**

b. What are the advantages , limitations and applications of EBM process? **(06 Marks)**

c. Explain need for EBM and mechanism of metal removal of EBM process. **(04 Marks)**

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Gurunath Mecoundi

Solved Question Paper — Dec-2019/Jan-2020.

Non-Traditional Machining. (VI Sem)

Previous scheme 17ME554
Current scheme 18ME641

Module- 1

Q1.a. Non traditional machining (also called as unconventional machining) are machining processes where the tool and workpiece donot come in physical contact and material removal happens by abrasion action/ spark erosion/ electrochemical/ chemical/radiant energy.

Need for N.T.M.: With the requirement of advanced technology, there is rapid growth in the development of hard and difficult to machine metals and alloys. Conventional contact tool machining is uneconomical for such materials. Also the accuracy and surface finish obtained by conventional machining is poor (Except CNC). In view of seriousness of this problem, there was/is need for the development of newer concepts in metal machining.

By adopting a unified programme and utilising the results of basic & applied research, it has now become possible to process some of the materials which were earlier considered to be unmachinable.

Also in many engineering applications intricate profiles have to be machined, many a times after the heat treatment. These complex profiles cannot be machined by conventional processes. This is also the need for development of alternate machining processes.

[Definition – 1 M
Explanation of need for NTM – 5 M.]

Q1.b. Comparison b/w conventional & non-conventional machining

Conventional Machining	Non conventional Machining
1) Physical contact b/w w/p & tool	No physical contact
2) Tool directly exerts the force on w/p & material removal is by Shearing	Material removal is by abrasion/ Spark erosion/ chemical/ electro chemical / radiant energy process
3) Machining process becomes difficult as the w/p hardness & strength increase	workpiece hardness & strength have least impact on the process
4) Vibrations generated are high	Negligible

5) Difficult to machine complex and intricate shapes	Complex & intricate shapes can be machined.
6) Hardened & heat treated materials can not be machined	Can be machined
7) Distortion of workpiece can take place	Negligible
8) Machining time is usually less (depending upon the process & volume of material removed)	High for - EDM, ECM, CM Less for - LBM, EBM, AJM etc.
9) Process is predominantly used for component manufacturing & initial machining of tools & dies.	Process is used for ~~[illegible]~~ finishing of tools & dies, new product development & in some cases for component manufacturing also.

[Minimum of 4 to 6 points - 6M.]

Q1. c. Various aspects to be considered before selecting NTM process:

Selection of a right NTM process for manufacturing is dependent on various factors like work material, shape to be produced, accuracy, surface finish etc.

In the current conditions (with existing technology) NTM processes cannot completely replace conventional machining processes. Also many times more than 1 processes can be applicable/suitable for machining a given component.

Following aspects must be studied carefully.

1) Physical parameters or conditions
2) Properties of work material (constituents, initial process, hardness, strength etc.)
3) Accuracy and surface finish requirement
4) Process feasibility
5) " capability
6) Economic considerations

Some specific conditions also have to be considered.

For ex: EDM & ECM can be used for conducting materials.

- AJM is more effective on brittle materials.
- LBM is not effective on Aluminium etc.

Experimental research work and experience with facts play a major role in selecting the right NTM process for the application.

(aspects to be considered with points & ex – 8M)

Q2.a. Classification of NTM processes.

NTM

- Mechanical type
- Electrochemical type
- Chemical type
- Thermal type

P.T.O.

Type of Energy	Mechanism of material removal	Energy Source	Processes
Mechanical	Erosion ~~Shear~~	Pneumatic/ hydraulic pressure ~~Plasy~~	Abrasive jet machining, Ultrasonic machining, Waterjet machining
Electroche--mical	Ion displac--ement	High electric current	Electrochemical machining " grinding " honing " deburring
Chemical	Ablation action by chemicals	Corrosive agent (resists)	chemical machining, " blanking
Thermo electric	Fusion ~~Elec~~	Hot ionised gases ~~Neep~~ Electrons, high voltage	Plasma arc machining Electric discharge machin--ing Travelling wire EDM, EDG
	Vapourisation	Radiations (LASER) Ionised material	Laser beam machining. Plasma arc machining.

(4 classifications $4 \times 1.5M = 6M$)

Q2.b. Advantages of NTM:

1) Hard, brittle materials, super alloys can be machined
2) Heat treated materials can be machined
3) Distortion is minimum
4) Tool wear is less
5) Vibrations are minimum in the process
6) Accuracy, repeatability & surface finish are higher (when used with CNC/PLC controllers)
7) Complex & intricate profiles can be machined
8) Complex fixturing is not required.

Limitations of NTM:

1) These cannot completely replace conventional processes
2) Most of the processes are not suitable for mass production as the cycle time requirement is high
3) Most of these processes require CNC/PLC control (No manual operation)
4) Not all processes are suitable at machining

of all types of materials.

Ex: EDM is not suitable for insulating materials

AJM is not suitable for ductile materials.

Applications of NTM.

1) Machining of difficult to machine materials, superalloys.
2) Die & mould machining – machining of press tools, plastic moulds, die casting dies by EDM, ECM processes.
3) Machining of turbine blades – ECM.
4) Machining of brittle materials like glass & ceramics by AJM & USM.
5) New product development – Automotive sheet metal components can be produced by LBM / WJM in prototype stage (heavy investment on die can be avoided).
6) Deburring & finishing processes – ex: electrochemical deburring, electrochemical grinding / honing.

[Advantages – 3M
Limitations – 3M
Applications – 4M.]

Q2.C. Physical parameters of the NTM Process.

1) Potential (V) - voltage

2) Current (Amp)

3) Power (W)

4) Gap between work & tool (mm)

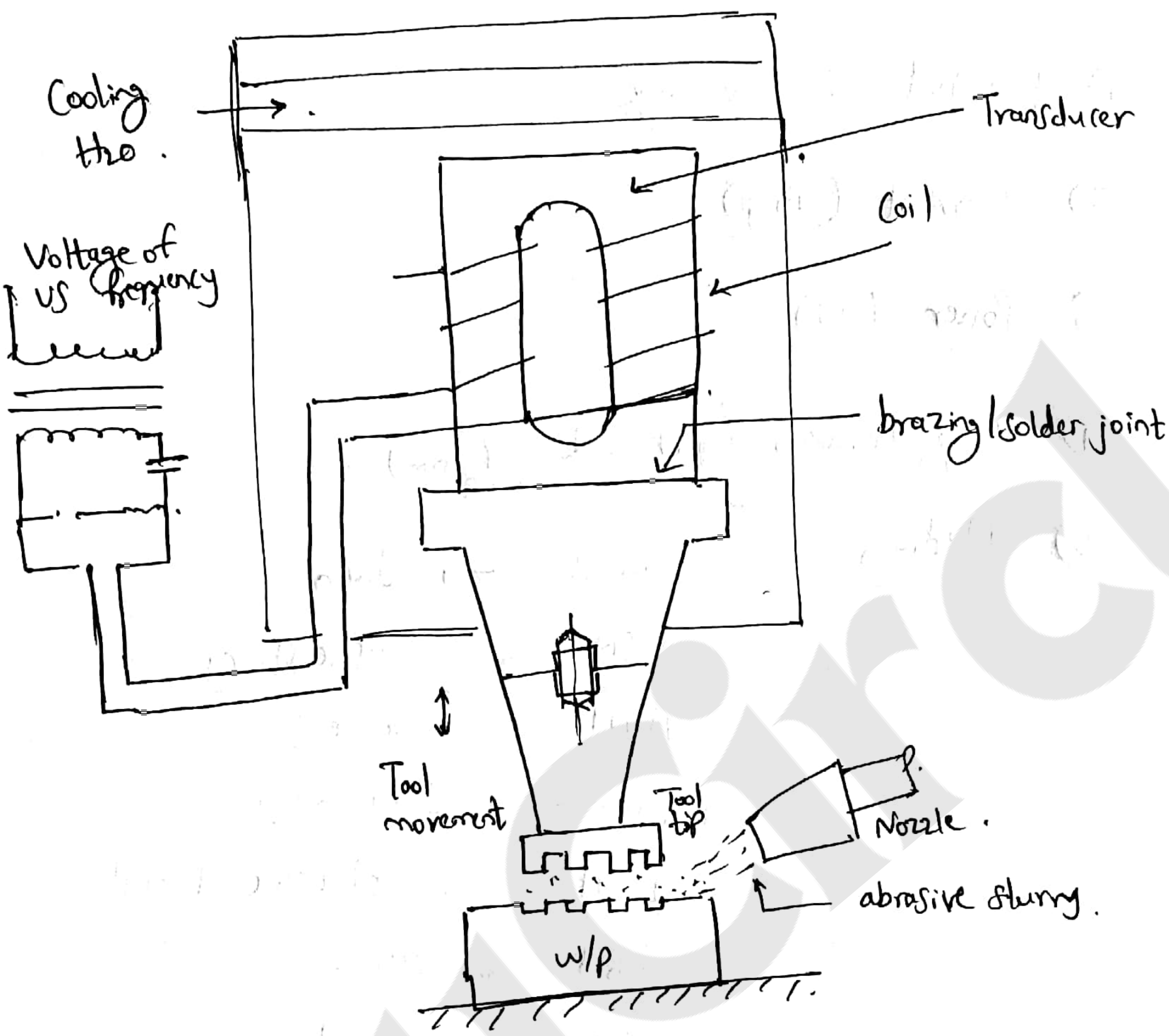
5) Medium -

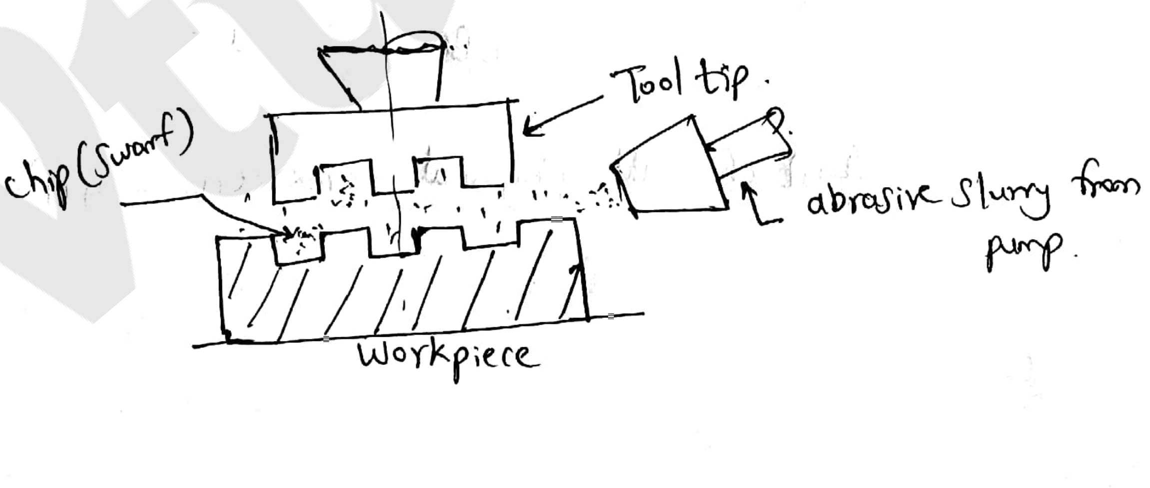
Process	medium
USM	abrasive slurry
AJM	abrasive + gas
ECM	Electrolyte
EDM	Dielectric fluid
EBM	vacuum
PAM	Ar / H_2
LBM	air

(List of all physical parameters - 4M)

Module-2

Q3.a. Ultrasonic machining process:





Ultrasonic machining is a process in which material is removed due to the action of abrasive grains brought about by Ultrasonic vibrations (Vibrations more than 16,000 Hz or 20,000 Hz).

- The set up of USM is as shown in the figure. It consists of tool connected to magnetostrictive or piezoelectric transducer, nozzle to deliver abrasive slurry and work holding arrangements.

- The tool will be -ve replica of the shape to be produced. The tool is made up of soft material oscillated @ frequencies of the order of 20 to 30 KHz, with an amplitude of 0.02 mm.

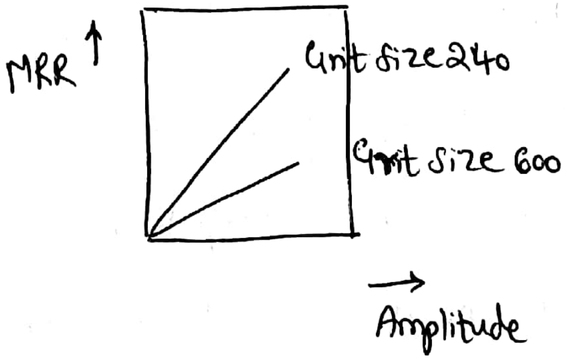
- It is pressed against the w/p with a load of few kg and fed downwards continuously as the cavity is cut in the workpiece. The excitement of the tool is given by means of piezoelectric/magneto-strictive transducer.

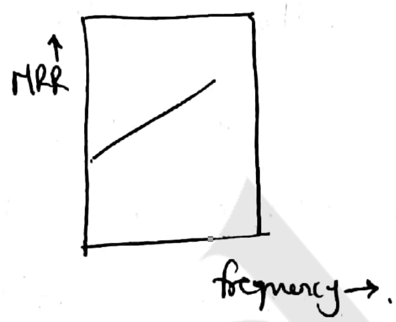
- The slurry which is made up of abrasive particles suspended in the liquid is fed into the cutting zone under pressure.

[Sketch – 5M
Explanation – 5M]

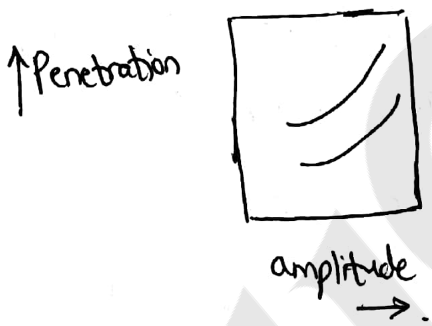
Q3. b. **Process parameters in USM:**

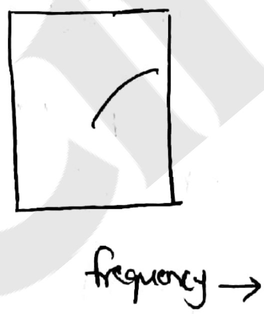
1) Amplitude & frequency of vibrations:





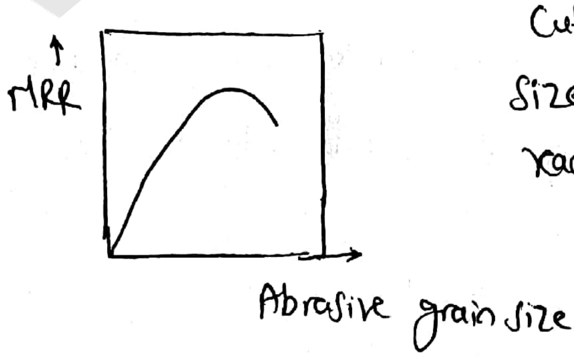
According to research work carried out MRR increases with increase in amplitude and frequency.





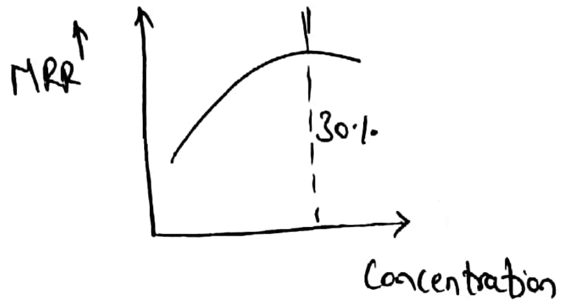
Penetration of the tool increases with increase in amplitude and frequency.

2) Grain diameter:



Cutting rate increases with grain size & then decreases after reaching maximum value.

3) Effect of slurry, tool & work material:



Increase in slurry concentration increases MRR & saturation occurs at 30% to 40% concentration.

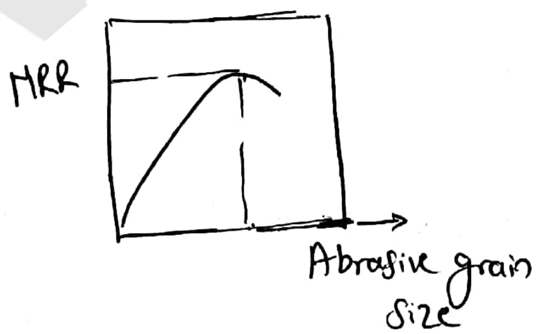
- Shape of the tool also has influence on MRR. For ex: Conical tool has 50% more MRR than equivalent cylindrical tool.

- Hardness / strength of work material has less implications on the process, but still the process is more economical and satisfactory with brittle materials.

[3 parameters X 2M = 6M]

Q3. c. Process characteristics of USM:

1) Material removal rate.



MRR increases with abrasive grain size (upto optimum value).

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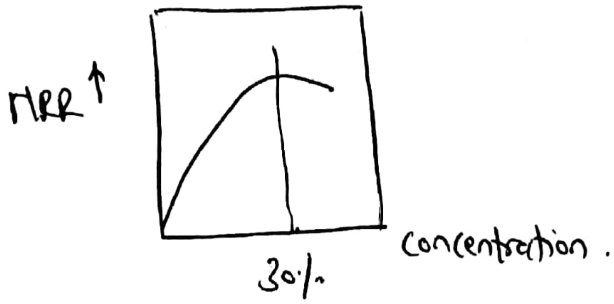

MRR increases with concentration upto 30% optimum value.

- Boron carbide has highest MRR.

2) Tool wear : Tool wear ratio = $\frac{\text{Volume of material removed from w/p}}{\text{Volume of material eroded from tool}}$.

3) Accuracy: Accuracy (size) is influenced by grit of the abrasive. Use of 2 or more tools / sequency is recommended.

Stage 1 : undersize tool, high frequency, coarse grit
Stage 2 : " " finer grit
Stage 3 : full size tool, low frequency, very fine grit

4) Surface finish: SF in USM depends upon size of abrasive particles, work materials, tool amplitude and slurry circulation.

[4 characteristics × 1M = 4M]

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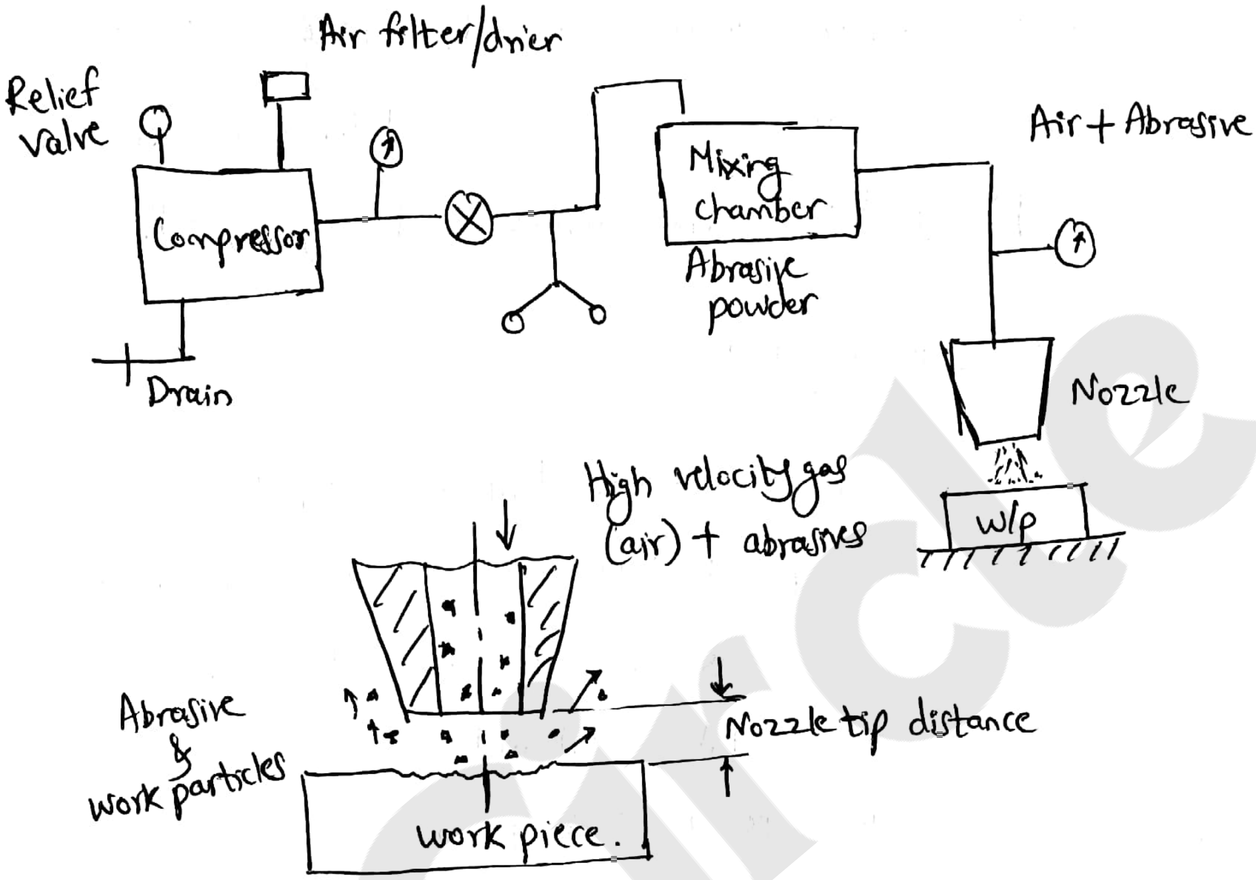
Q4. a. Abrasive Jet Machining :



- Figure shows schematic layout of AJM. It consists of compressor, mixing chamber, ~~and~~ nozzle and set of gauges and valves.
- Filtered gas is supplied under pressure to the mixing chamber, ~~nozzle and set of gauges & valves.~~ containing the abrasive powder and vibrating at 50 cycles/s. Then it is passed into connecting hose. The abrasive and gas mixture emerges from the nozzle at high velocity. This stream is directed by

means of a suitably designed nozzle onto the work surface to be machined. ~~XXX~~ Material removal occurs due to erosion caused by abrasive particles impacting the work surface at high speed.

Advantages of AJM:

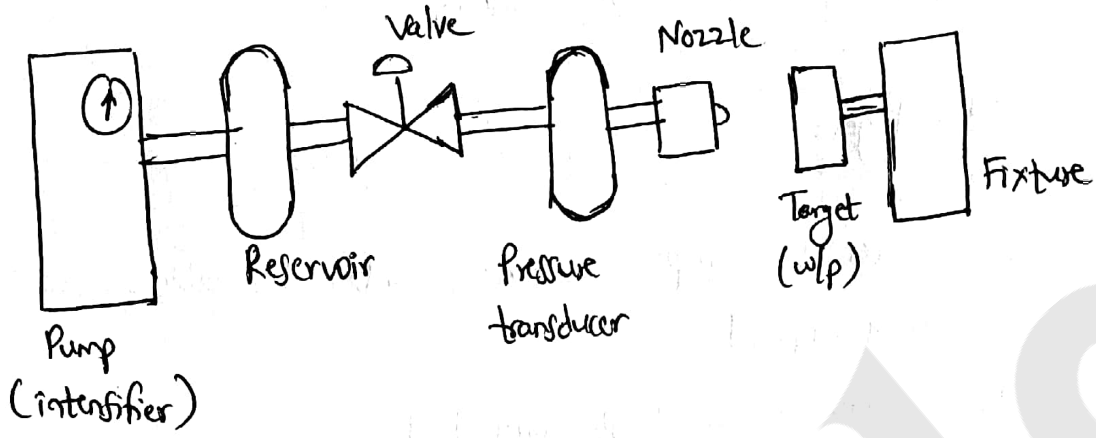
- Ability to machine brittle materials
- Machining of thin sections of brittle materials
- No damage of work ∵ heat generation
- low capital investment
- " power consumption

Applications of AJM:

- Removing flash & parting lines from injection moulded parts
- Deburring & polishing plastic, nylon & teflon components
- Cleaning metallic mould cavities which are difficult to access
- Cutting thin sectioned fragile components made of glass, refractories, ceramics, mica etc.
- Removing paint & glue from paintings & leather objects
- Etching, designing on glass.

[Sketch – 3M   Advantages – 2M
Explanation – 3M   Applications – 2M]

Q4. b. **Water Jet Machining:**



- In water jet machining the jet of water is directed at the target workpiece in such a way that on striking the surface, high velocity flow is virtually stopped, then most of KE of water is converted into pressure energy. Erosion occurs if the local fluid pressures exceed the strength of the bond binding together the materials making up the target.

Sometimes polymer is added to check the divergence of stream coming from nozzle.

- Hydraulic intensifier increases the intensity of pressure of H_2O & supplies it to accumulator (reservoir) Then the high pressure H_2O enters the nozzle through stop-start valve, In the nozzle velocity of the water jet increases & the high velocity stream coming out of the nozzle cuts the workpiece & is then collected in the drain system.

Advantages:

1) Water is cheap, nontoxic, readily available & can be easily disposed.
2) Water jet ≃ single point tool
3) Clean & Sharp cut
4) Contour cutting is possible
5) No heat — ∴ No thermal damage
6) Best suited for explosive environments
7) Dustless atmosphere
8) No moving parts — less maintenance
9) Jet takes away all the cutting residue
10) Fluid can be reused
11) Only small amount of fluid is required.

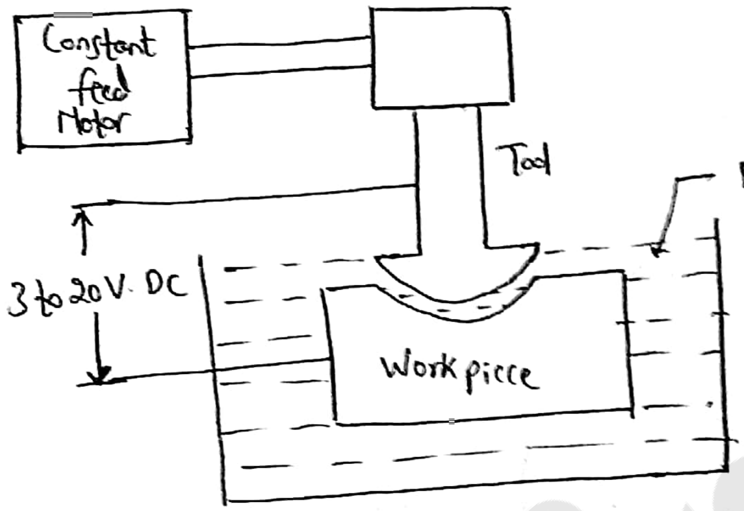
Disadvantages:

1) Corrosive environment
2) blind machining, pocket machining is difficult
3) Sometimes problem of splashing of water
4) Not suitable for workpieces of higher thickness.

[Sketch — 3M
Explanation — 3M
Advantages & disadvantages — 4M]

Module-3

Q5.a. Electrochemical Machining Process:

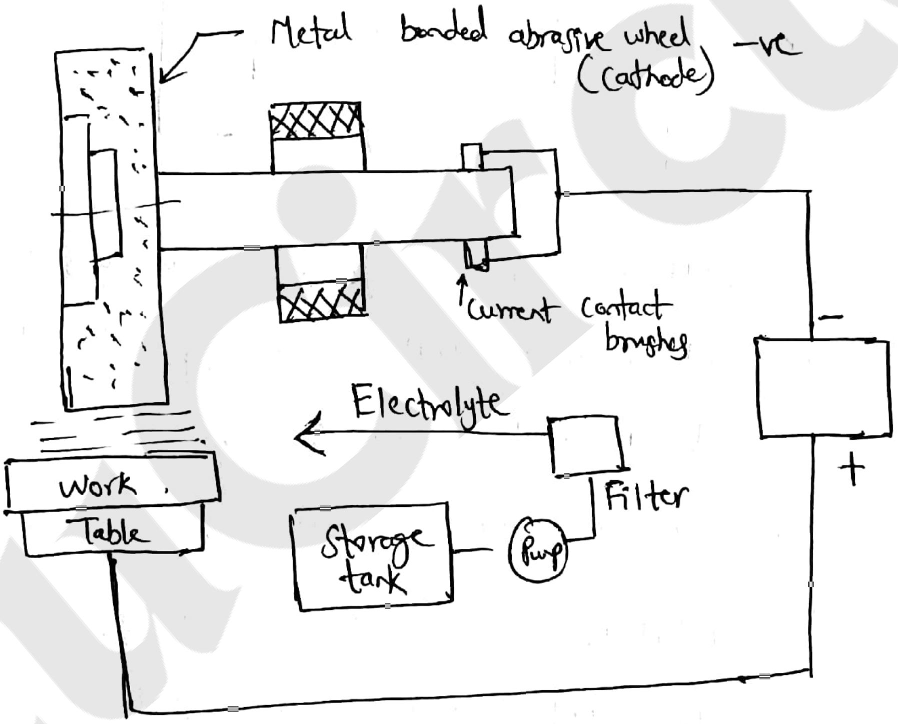


- ECM principle is based on Faraday's law. If 2 electrodes are placed in a bath containing electrolyte & a D.C. potential is applied across them, metal can be depleted from anode & placed on cathode. — Electroplating.
- ECM is reverse of electroplating with some modifications.
- In ECM tool is made cathode & work piece the anode, separated by small distance & are dipped in electrolyte.
- Tool will have same replica of the shape to be produced on workpiece.
- Electrolyte is under continuous circulation.

- Electrolyte is such chosen that constituents of work material go into the solution by electrolytic process, but do not plate on to the tool.

[Sketch – 4M
Explanation – 6M]

Q5. b. Electrochemical Grinding:



ECG uses a grinding wheel in which insulating abrasive is set in conducting metal bonding material.
Work is made anode & GW cathode.
Brushes are used on the GW spindle for the supply of current into the spindle & then to grinding wheel.

The region b/w w/p & GW is flooded with electrolyte. W/P is anode & GW is cathode. The insulating abrasive particles in the GW protrude evenly above the wheel surface.

DC voltage used – 5 to 15 V

Current densities 2 to 3 A/cm2.

Material removal

mostly ← → little %

electrochemical action

mechanical action of abrasives.

[Sketch – 3M
Explanation – 3M]

Q5.C. ECM Process parameters:

1) Current density, $S = \dfrac{\text{Voltage}}{\text{resistance} \times \text{area}}$

Increases material removal rate.

2) Tool feed rate: It is the rate at which the tool penetrates inside the work material (mm/min)

High feed rate → higher MRR

– reduces equilibrium machining gap – surface finish improves.

3) <u>Gap b/w tool & workpiece</u>

Stable gap b/w tool & w/p is known as equilibrium machining gap & this decides accuracy & surface finish. This equilibrium gap is maintained by constant tool feed mechanism - servo control.

4) <u>Velocity</u> of the electrolyte decides rate of reaction, MRR, accuracy & surface finish. It is decided by pump capacity, tubing & nozzle design.

5) <u>Type of electrolyte:</u>

Type of electrolyte, concentration of electrolyte, temperature & pressure of electrolyte also decide MRR, accuracy & surface finish.

Electrolytes used - NaCl in water, $NaNO_3$ in water, KCl / KNO_3 in water etc.

[List of ECM process parameters & briefing - 4M]

Q6. a. Chemical Machining [Elements of the process]

i) Maskants: Maskants or resists are the materials which are used to cover the area of the workpiece where material is not to be removed in chemical machining. These protect the areas covered under them with attack of acid/alkali.

a) Cut & peel type resists are applied to entire area by spray/dip methods then cut from the areas to be etched.

b) Photographic resists - when exposed through high contrast -ve, the materials can produce +ve or -ve image of the original image.

c) Screen resists are the materials which can be used on the workpiece through silk screening technique.

ii) Etchant: The basic function of an etchant is to convert a material (metal) into metallic salt that can be dissolved in the etchant and thus removed from the work surface.

Factors for selection of etchant:

1) Material to be etched

2) Type of maskant used

3) Depth of etch

4) Surface finish required

5) Potential damage to metallurgical properties of work

6) Rate of material removal

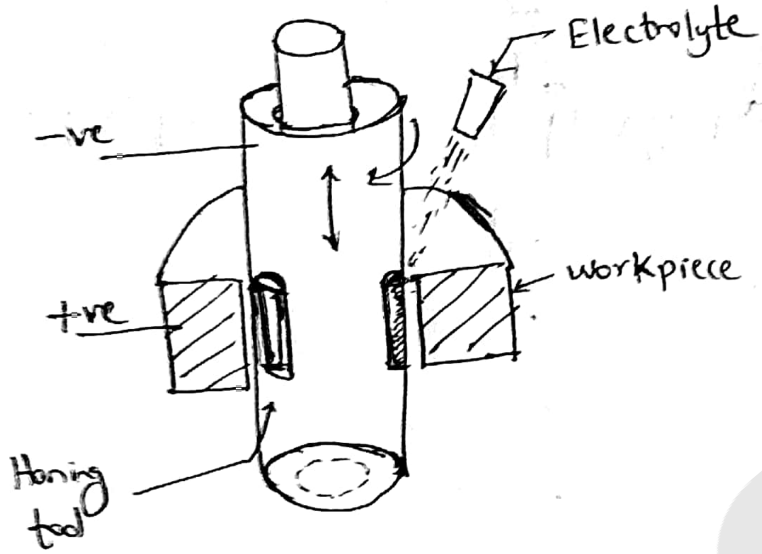
7) economics.

[Maskants – 3M

Etchants – 3M]

Q6. b.

Electrochemical Honing.



Electrochemical Honing consists of rotating & reciprocating tool inside the cylindrical component. The electrolyte is fed under pressure through the holes in the tool so that uniform flow & velocity is maintained.

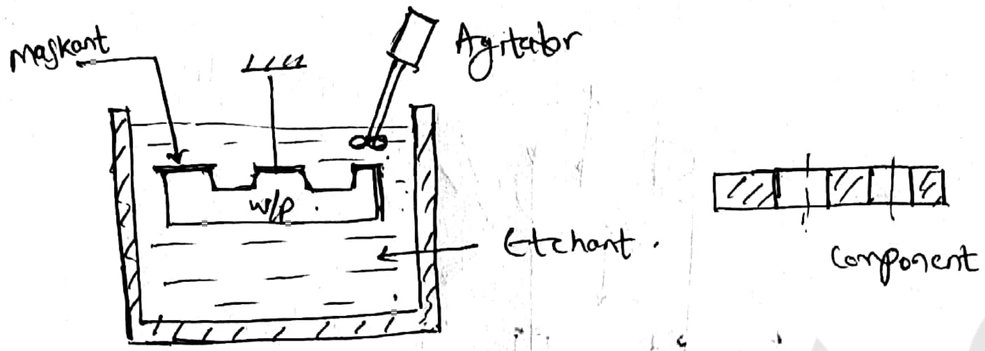
The gap b/w tool & w/p is adjusted by the use of expanding tool. Bonded abrasive honing stones are forced out with equal pressure in all directions from slots in the tool.

The stones are non conductive & assist in electrochemical action. They also abrade the residue in the operation. Accuracy of 0.01 mm & surface finish of 0.1 to 0.5 μ CLA are obtained.

[Sketch - 3M Explanation - 3M]

Q6.c.

Chemical blanking:



Chemical blanking is used mainly on thin sheets, foils & thin workpieces.

Process steps:

Preparation of w/p: cleaning, degreasing, acid pickling.

↓

Preparation of masters
- prepare artwork/negatives
- reducing to actual size
- multiple image masters

↓

Masking with photo resists
dipping / spray coating

↓

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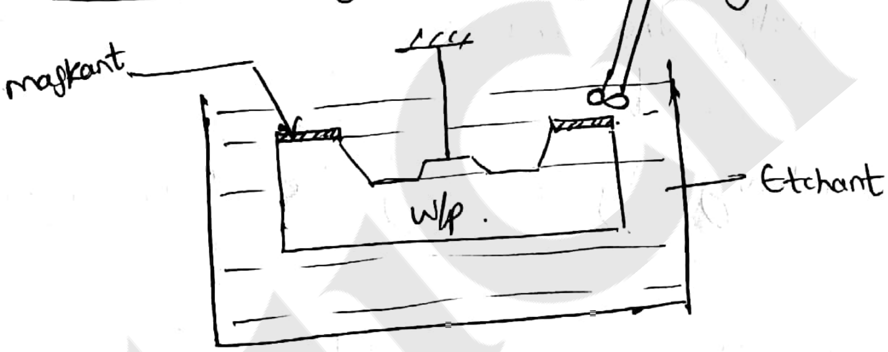
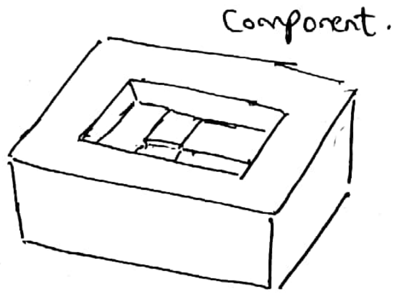
Etching for blanking.

Here w/p is immersed in bath containing etchants for suitable time. Metal is converted into metallic salt, which is dissolved in the etchant.

Applications: manufacture of burrfree stampings, laminations for electric motors, camera parts, fine screens etc.

Chemical Milling:





Chemical milling is used mainly to produce 3-dimensional shapes by selective or overall removal of metal, from relatively large surface area. Here shallow & complex profiles can be produced.

Process steps:

Preparation of workpiece

- clean, degrease, pickling, rinsing

↓

Preparation of tools (templates / -ves)

↓

Masking (dipping / spraying / brushing etc.)

↓

Dry & curing of maskant

↓

Expose areas for etching by peeling the maskant

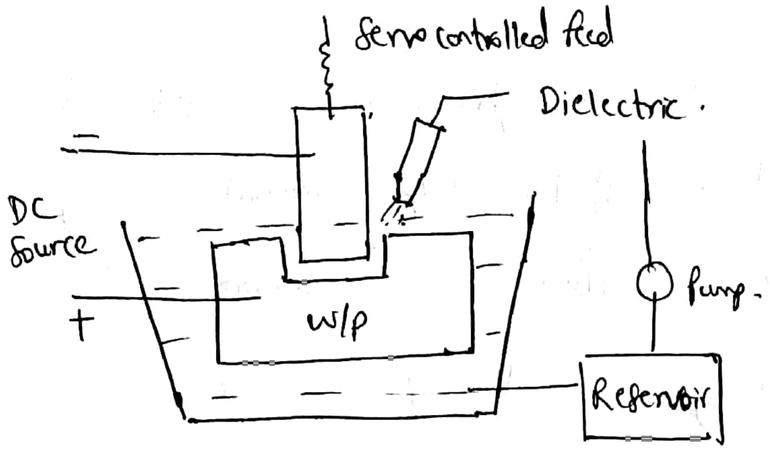
↓

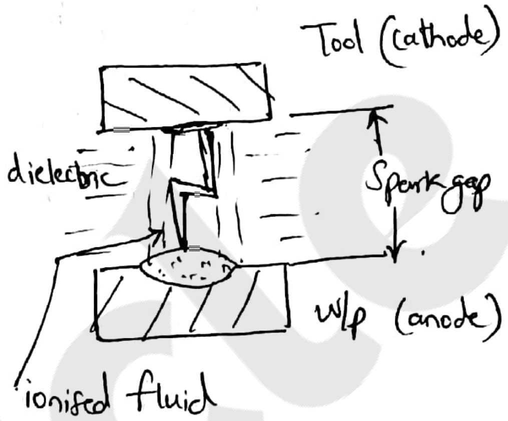
Etching by immersing the w/p in etchant.

[Chemical blanking – 4M
Chemical milling – 4M.]

Module-4

Q.7.a. **Electrical discharge machining process.**





- In EDM process, the tool will have replica shape of that required on the workpiece. Tool is made the cathode & workpiece the anode.

- Both are separated by small gap (0.01 to 0.5 mm) known as spark gap. The arrangement is either flooded or immersed under dielectric fluid.

EDM involves controlled erosion of w/p by initiation of rapid & repetitive spark discharge b/w tool & workpiece.

The spark discharge is produced by the controlled pulsing of direct current b/w workpiece & tool.

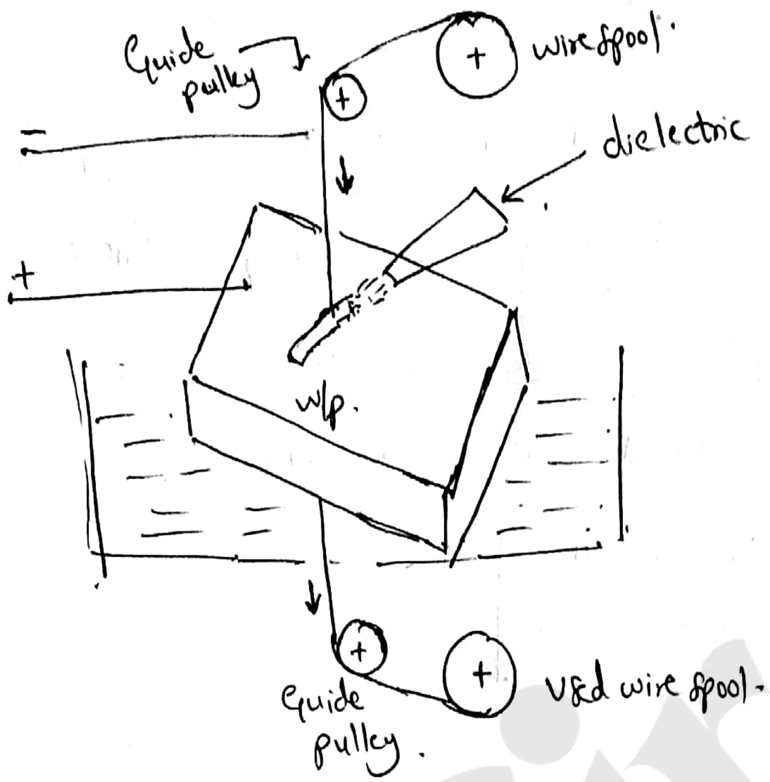
The dielectric fluid in the spark gap is ionised, thus enabling spark discharge to pass b/w the tool and workpiece.

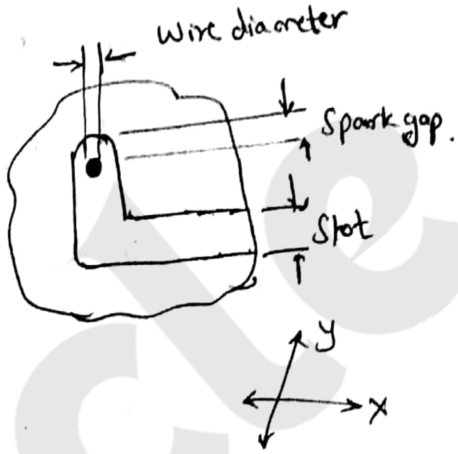
Each spark produces enough heat to melt and vaporise tiny volume of the w/p material leaving small crater on its surface. The liberation of energy accompanying the discharge leads to the generation of extremely high temperature (8000°c to 12,000°c) which can melt & vapourise any material locally.

[Sketch - 3M

Explanation - 5M]

Q7.b. Travelling wire EDM Process:





In travelling wire EDM, the wire is used as electrode (||| to EDM principle) to produce through intricate shapes in the components.

- Here the wire (brass wire) is made cathode & workpiece the anode. Arrangement is immersed in dielectric & flooded with dielectric.

- First a hole is drilled in the w/p, then the wire is passed into it. Wire is continuously under movement (feed movement) to initiate sparks across the thickness of component.

Workpiece is given X, Y movements with the help of NC/CNC control.

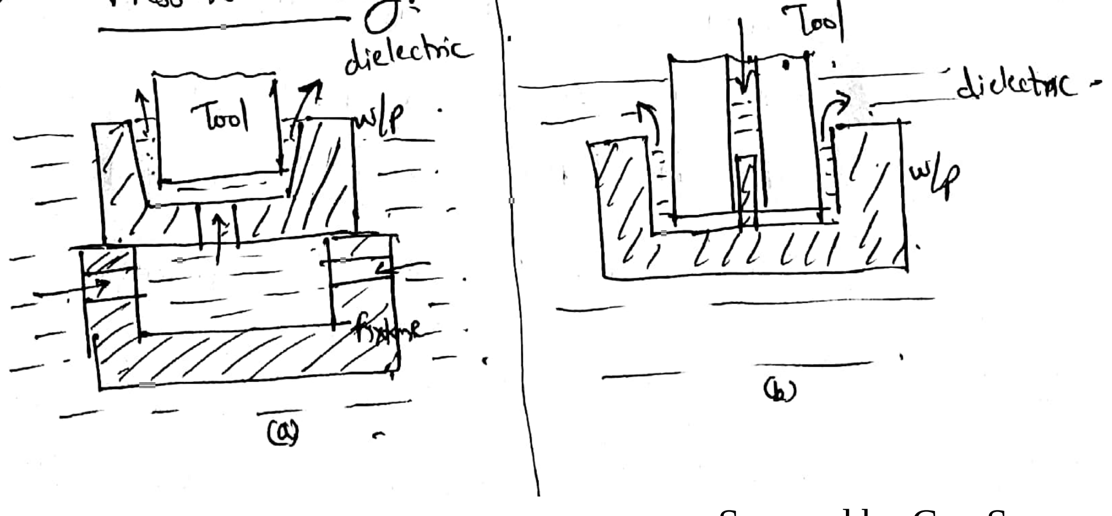
Travelling wire EDM or wire cut machining process is extensively used to produce through intricate profiles in blanking dies, components, extrusions & wire drawing dies. Accuracy of ±0.01 mm can be obtained.

[Sketch - 3M
Explanation - 3M]

Q7.C. Dielectric flow patterns in EDM:

- Pressure flushing
- Suction flushing
- Side flushing
- Flushing by dielectric pumping

1) Pressure flushing:

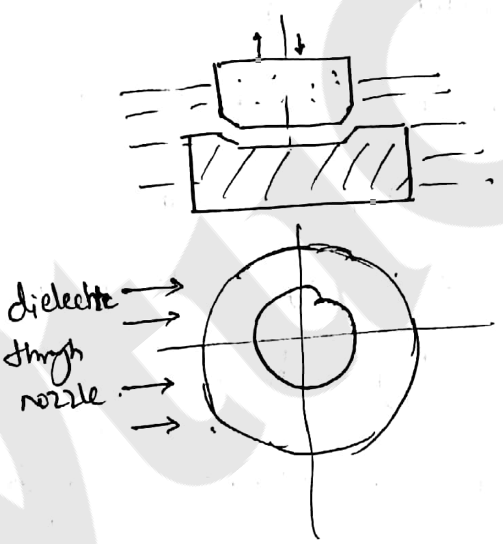


In pressure flushing, the dielectric fluid is injected under pressure through the hole in the workpiece (fig a) or through the ~~for~~ hole in the tool (fig b) whichever is permissible.

Pressure : 1.5 to 2 kg/cm2.

Components machined using this method are slightly tapered (∵ of particles being forced up the sides of electrode producing lateral discharges).

2) <u>Side flushing</u>:



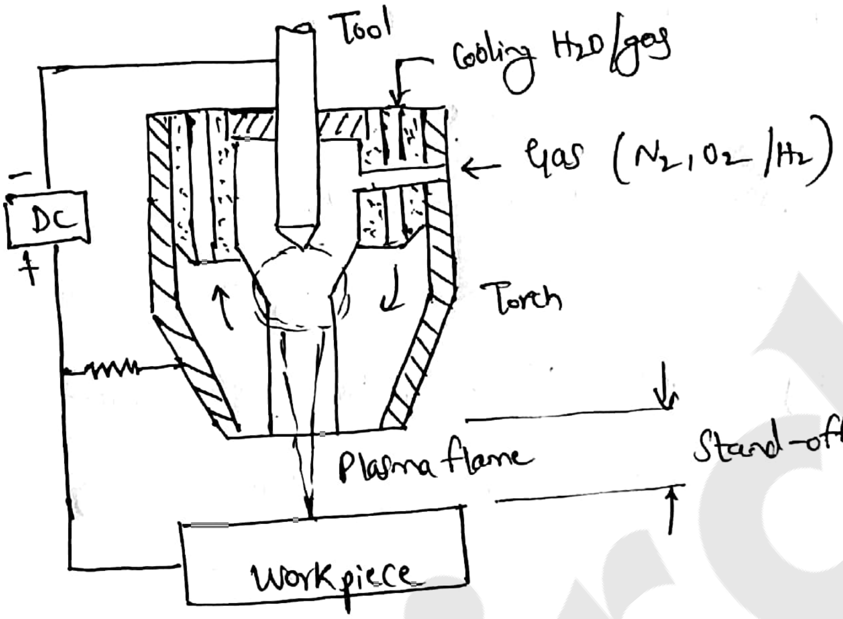
In this method dielectric fluid is fed through nozzles which are carefully placed so that entire area is evenly flushed.

This method is used when there is no chance to drill holes in w/p & tool.

This method is used for machining of coining dies or deep narrow slots.

[List of dielectric flow pattern – 1 M.
Sketch & explanation of 2 – 5 M]

Q8. a. Plasma arc machining:



The construction of PAM setup is as shown in the figure. The tool is made cathode & workpiece the anode. In one type of mode, the torch is connected through a resistor to DC supply. Torch houses flow lines for gas & cooling medium.

- The cathode emits the electrons, & high velocity electrons of the arc collide with the gas molecules and produce dissociation of diatomic molecules followed by ionisation of the beam.

The plasma forming gas is forced through the nozzle duct in such a way that it stabilizes the arc. Heating of the gas takes place in constricted region of the nozzle duct, resulting in high exit gas velocity & high temp (16,000°c).

The w/p material gets heated as a result of anodic heating (due to direct bombardment) plus convection heating from high temperature plasma.

The heat produced is sufficient to melt the workpiece material and high velocity gas stream blows the molten metal away.

[Sketch – 4M

Explanation – 6M]

Q 8. b.

PAM process parameters :- can be categorised into :

1) Those associated with the design & operation of the torch

2) " " " " physical configuration of the setup.

3) Environment in which work is performed.

1) Torch :

Plasma torch consists of nonconsumable cathode rod of 2% thoriated tungsten and converging anode nozzle with a suitable orifice. The 2 electrodes are separated by insulator – carbonate resin / rubber

– Gas is fed tangentially or through small ports around the cathode.

Important points : cathode taper @ tip, convergence of anode nozzle, nozzle orifice etc.

~~2) Configuration of the setup~~ (modes of operation) :

- Transferred arc mode
- Non transferred arc mode

- Turbulent mode
- Laminar mode.

2) Physical configuration of setup:

torch stand off distance
torch L/c
depth of cut,
feed &
Speed of the work

} influence volume of metal removed, accuracy & surface finish.

3) Work environment

These variables include any cooling that is done on the cathode, any protective type of atmosphere used to prevent oxidation and any means that might be utilised to spread out / deflect the arc & plasma impingement area.

[PAM parameters - briefing - 5M]

Q8.C. Safety Precautions in PAM:

Plasma flame emits a highly intense beam, particularly strong in UV & IR radiations. These can cause damage to eye (cataract). Also the high temp produced has to be taken care. Exposure to radiations can cause skin burns / cancer etc. Some of the safety precautions are as below:

1) Wearing of proper glasses & dress to cover the body. Glasses should be good at UV & IR cut off.

2) Torch should be operated in airy room with proper exhaust (toxic gases like NO_2 may be present).

3) Ear muffs / plugs ($\because$ of high noise level)

4) Asbestos gloves with inner layer of leather should be worn for operating the torch

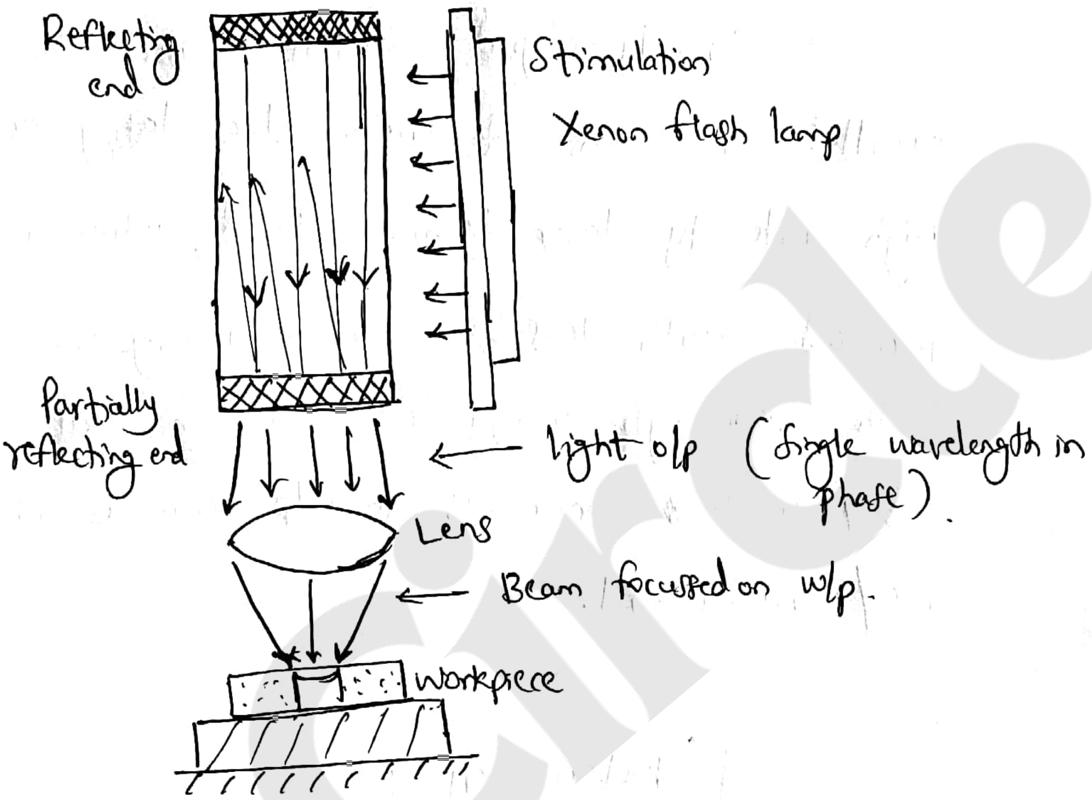
5) For spraying / chemical synthesis — the process should be mechanised.

6) Operators should consult the physicians — regarding the No. of hours of operation / mishappenings.

[Explanation of safety precautions – 5M]

Module- 5

Q9. a. Laser beam machining (LBM)



LBM setup is as shown in the figure. It usually uses gas laser (CO_2) (rarely solid state lasers are used).

CO_2 gas laser uses 3 gases – viz N_2, CO_2 & helium flowing through gas discharge tube.

N_2 functions as an intermediary b/w electrical energy & vibrational energy of CO_2 molecules.

Helium cools the gas mixture so that it can be reused again.

- When electrical discharge energy is generated through these gases (Xenon lamp), photons are generated when CO_2 molecules absorb & emit the energy.

- 2 Properly aligned mirrors direct the randomly emitted radiations to sustain the lasing action & high intensity laser beam is obtained, which is further focussed with lens & made to impinge on w/p.

With very high energy density it can melt any material. X & Y directions movements to w/p can be obtained with NC / CNC control.

[Sketch - 3M
Explanation - 5M]

Q9. b. **Advantages of LBM:**

1) Machining of any material (including non metals) is possible irrespective of their hardness & brittleness
2) Welding, drilling & cutting of inaccessible areas.
3) Heat affected zone is small (0.1mm)
4) Extremely small holes can be machined.
5) No tool wear problems
6) Soft materials like rubber & plastics can be machined.

Limitations of LBM:

1) Its overall efficiency is low 10 to 15%.
2) Depth limitation & low MRR
3) Machined holes are not round & straight.
4) Certain materials like FRP, phenolics & vinyl cannot be machined (∵ these materials burn & char).
5) Effective safety procedures are required.
6) Cost is high.

Applications of LBM:

- Machining of small holes
- Cutting complex profiles
- Sheet metal trimming, blanking, resistor trimming.
  [Especially for new product development.
  Usage of LBM avoids investment on stamping dies].
- Partial cutting, engraving.
- marking of part number on components etc.

[Advantages – 2M, Limitations – 2M, Applications – 2M]

Q9. C. **Process characteristics of LBM.**

* Machining rate: Material removal rate of LBM is comparatively low ($4000 mm^3/hr$).

Cutting rate, $C = k \cdot \dfrac{P}{E A t_1}$.

[for cutting of sheets, matl]

P = laser power

E = Vaporisation energy of material

A = area of laser beam @ focal point

t_1 = thickness of material (mm)

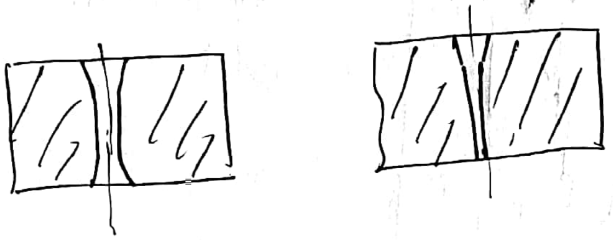
K = constant.

The process can be accelerated, if a gas jet is directed to heated area, by removing melted mass & vapour.

Accuracy:

Accuracy in profile cutting with numerical control is ±0.1 mm.

Holes drilled by laser are not round, Hence while drilling w/p itself is rotated. Taper is also observed in the drilled holes.



Types of taper observed in the drilled holes.

Cutting Speed:

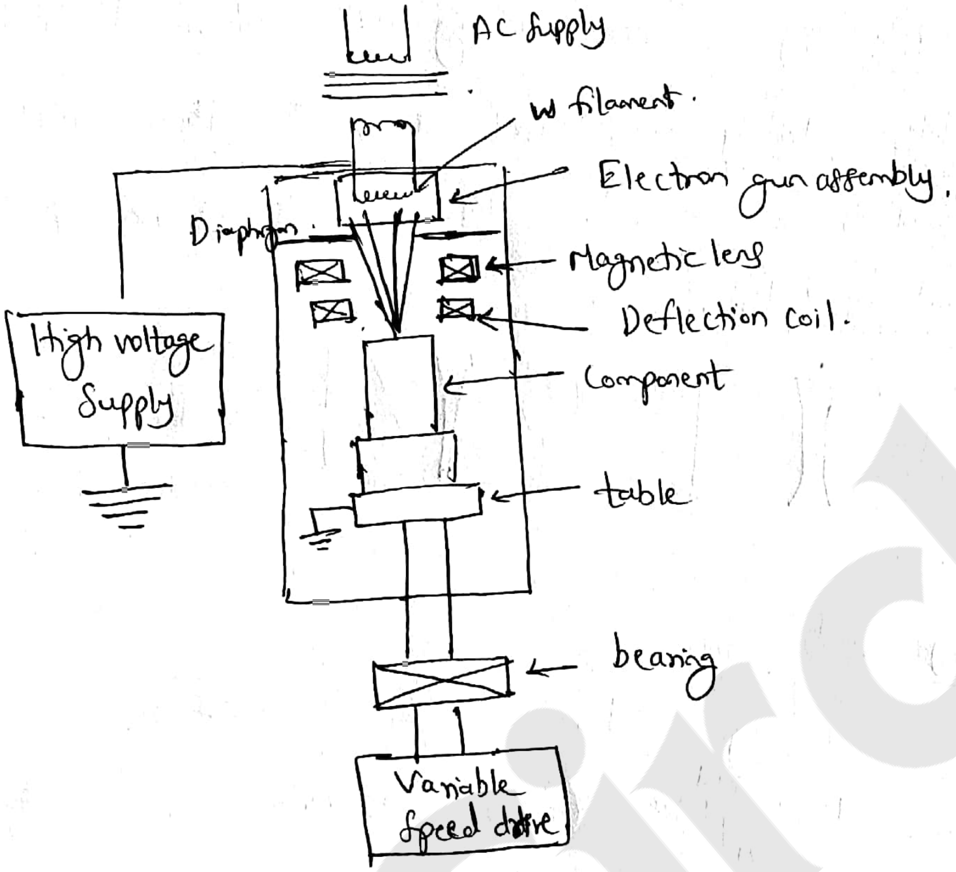
Cutting speed is high for thin sheets.

3 mm thick metal plates can be cut with a speed of 1.5 to 2 m/min.

[Explanation of process characteristics — 6M]

Scanned by CamScanner

Q10.a. Electron beam machining [EBM]



Set up of EBM is as shown in the figure.

Electron beam is generated, accelerated & focussed inside a device called electron gun. Electron gun consists of

* Cathode - Source of electrons
* Grid cup - -vely biased w.r.t. filament
* Anode @ ground potential through which electrons pass.

The beam is generated in vacuum to avoid deflection of electrons & prevent oxidation of emitter.

The beam of electrons is emitted from the tip of hot cathode. It is accelerated towards the anode by the high potential applied b/w anode & cathode. (Flow is controlled by -ve bias).

Magnetic lens will make the electron beam circular in c/s & deflect in anywhere.

Power density as high as billion watts/ cm^2 is attained in the beam. This is sufficient to immediately fuse and vapourise any material on which it falls.

[Sketch - 4M, Explanation - 6M]

Q10 b.

Advantages of EBM:

- Process is not dependent on work material properties (hardness, strength etc).
- All types of materials - metals, ceramics, refractory materials can be cut.
- Accuracy is high [compared to other NTM processes]
- Can machine delicate & consistent shapes.

Limitations:

- Low material removal rate
- High investment cost
- Vacuum requirement.
- Difficulty in focussing electrons.

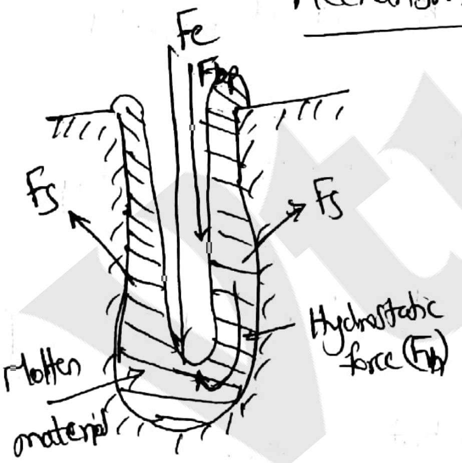
Applications of EBM :

- Cutting & welding of materials
- machining of all types of materials - Al, Cu alloys, Carbides, Ti, Ta, Ceramics, alloy steel, glass, W, Zr etc.
- Cutting of delicate & intricate shapes.
- drilling apertures of electronic microscope, drilling in ruby crystals.

[Advantages - 2M, Limitations - 2M, Applications - 2M]

Q10. C. **Need of EBM:** A process which overcomes limitations of other NTM processes & conventional processes - like machining of all types of materials - metals, ceramics, refractory etc. & machining to a higher accuracy & surface finish with very little heat affected zone.

Mechanism of material removal in EBM process:



High Power density electron beam (billion W/cm²) is focussed on w/p - this can melt & vapourise any material (locally).

Different forces which may be seen in EBM :

(a) Force due to electron pressure (Fe)

(b) Force due to back pressure of evaporating atoms (Fbp)

(c) Surface tension force (Fs)

(d) Hydrostatic force (Fh)

H.O.D. (Mechanical Engg)

[Need of EBM - 1M.
Mechanism of material removal in EBM - 3M.]

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