CBCS SCHEME

BME405A

Fourth Semester B.E./B.Tech. Degree Examination, June/July 2025

Non Traditional Machining

Max. Marks: 100

***Note:** 1. Answer any FIVE full questions, choosing ONE full question from each module.*
2. M : Marks , L: Bloom's level , C: Course outcomes.

		Module – 1	M	L	C
Q.1	a.	Define Non-traditional Machining process. Also give the classification of non-traditional machining process based on different energy sources.	10	L1	CO1
	b.	Explain the need for non-traditional machining process.	10	L2	CO1
		OR			
Q.2	a.	Explain the selection of non-traditional machining process.	08	L2	CO2
	b.	What are the specific advantages , disadvantages and applications of non-traditional machining process.	12	L2	CO2
		Module – 2			
Q.3	a.	Write a neat sketch of Ultrasonic Machining (USM) process and label the important parts. Also explain principle of working.	12	L2	CO2
	b.	Discuss the process characteristics like material removal rate, tool wear, accuracy and surface finish of USM.	08	L2	CO3
		OR			
Q.4	a.	With a neat sketch explain working principle of Abrasive Jet Machining process.	12	L2	CO2
	b.	Explain the process variables in Abrasive Jet Machining process.	08	L1	CO2
		Module – 3			
Q.5	a.	With a neat sketch explain principle of working of Electro Chemical Machining process (ECM).	12	L2	CO2
	b.	Explain the process parameters of ECM like current density, tool feed rate, gap between tool and workpiece, flow rate of electrolyte.	08	L1	CO2
		OR			
Q.6	a.	With a neat sketch explain electrochemical honing process, also write advantages and limitations of the process.	08	L2	CO2
	b.	Explain the following with respect to chemical machining process: i) Chemical blanking process ii) Chemical Milling process	12	L2	CO2
		Module – 4			
Q.7	a.	With a neat sketch explain mechanism of metal removal in EDM process.	12	L1	CO4
	b.	What is Dielectric Fluid? Explain the desirable properties of a dielectric fluid medium used in EDM process. Also list the different dielectric fluids.	08	L2	CO4
		OR			
Q.8	a.	With a sketch explain working of Plasma Arc Machining process (PAM).	10	L2	CO4
	b.	Explain the safety precaution in PAM.	06	L2	CO4
	c.	Write the applications of EDM process.	04	L2	CO4
		Module – 5			
Q.9	a.	With a help of neat sketch explain working principle of Laser Beam Machining process (LBM).	12	L2	CO2
	b.	What are the advantages , limitations and applications of LBM.	08	L1	CO2
		OR			
Q.10	a.	With a neat sketch explain Electron Beam Machining process (EBM).	12	L2	CO2
	b.	What are the advantages , limitations and applications of EBM.	08	L1	CO2

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VTU QUESTION PAPER SOLUTIONS [June/July 2025]

SUBJECT : NON TRADITIONAL MACHINING [BME405A]

Q 1. a) **DEFINITION OF NON-TRADITIONAL MACHINING :**

Non-traditional machining is the process defined as a group of processes that remove excess material by various techniques involving mechanical, thermal, electrical and chemical energy or combination of all these energies, but donot use a sharp cutting tool unlike in traditional machining process.

CLASSIFICATION OF NON-TRADITIONAL MACHINING PROCESS BASED ON DIFFERENT ENERGY SOURCES :

The classification is as follows:

1. MECHANICAL ENERGY:
   - Abrasive jet machining
   - Ultrasonic machining
   - Water jet machining
2. ELECTROCHEMICAL ENERGY:
   - Electrochemical Machining

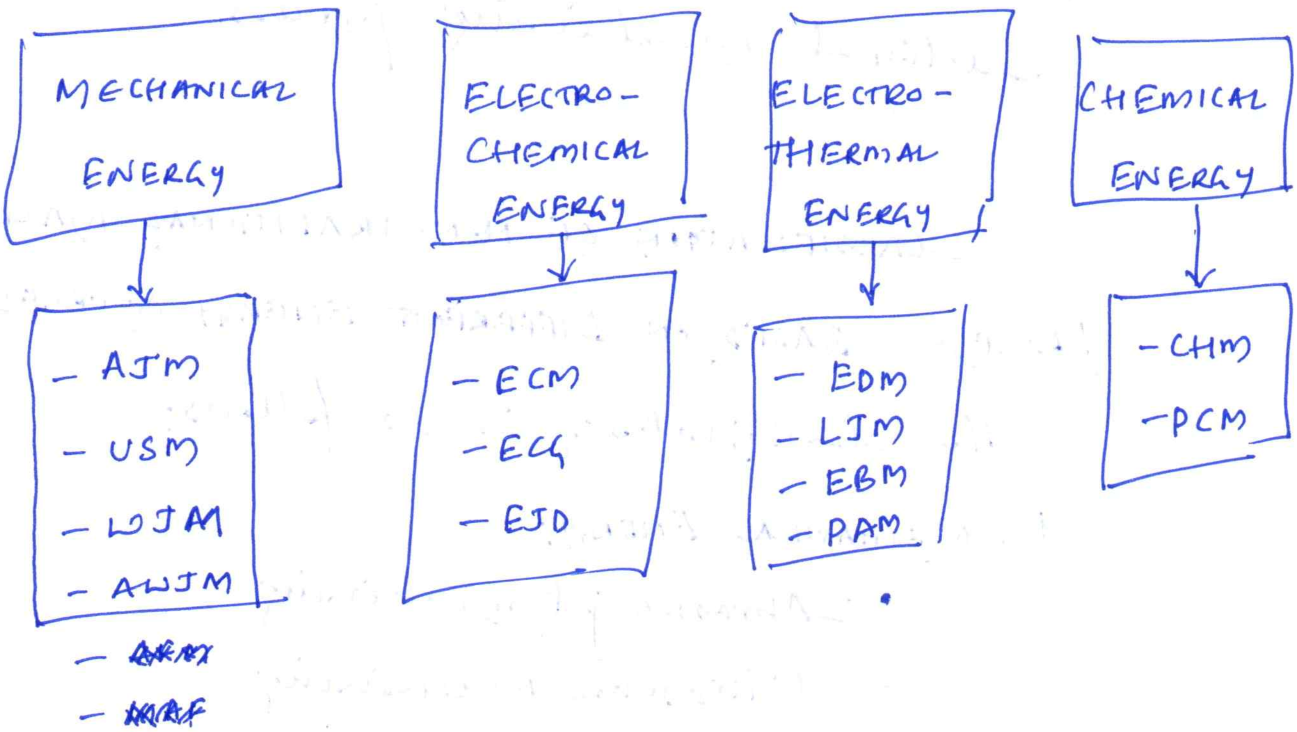
- Electrochemical Grinding
- Electrojet Drilling.

3. ELECTRO-THERMAL ENERGY:

- Electrodischarge Machining
- Laser Jet Machining
- Electron Beam Machining
- Plasma Arc Machining

4. CHEMICAL ENERGY:

- Chemical Milling
- Photo-chemical Milling



Q. 1. (b) NEED OF NON-TRADITIONAL MACHINING PROCESS

The development of harder and difficult to machine products (metals) and alloys has resulted in usage of Non-traditional machining process. Conventional edged tool machining is uneconomical for such materials and degree of accuracy and surface finish attainable is poor. The advancing strength levels would have a catastrophic effect on total machine tool. So, the newer concepts started developing in metal machining. By adopting a unified program and utilizing the results of basic and applied research, it has now become possible to process some unmachinable materials. The following points justify the needs of NTM:

i.) Technically advanced industries like aerospace, nuclear power, wafer fabrication has ever increasing use of High strength temperature resistant (HSTR) alloys and other difficult to machine materials like titaniums, SST, ceramics and semiconductors.

ii) Production & processing parts of complicated Shapes (in HSTR and other hard to machine alloys) is difficult and time consuming

iii) Innovative geometric design of products and components made of new exotic materials with desired tolerances, surface finish can't be produced economically.

Q. 2. (a) SELECTION OF NON-TRADITIONAL MACHINING PROCESS :

The correct selection of non-traditional machining method must be based on following aspects:

i) Physical parameters of process
ii) Shape to be machined.
iii) Process capability
iv) Economics of process

i) Physical Parameters: Following are the parameters to be counted.

PARAMETERS	USM	AJM	CHM	ECM	EDM	EBM	LBM	PAM
POTENTIAL (VOLTS)	220	220	–	10-30	100-300	150kV	4.5kv	100
CURRENT (Amps)	12	1	–	10,000	50	0.001	2	500
POWER (kW)	2.4	0.22	–	100	2.7	0.15	–	50
GAP (mm.)	0.25	0.75	–	0.2	0.025	100	150	7.5

EDM and USM require medium power whereas, PAM & ECM require high power. EBM can be used in vacuum and PAM uses oxygen and hydrogen gas.

ii) Shape of Material: The different shapes can be machined by NTM, EBM & LBM are used for microdrilling and cutting. USM & EDM are useful for cavity sinking and standard hole drilling.

iii) Process Capability: The process capability is the measure of process ability to achieve the design model.

Q. 2 (b)

SPECIFIC ADVANTAGES OF NON-TRADITIONAL MACHINING PROCESS

i) It provides high accuracy & surface finish

ii) No physical tool is used, hence, no wear of tool occurs.

iii) No generation of chips as microscopic chips

iv) These are quiter in operation.

v) It can be easily automated.

vi) It can machine any complex shape.

vii) This process has an advantage of machining hard and brittle materials.

viii) The machines have no high speed moving parts.

ix) Working on machines of NTM is not hazardous.

x) Considerable economy may be achieved in non-traditional machining.

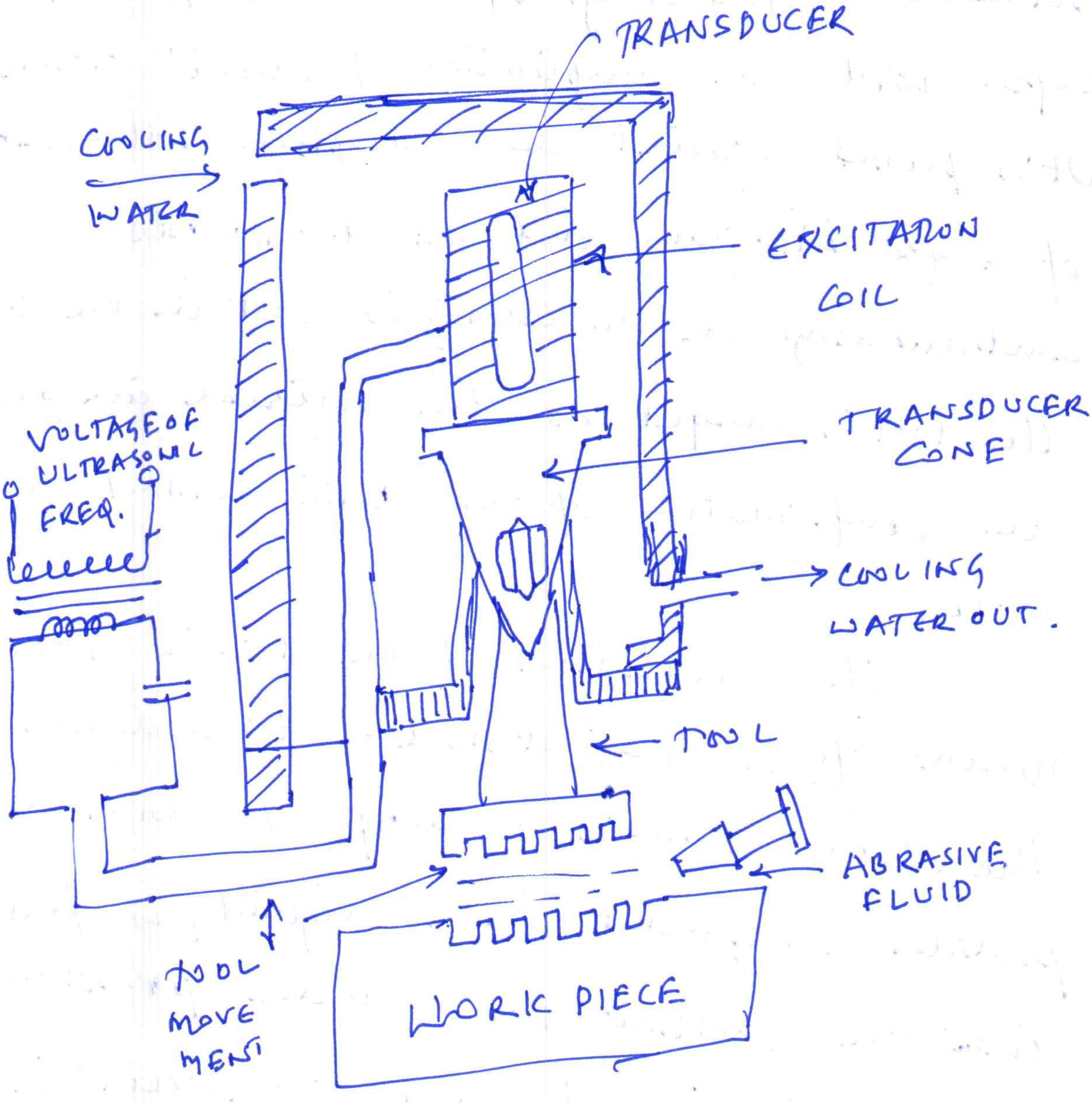
DISADVANTAGES:

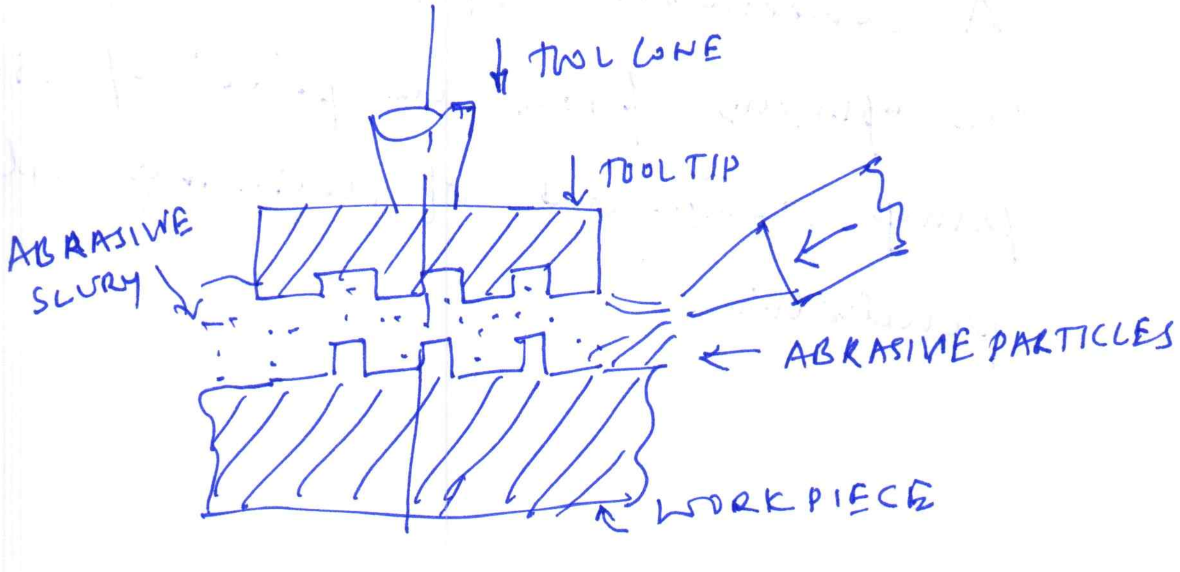
1. High initial cost for setup.
2. Highly skilled labour requirement.
3. Lower metal removal rate.
4. More power required for machining.
5. It is not economical for bulk production.
6. The process usually employed in electrically conductive materials.
7. The overall speed of machining is slow as compared to conventional machining.
8. Unwanted erosion or overcutting of the metal may take place.
9. High maintenance cost.
10. Thick parts can't be economical to cut.

APPLICATIONS:

1. Tungsten and other hard carbides and gem stones being successfully machined.
2. NTM process are suitable make holes in curved axis
3. Small holes of size 0.05 mm may be machined.
4. Burrfree machining.
5. Facing & turning of complex shapes is possible.

Q. 3 (a) ULTRASONIC MACHINING (USM)





PRINCIPLE OF WORKING:

The tool is made up of soft material oscillated at frequency of the order of 20 to 30 kcps. with an amplitude of about 0.02 mm. It is pressed against the workpiece with a load of a few kilograms and fed downwards continuously as the cavity is cut in the work the tool is shaped as the mirror image of the configuration of the cavity desired in the work.

The excitation of the tool is given by means of a magnetostrictive transducer. The slurry which is madeup of abrasive particles suspended in a liquid, is fed into the cutting zone under pressure. A concentration of about 30 percent is the optimum from the point of view of pump design and of achieving adequate penetration.

Q 3 (b) PROCESS CHARACTERISTICS OF USM:

i) Material Removal Rate
ii) Tool wear
iii) Accuracy
iv) Surface finish.

i) Material Removal Rate (MRR): For deriving the expression for MRR, the following assumptions are made:

a) Cutting involves plastic flow of material.
b) Abrasive particles are cubes of side d.
c) All particles under the tool cut effectively.

$$V = v(PD)(TN)(WHR)(VC)(CR)(T)$$

where, V = Volume rate of mrr.

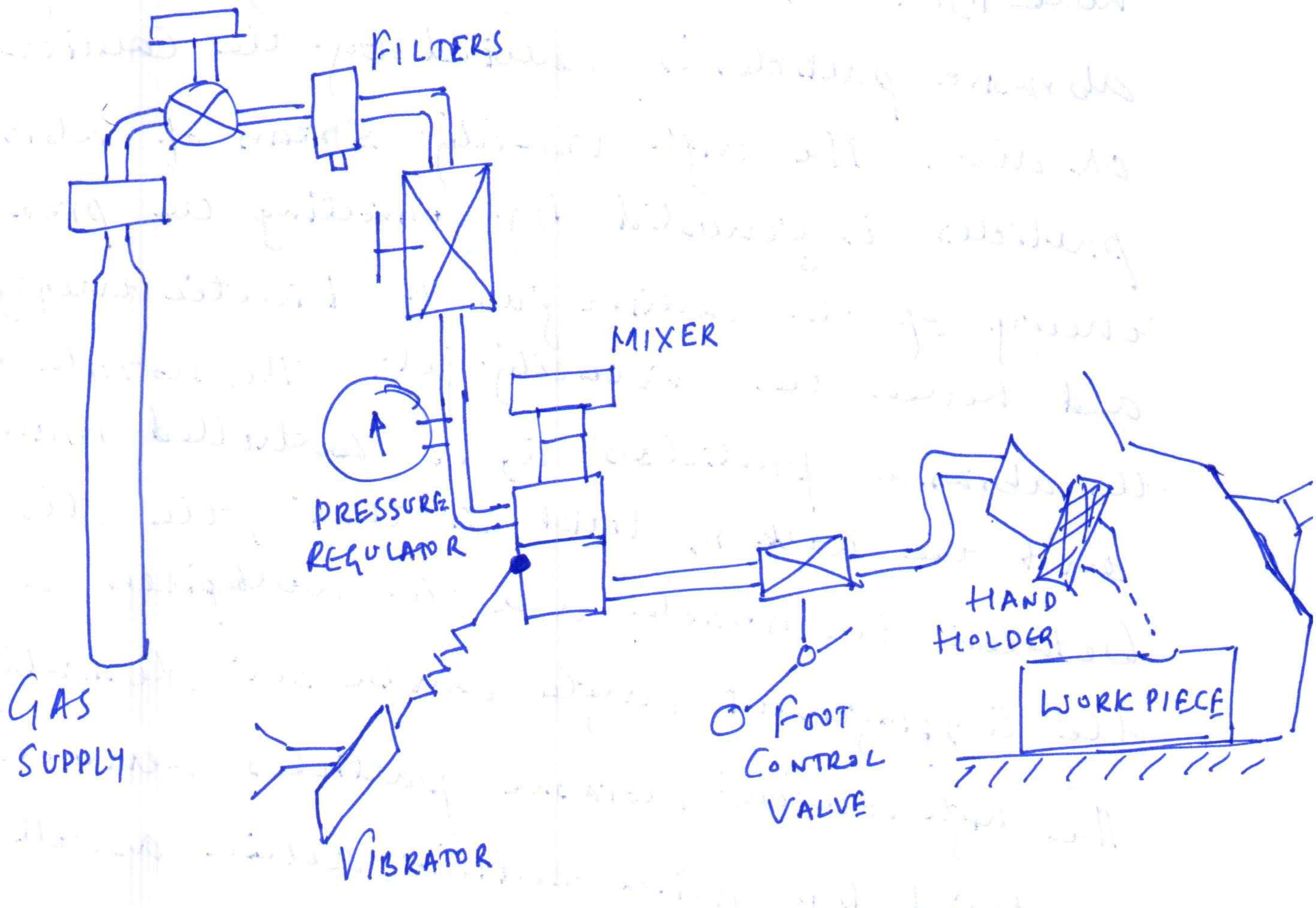
v = Function
PD = Plastic deformation
TN = No. of Abrasive particles.
WHR = Work Hardening
VC = Volume of work material chipped.
CR = Blow rate
T = Rate of flow of abrasive particles.

ii) Tool Wear: Tool wear is an important factor in ultrasonic machining. It has a large impact on the material removal process and hence influences the machining performance. It was found that tool materials having high flexibility shown the wear of the abrasive and thus improved machining efficiency.

iii) ACCURACY: It refers to the degree of closeness of measured dimension to the true dimension. It is also referred as degree of conformity. USM is a non-thermal process, so machined surface doesnot contain any undesired effects like recast layer, heat affected zone etc.

iv) SURFACE FINISH: Surface finish in USM refers to the nature of machined surface. This is defined by three characteristics: i) Lay, ii) Surface roughness and iii) waviness. The abrasive grain size is the main factor that governs the surface finish.

Q 4. (a) ABRASIVE JET MACHINING (AJM)



EQUIPMENT OF AJM.

WORKING PRINCIPLE OF ABRASIVE JET MACHINING:

In abrasive jet machining (AJM) the abrasive particles are made to impinge on the work material at a high velocity. The jet of abrasive particles is carried by the carrier gas or air. The high velocity stream of abrasive particles is generated by converting the pressure energy of the carrier gas to kinetic energy and hence the velocity jet. The nozzle directs the abrasive particles in a controlled manner on to the work material so that, the distance between the nozzle and the workpiece and the impingement angle can be set desirably. The high velocity abrasive particles remove the material by micro-cutting action as well as brittle fracture of the work material.

In AJM, air is compressed in an air compressor at a pressure around 5 bar is used as a carrier gas. Gases like CO_2, N_2 can be used as carrier gases.

Q. 4 (b) PROCESS VARIABLES IN ABRASIVE JET MACHINING

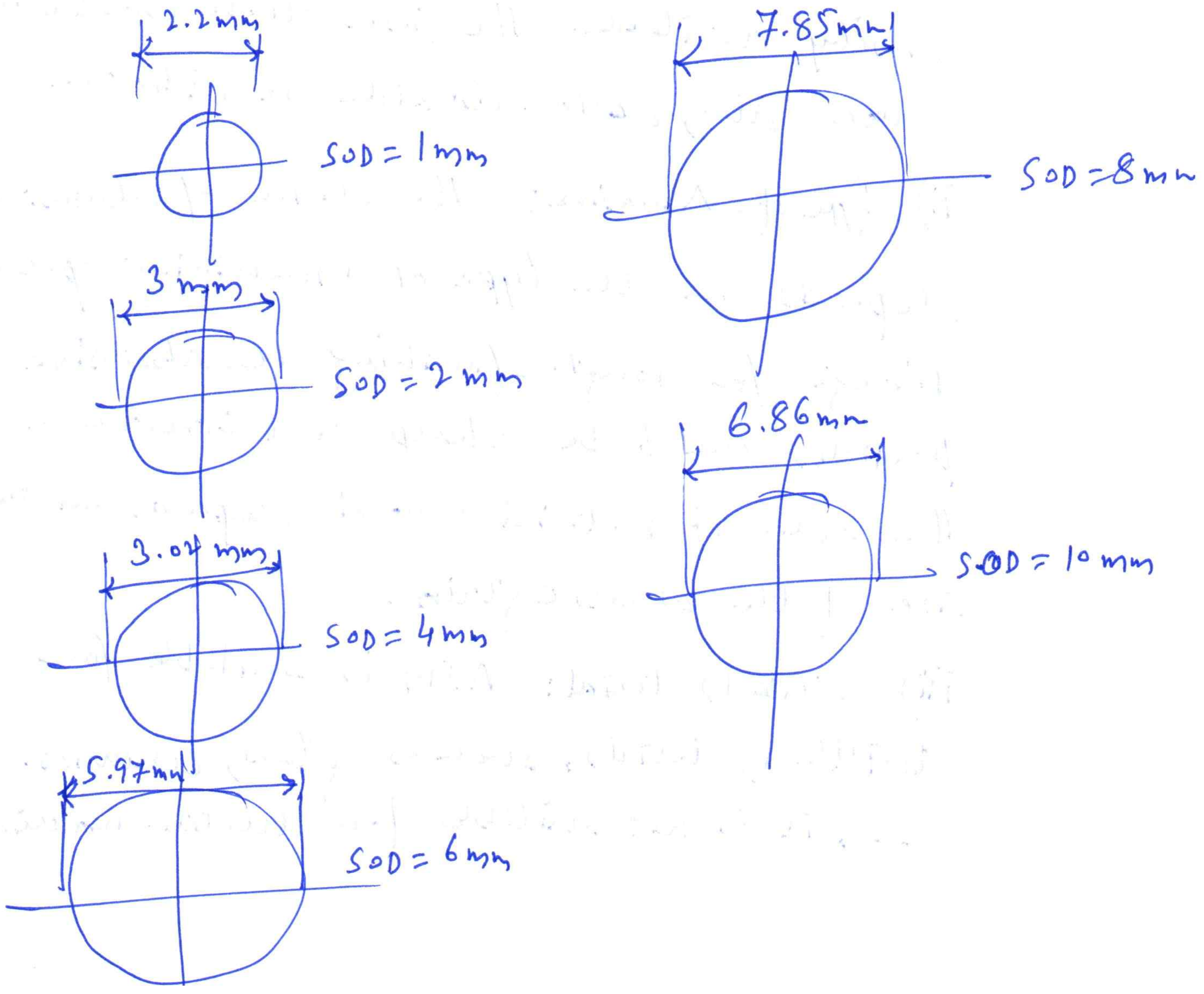
i) CARRIER GAS
ii) TYPE OF ABRASIVE
iii) WORK MATERIAL
iv) STAND OFF DISTANCE (SOD)

i) Carrier Gas: It should have the characteristic not to flare much when discharged from nozzle. Gas should be non-toxic, cheap and easily available. The gases those can be used are air, carbon dioxide or nitrogen.

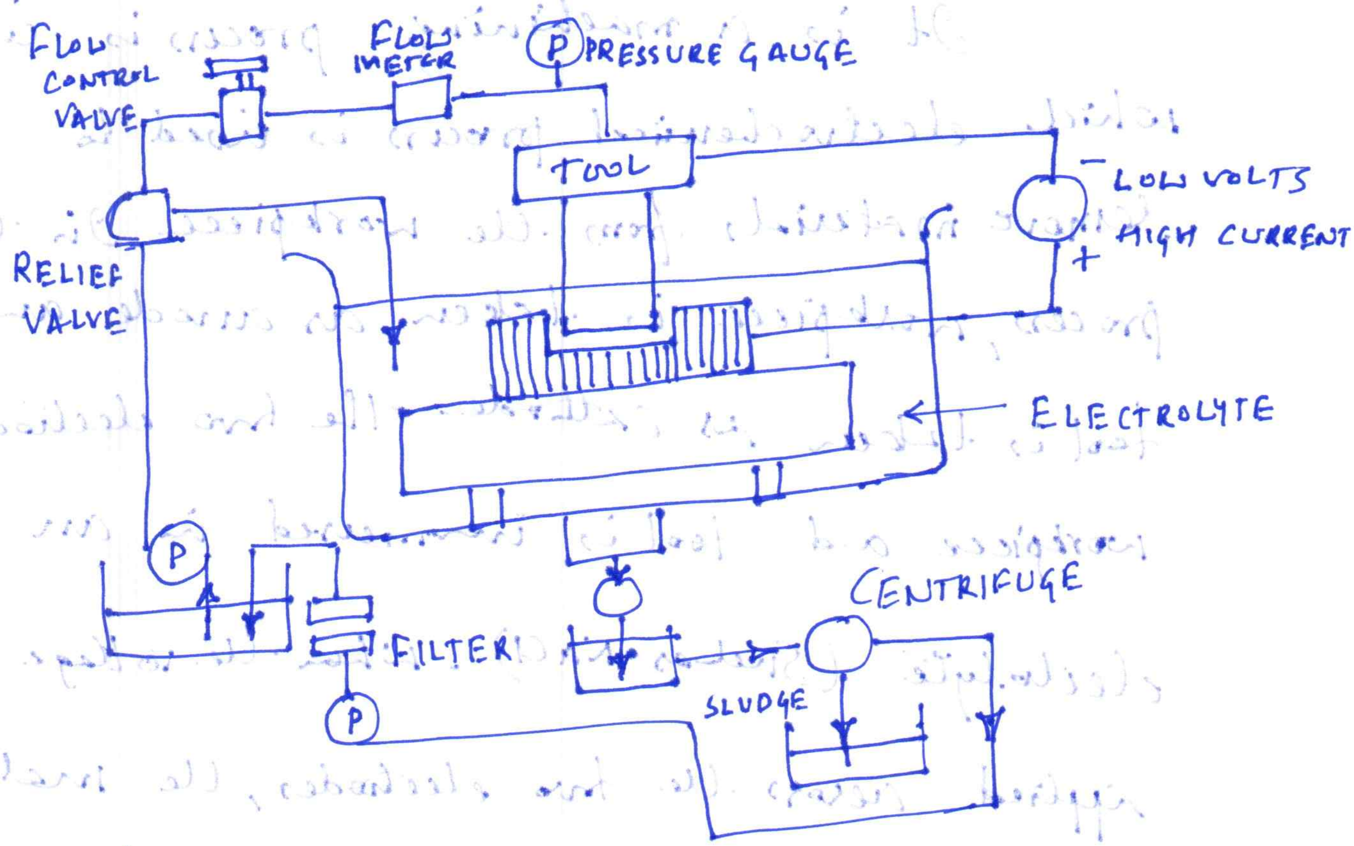
ii) Type of Abrasive: The choice of abrasive depends on the type of machining operation. For eg. for rough finishing the abrasive particles are to be sharp and irregular. The rate of material removal depends on the size of the abrasive grain.

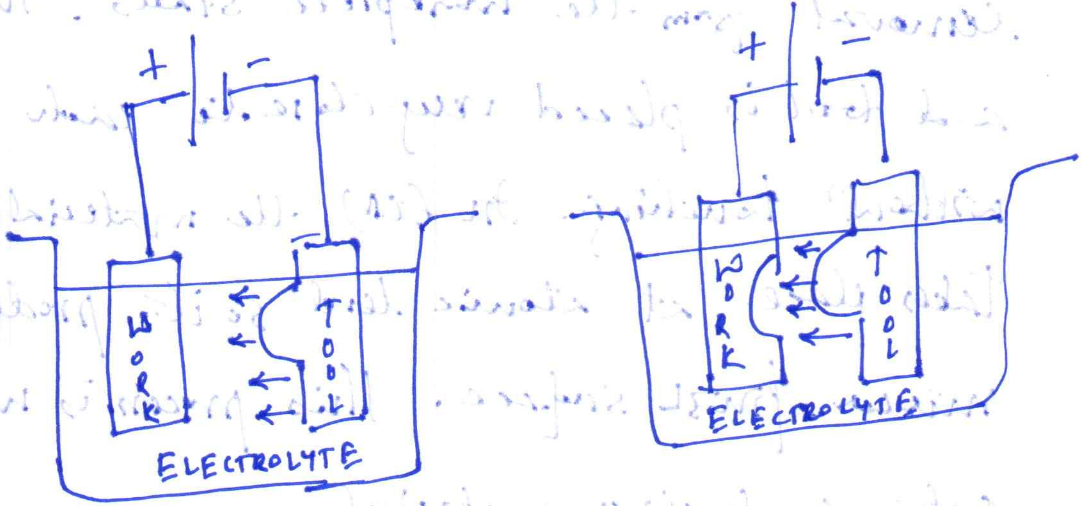
iii) Work Material: AJM is suitable for brittle materials, such as glass, ceramics. So, it is not suitable for ductile material.

iv) STANDOFF DISTANCE: It is the distance between the face of nozzle and the surface of the work. SOD has been found to have considerable effect on the rate of metal removal as well as accuracy. A ~~large~~ large SOD results in the flaring up of the jet which leads to poor accuracy. The following figures show the effect of SOD on machining.



Q 5. (a) ELECTRO-CHEMICAL MACHINING PROCESS:





WORKING PRINCIPLE : (ECM)

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

During ECM process, the reactions take place at the electrodes i.e., at the anode (workpiece) and cathode (tool) and within the electrolyte.

Q. 5. (b) PROCESS PARAMETERS OF ECM :

i) Current Density
ii) Tool feed rate
iii) Gap between tool and workpiece.
iv) Flow rate of electrolyte.

i) Current Density : It is defined as the amount of electrical current passed per unit area of work surface.

- Material removal : The rate of metal removal is directly proportional to the current density employed.

- Surface finish : High current densities generally produce better surface finishes by suppressing the influencing of crystallographic orientation and surface details.

- Power requirement : ECM typically requires high direct currents (ranging from 50 to 40,000 A) at low voltage (5 to 35 V) to drive these densities.

ii) Tool feed rate: The tool is fed forward the workpiece to maintain a stable machining gap as material is dissolved.

- Equilibrium Gap: A stable spacing is established when the tool is fed at a constant speed equal to the linear rate of machining.

- Surface quality: High feed rates are not only more productive but also tend to produce the best quality of surface finish.

- Short Circuits: If the tool is feed too quickly, it may touch the workpiece, causing a short circuit that can damage both the tool and the part.

iii) Inter-Electrode Gap:

- Smaller gaps that maximises current flow.

- Accuracy may be obtained by uniform small gap.

iv) Electrolyte flow rate:

- Sludge & heat removal.
- Surface consistency
- Pressure.

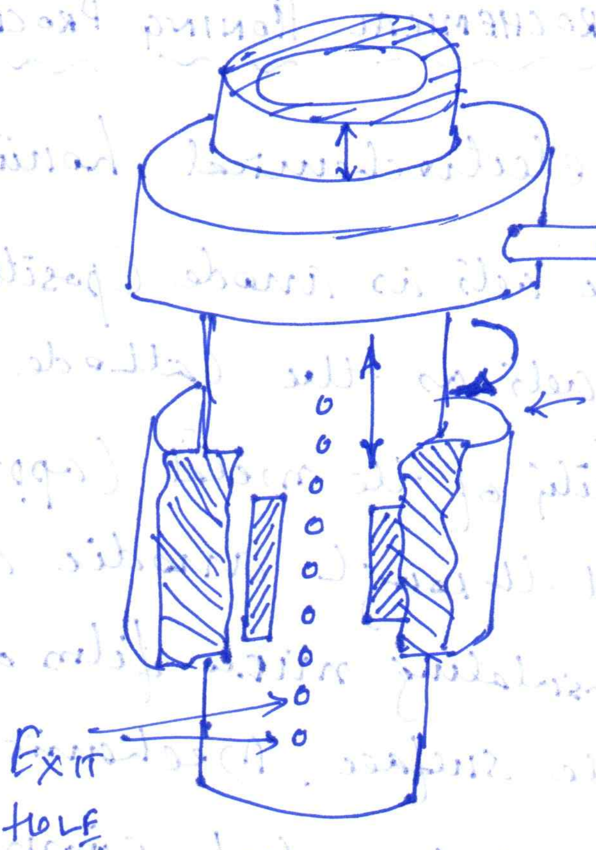
Q. 6 (a) ELECTROCHEMICAL HONING PROCESS:

In electrochemical honing process, the workpiece acts as anode (positive) and special tool acts as the cathode (Negative). While majority of the metal (approx. 80 - 90 %) is removed through anodic dissolution, a thin, insulating micro-film of metal oxide forms on the surface. Mechanical honing stones, mounted on tool, simultaneously rotate and reciprocate to scrub away this oxide layer from high spots, exposing fresh metal for continued electrochemical action.

Components of ECH:

- Honing tool
- Electrolyte Systems
- Power Supply

ECM:



ADVANTAGES:

i) High metal removal rate
ii) Superior surface quality
iii) Increased tool life
iv) Stress free machining
v) Burr-free operation

LIMITATIONS:

i) Conductive Materials only
ii) Specific Geometries can't be obtained.
iii) Blind hole drilling is difficult.
iv) High Capital investment
v) Skilled labour requirements.

Q. 6 (b)

i) CHEMICAL BLANKING PROCESS:

Steps involved in blanking process:

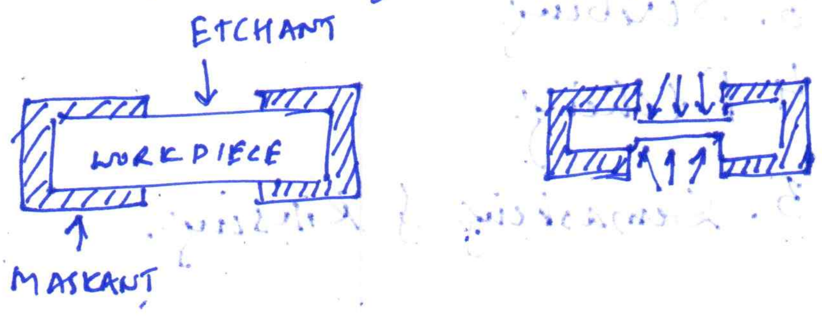
i) Precleaning: The metal is thouroughly degreased and cleaned to ensure the masking agent adheres properly.

ii) Masking: ~~A~~ chemical resistant coating (maskant) is applied to the areas of the metal that should not be removed.

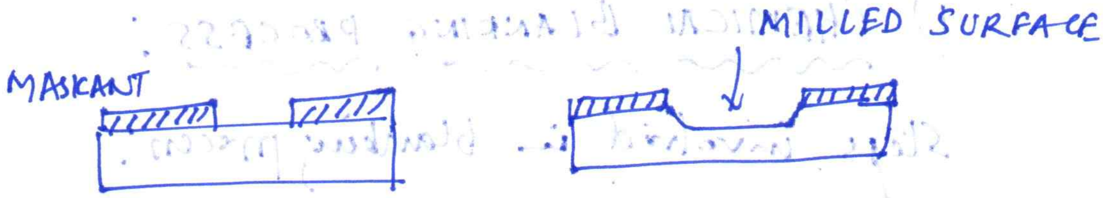
iii) Scribing/Developing: For photo resist masks, the sheet is exposed to UV light a through a negative of the desired part.

iv) Etching: It is the material removal process.

v) Demasking & finishing: Remaining maskent is stripped away



ii) CHEMICAL MILLING PROCESS:

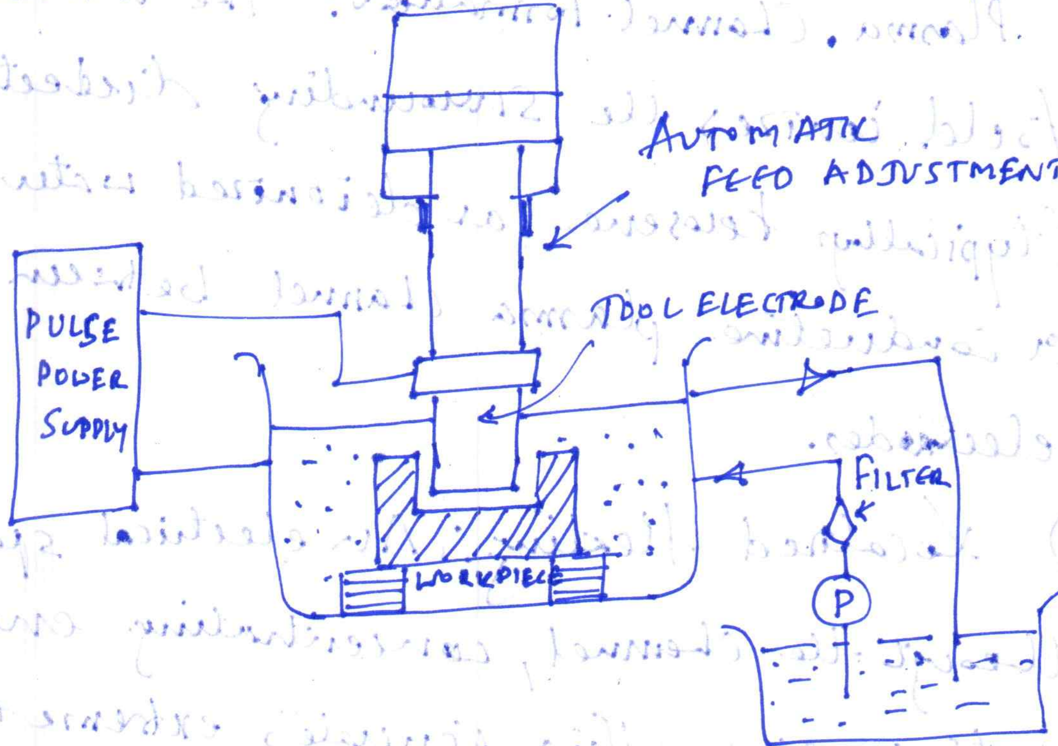


• Chemical milling process uses temperature-regulated chemical reagents (etchants) to selectively dissolve and remove material from a workpiece. Primarily used for weight reduction in the aerospace industry, it allows for the creation of complex pockets and contours without applying mechanical force or heat, ensuring parts remain burr-free and stress-free.

Stages of Process:

1. Surface Preparation
2. Masking
3. Scribing
4. Etching
5. Demasking & Rinsing.

Q 7 (a) MECHANISM OF METAL REMOVAL IN EDM PROCESS



Metal Removal Steps:

i) Spark initiation
ii) Plasma Channel formation
iii) Localised Heating
iv) Melting and Vapolization
v). Material Expulsion
vi). Flushing

i) Spark Initiation: ~~A~~ high voltage is applied between a tool electrode (Cathode) and a workpiece (anode) seperated by a small 'spark gap'.

ii) Plasma Channel formation: The intense electric field ionizes the surrounding dielectric fluid (typically kerosene or deionized water), creating a conductive plasma channel between the two electrodes.

iii) Localized Heating: An electrical spark jumps through the channel, concentrating energy in a tiny area. This generates extreme temperatures between 8000°C and 12000°C.

iv) Melting & Vaporization: This intense heat causes a minuscule amount of metal on the workpiece surface to instantaneously melt & vaporizes.

Q 7 (b) DIELECTRIC FLUID : It is an insulating liquid that fills the gap between the tool and the workpiece, acting as both a catalyst for the spark and a cooling agent.

Roles of dielectric fluid :

i) Insulation
ii) Constriction
iii) Cooling
iv) Flushing

Types of dielectric fluids :

i) Hydrocarbon oils in sinker EDM.
ii) Deionized water in Wire EDM
iii) Gaseous Dielectric in Dry EDM

DESIRABLE PROPERTIES OF DIELECTRIC FLUIDS :

i) High Dielectric Strength
ii) Low Viscosity
iii) Rapid Ionization & De-ionization
iv) High Specific heat & thermal Conductivity

v) High Latent heat of Vaporization

vi) High flash point

vii) Chemical Stability

viii) Non-toxicity & Low fuming

ix) Chemical Neutrality

x) Low Volatility

DIFFERENT DIELECTRIC FLUIDS:

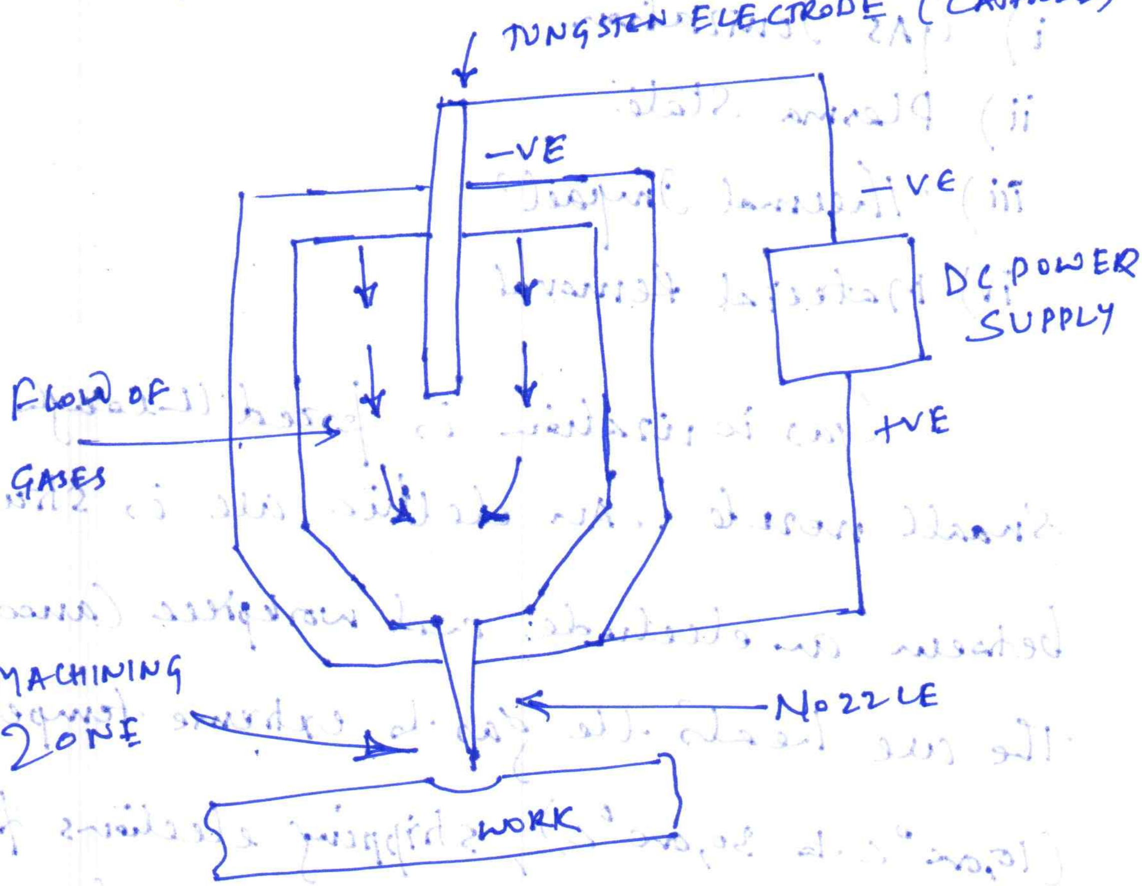
i) Hydro-carbon based oils:
- Kerosene
- Mineral oils
- Synthetic Hydrocarbons

ii) Deionized Water

iii) Gaseous dielectrics:
- Air
- Oxygen
- Nitrogen
- Argon

Q 8 (a)

PLASMA ARC MACHINING PROCESS :



WORKING PRINCIPLE :

Plasma Arc machining is a high velocity thermal cutting process that uses a constricted stream of ionized gas (plasma) to melt and remove.

PROCESS OF MACHINING:

i) Gas Ionization
ii) Plasma State
iii) Thermal Impact
iv) Material Removal

Gas ionization is forced through a small nozzle. An electric arc is struck between an electrode and workpiece (anode). The arc heats the gas to extreme temperatures (10,000°C to 30,000°C), stripping electrons from the gas atoms to create plasma – the fourth state of matter. This high energy plasma jet is focused onto a small area of the workpiece, instantaneously melting the metal. The high velocity gas stream physically blows the molten metal away, creating a clean 'kerf' (cut).

Q 8 (b) **SAFETY PRECAUTIONS IN PAM:**

i) Personal protective Equipment (PPE)
ii) Environmental & Operational Safety
iii) Gas Cylinder Safety.

Following are the personal protective Equipment:

- Eye Protection
- Flame resistant Clothing
- Insulated Gear
- Hearing Protection.

Now, the environmental & Operational safety precautions may be listed as,

- Fume Extraction
- Fire Prevention
- Electrical Grounding
- Safe Handling

The Gas cylinder safety is also an important precautionary measure as,

- Store Cylinders always in upright position
- Ensure all hoses are inspected daily for leaks or wear and never use tape or splice them.

Q 8

(c) APPLICATIONS OF EDM PROCESS:

i) Tool & Die Making: EDM is a standard for producing injection moulds, extrusion dies, and blanking punches due to its ability to create deep cavities and sharp internal corners.

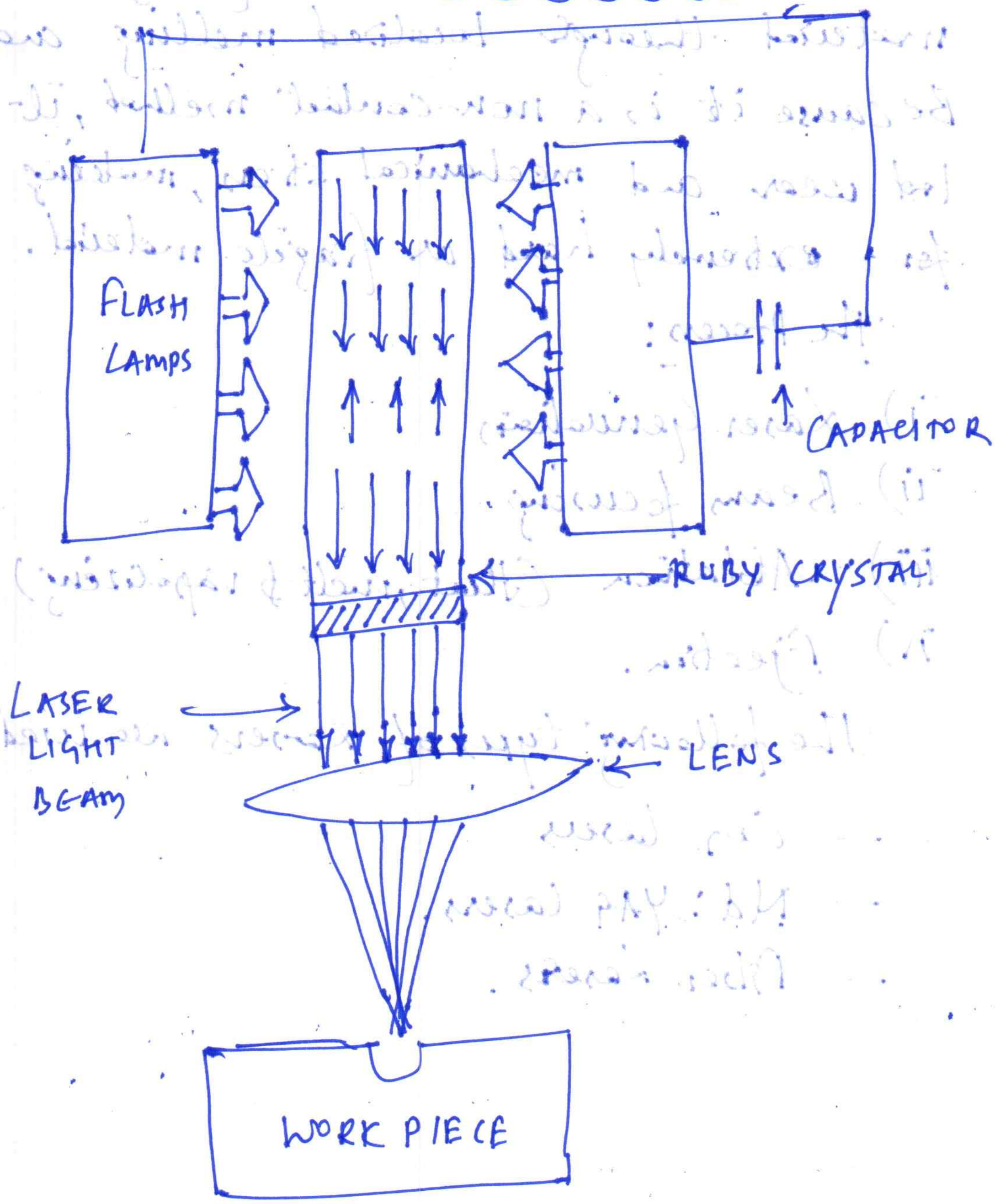
ii) Aerospace Components: It is used to machine critical, heat resistant parts like turbine blades, fuel nozzles, and compressor discs from exotic alloys like Inconel and titanium.

iii) Medical Device Manufacturing: EDM produces burr-free, bio-compatible components for surgical instruments, orthopaedic implants and miniature devices like stents & pacemakers.

iv) Small hole Drilling: Specialised 'hole poppers' can drill small holes.

v) Electronics: It facilitates the production of micro-components, including connectors, sensors and semi-conductor tooling.

Q. 9 (a) **Laser Beam Machining Process : (LBM)**



WORKING PRINCIPLE OF LASER BEAM MACHINING (LBM)

LBM is a thermal process that uses highly concentrated, coherent beams of light to remove material through localised melting and vaporization. Because it is a non-contact method, it eliminates tool wear and mechanical stress, making it ideal for extremely hard or fragile material.

The Process:

i) Laser Generation
ii) Beam focusing
iii) Ablation (Heat, melt & vaporizing)
iv) Ejection.

The following types of Lasers are used:

- CO_2 lasers
- Nd: YAG Lasers.
- Fiber Lasers.

Q 9 (b) ADVANTAGES OF LBM:

i) No tool wear.
ii) Micro-level precision.
iii) Zero Mechanical Stress
iv) Material Versatility.
v) Complex geometries may be obtained.
vi) Speed & suitable for automation
vii) Small heat affected zone

LIMITATIONS OF LBM:

i) High Initial investments.
ii) Material Reflectivity
iii) Tapering and Kerf.
iv) Heat affected zone.
v) Safety hazards.
vi) Thickness limits
vii) Higher energy consumptions.
viii) Rough surface finish.

APPLICATIONS OF LBM:

i). Micro-hole drilling in,
- Aerospace parts
- Automotive parts
- Special equipment.

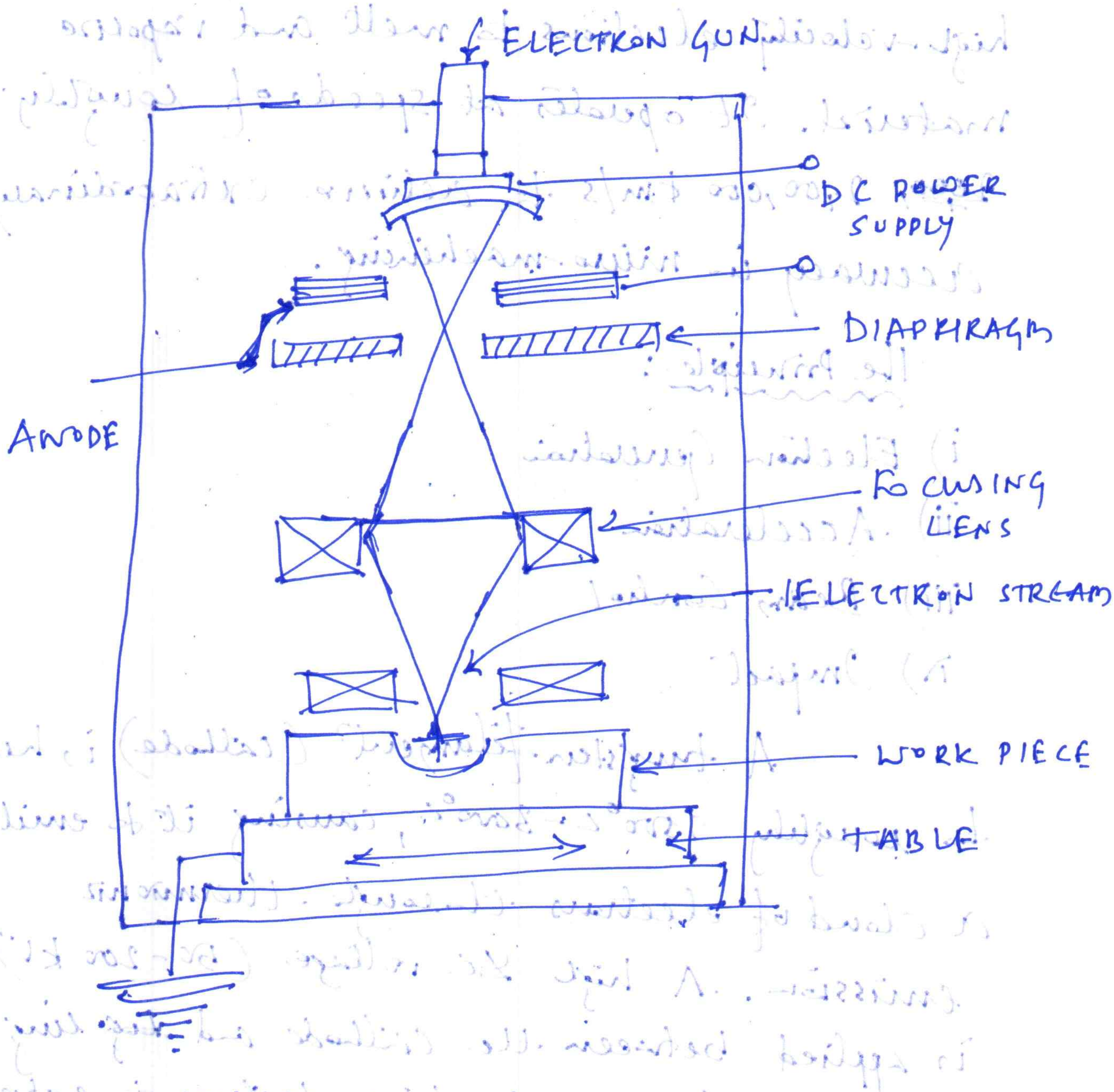
ii) Medical Device Fabrication
- Stent Manufacturing
- Surgical tools.

iii) Electronics & Semiconductors.
- PCB processing
- Silicon wafer dicing

iv) Industrial cutting & Engraving.
- Complex profile cutting
- Marking and coding.

v) Hard material processing
- Diamond tooling (Sharpening tools)
- Ceramics machining

Q 10 (a) ELECTRON BEAM MACHINING PROCESS (EBM)



WORKING PRINCIPLE OF EBM :

It is a high-precision thermal process that uses a concentrated stream of high-velocity electrons to melt and vaporise material. It operates at speeds of roughly ~~2000~~, 2,00,000 km/s to achieve extraordinary accuracy in micro-machining.

The Principle:

i) Electron Generation
ii) Acceleration
iii) Beam Control
iv) Impact

A tungsten filament (cathode) is heated to roughly 2500°C - 3000°C, causing it to emit a cloud of electrons through thermionic emission. A high DC voltage (50-200 kV) is applied between the cathode and ~~ring~~ ring shaped anode, accelerating electrons to extreme velocities. The beams passes through magnetic lenses to focus in to tiny spot. When beams strikes the workpiece the high heat vaporises metal.

Q 10 (b)

ADVANTAGES OF EBM :

i) Extreme aspect ratios in drilling holes.
ii) Material Independence.
iii) Vacuum-purity results.
iv) Highly focussable.
v) No mechanical stress.
vi) High energy density.
vii) Precise CNC controlled beam.

LIMITATIONS OF EBM :

i) High capital & operating costs:
- High initial investment
- High operating cost.

ii) The "Vacuum" constraint
- Size limitations.
- Longer cycle times.

iii) Technical & Material Limitation.
- X-ray Hazard.
- Conductive material requirement
- Heat affected Zone (HAZ).

iv) Maintenance & Skill
- Filament life is less
- Expertise required.

APPLICATIONS OF EBM:

i) Aerospace & Defense:
 - Turbine blades with tiny holes can be produced.
 - Combustion domes with perforated sheets.
 - Propulsion systems of rocket engines.

ii) Medical & Bio-medical Engineering:
 - Costum implants
 - Surgical Instruments
 - Sterilization

iii) Nuclear & Energy Industry:
 - Nuclear reactors
 - Refining reactive metals.

iv) Electronics & micromachining:
 - Lithography
 - Circuit fabrication
 - Wire drawing dies.

v) Specialized manufacturing
 - fuel Injectors.

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