

Code: 23ME4601B

III B.Tech - II Semester - Regular Examinations – APRIL 2026**ADVANCED MANUFACTURING PROCESSES
(MECHANICAL ENGINEERING)**

Duration: 3 hours

Max. Marks: 70

Note: 1. This question paper contains two Parts A and B.

2. Part-A contains 10 short answer questions. Each Question carries 2 Marks.

3. Part-B contains 5 essay questions with an internal choice from each unit. Each Question carries 10 marks.

4. All parts of Question paper must be answered in one place.

BL – Blooms Level

CO – Course Outcome

PART – A

		BL	CO
1.a)	Classify NTM processes based on energy source.	L2	CO1
b)	Define Ultrasonic Machining (USM).	L2	CO1
c)	Identify nozzle material important in abrasive jet machining (AJM).	L2	CO1
d)	How does abrasive water jet machining (AWJM) differ from Water Jet Machining (WJM)?	L2	CO1
e)	Define Electro chemical grinding (ECG).	L2	CO2
f)	Write about an etchant in chemical machining.	L2	CO2
g)	Define discharge gap in Electric Discharge Machining (EDM).	L2	CO3
h)	List two advantages of EDM over conventional machining.	L2	CO3
i)	Explain any two types of Lasers.	L2	CO4
j)	Define stand-off distance in plasma arc machining (PAM).	L2	CO4

PART – B

			BL	CO	Max. Marks
UNIT-I					
2	a)	Compare conventional and non-traditional machining.	L2	CO1	5 M
	b)	Explain the factors affecting process selection in NTM.	L2	CO1	5 M
OR					
3		Discuss process parameters influencing MRR and surface finish in ultrasonic machining (USM).	L2	CO1	10 M
UNIT-II					
4		Explain the Abrasive Jet Machining (AJM) process in detail with labeled diagram, process variables and metal removal mechanism.	L2	CO1	10 M
OR					
5	a)	Summarize the working principle of Abrasive Flow Finishing (AFF).	L2	CO1	5 M
	b)	Classify the factors influence MRR in abrasive water jet machining (AWJM).	L2	CO1	5 M
UNIT-III					
6		Relate the principle of electro stream drilling (ESD) and shaped tube electrolytic machining (STEM) including advantages, disadvantages and typical applications.	L3	CO2	10 M
OR					

7	a)	Interpret the principle of chemical machining (CHM).	L3	CO2	5 M
	b)	Prepare short notes on maskants and etchants used in chemical machining.	L3	CO2	5 M
UNIT-IV					
8		Interpret the Electric Discharge Grinding (EDG). Explain its working principle, advantages, limitations and applications.	L3	CO3	10 M
OR					
9	a)	Show the function of dielectric fluid and its properties.	L3	CO3	5 M
	b)	What are the major process parameters in Electric Discharge Machining (EDM) and how do they affect machining?	L3	CO3	5 M
UNIT-V					
10		Illustrate construction and working of laser beam machining (LBM) with advantages, limitations and applications.	L3	CO4	10 M
OR					
11	a)	Illustrate the working of Plasma Arc Machining.	L3	CO4	5 M
	b)	Articulate the theory of material removal in electron beam machining (EBM).	L3	CO4	5 M

1.a) Classify NTM processes based on energy source: Any 2pionts($2*1=2M$)

b) Define Ultrasonic Machining (USM): Any 2pionts($2*1=2M$)

c) Identify nozzle material important in Abrasive Jet Machining (AJM):
Any 2pionts($2*1=2M$)

d) Difference between AWJM and WJM: Any 2pionts($2*1=2M$)

e) f) Write about an etchant in chemical machining: Any 2pionts($2*1=2M$)

g) Define discharge gap in EDM: Any 2pionts($2*1=2M$)

h) List two advantages of EDM over conventional machining: Any 2pionts($2*1=2M$)

i) Explain any two types of Lasers: Any 2pionts($2*1=2M$)

j) Define stand-off distance in Plasma Arc Machining (PAM): Any 2pionts($2*1=2M$)

e) Define electrochemical grinding - Any 2pionts ($2*1=2M$)

2(a) Comparison of Conventional and Non-Traditional Machining (NTM)(5)

Any 5pionts($5*1=5M$)

2(b) Explain the factors affecting Process Selection in NTM (5M)

Any 5pionts($5*1=5M$)

3.) Discuss process parameters influencing MRR and surface finish in ultrasonic machining (USM).

Any 8pionts($8*1=8M$)

2MARKS FIGURE

4). Explain the abrasive jet machining (ajm) process in detail with labelled diagram , process variables and metal removal mechanism.

Any 7pionts($7*1=7M$)

3MARKS FIGURE

5a) Summarize the working principle of Abrasive Flow Finishing (AFF).

Any 5pionts($5*1=5M$)

5(b) Classify the factors influencing MRR in Abrasive Water Jet Machining (AWJM).(5M)

Any 5pionts($5*1=5M$)

6) Relate the principle of Electro Stream Drilling (ESD) and Shaped Tube Electrolytic Machining (STEM) including advantages, disadvantages and typical applications(10M)

Electro Stream Drilling (ESD) :Any 5pionts($5*1=5M$)

Shaped Tube Electrolytic Machining (STEM): Any 5pionts($5*1=5M$)

7a) Interpret the principle of Chemical Machining (CHM).(5)

Any 4pionts($4*1=M$)

1MARKS FIGURE

7 b) Prepare short notes on maskants and etchants used in Chemical Machining.(5M)

Any maskants 5pionts($5*0.5=2.5M$)

etchants 5pionts($5*0.5=2.5M$)

8). Interpret the Electric Discharge Grinding (EDG). Explain its working principle, advantages, limitations and applications.

Any 7pionts($7*1=7M$)

3MARKS FIGURE

9a) Show the functions of dielectric fluid and its properties.

Any 5pionts($5*1=5M$)

9(b). What are the major process parameters in EDM and how do they affect machining?

Any 4pionts($4*1=M$)

1MARKS FIGURE

10) Illustrate the construction and working of Laser Beam Machining (LBM) with advantages, limitations and applications.(10M)

Any 7pionts($7*1=7M$)

3MARKS FIGURE

11 a) Illustrate the working of Plasma Arc Machining (PAM). **(5M)**

Any 4 points (4*1=M)

1 MARKS FIGURE

11(b). Articulate the theory of material removal in Electron Beam Machining (EBM).

(5M)

Any 4 points (4*1=M)

1 MARKS FIGURE

1.a) Classify NTM processes based on energy source:

Non-Traditional Machining processes can be classified based on the type of energy used to remove material:

1. Mechanical Energy Based:
 - o Ultrasonic Machining (USM)
 - o Abrasive Jet Machining (AJM)
2. Thermal Energy Based:
 - o Electric Discharge Machining (EDM)
 - o Laser Beam Machining (LBM)
 - o Plasma Arc Machining (PAM)
3. Electrochemical Energy Based:
 - o Electrochemical Machining (ECM)
 - o Electrochemical Grinding (ECG)

b) Define Ultrasonic Machining (USM):

USM is a mechanical material removal process in which high-frequency ultrasonic vibrations (20–40 kHz) of a tool, along with an abrasive slurry, are used to erode material from a hard and brittle workpiece.

c) Identify nozzle material important in Abrasive Jet Machining (AJM):

The nozzle in AJM must withstand high-speed abrasive particles. Tungsten carbide or diamond-coated nozzles are commonly used due to their high wear resistance.

d) Difference between AWJM and WJM:

Feature	AWJM (Abrasive Water Jet Machining)	WJM (Water Jet Machining)
Material Removal	Uses abrasive particles in water for cutting hard materials	Only uses high-pressure water
Cutting Ability	Can cut hard and brittle materials	Mostly suitable for soft materials
Surface Finish	Better cutting of metals and ceramics	Limited to softer materials like rubber, plastics
Applications	Metals, ceramics, composites	Soft materials like foam, rubber

e) Define Electrochemical Grinding (ECG):

ECG is a hybrid machining process combining electrochemical dissolution and mechanical abrasion. A conductive grinding wheel removes material while an electrolyte facilitates anodic dissolution, useful for hard metals.

f) Write about an etchant in chemical machining:

In chemical machining, an etchant is a chemical solution used to selectively dissolve material from a workpiece. Example: Ferric chloride (FeCl_3) is used for etching copper or stainless steel.

g) Define discharge gap in EDM:

The discharge gap in Electric Discharge Machining is the small distance between the tool electrode and the workpiece where sparks occur, causing localized melting and vaporization of material.

h) List two advantages of EDM over conventional machining:

1. Can machine very hard materials like tungsten carbide.
2. Can create complex shapes and fine details without mechanical stress.

i) Explain any two types of Lasers:

1. CO₂ Laser: Gas laser, high power, used for cutting and welding metals and non-metals.
2. Nd:YAG Laser: Solid-state laser, good for precise micro-machining and engraving.

j) Define stand-off distance in Plasma Arc Machining (PAM):

The stand-off distance is the gap between the plasma torch nozzle and the workpiece surface. It affects cut quality, arc stability, and kerf width.

UNIT-I:

2(a) Comparison of Conventional and Non-Traditional Machining (NTM)(5)

Feature	Conventional Machining	Non-Traditional Machining (NTM)
Material Removal	Mechanical cutting with a sharp tool	Mechanical, thermal, electrical, or chemical energy to remove material
Tool Wear	Significant due to contact cutting	Minimal in some processes; tool may not contact workpiece
Workpiece Material	Usually soft to medium hardness	Can machine very hard, brittle, or exotic materials
Complex Shapes	Limited by tool geometry	Can produce complex shapes, micro-features, or intricate cavities
Surface Finish	Moderate	Can achieve high precision and smooth finishes
Accuracy	Moderate	High, depends on process and parameters
Heat Generation	High (may affect workpiece)	Some processes have no heat-affected zone (e.g., AJM, ECM)
Applications	Simple parts like shafts, gears, plates	Aerospace, electronics, medical implants, composites

- Conventional machining uses **mechanical cutting** (lathe, milling, drilling).
- NTM uses **energy forms other than direct cutting**, such as **ultrasonic vibrations, water jet, electric sparks, plasma, or chemical dissolution**.
- NTM is preferred for **hard, brittle, or heat-sensitive materials** and **complex shapes**

2(b) Explain the factors affecting Process Selection in NTM (5M)

Ans) Conventional machining is suitable for **soft/medium materials with simple shapes**.

- **NTM processes** are preferred for **hard, brittle, exotic materials, complex geometries, and high-precision requirements**.
- Proper selection of NTM depends on **material, geometry, surface finish, MRR, cost, safety, and tool availability**.

1. Material Properties:

- Hardness, brittleness, conductivity, and thermal sensitivity determine which NTM process is suitable.
Example: **EDM** for hard conductive metals, **AJM** for brittle materials.

2. Workpiece Geometry & Complexity:

- Complex shapes, micro-holes, thin walls, and fine features favor NTM processes.

3. Required Surface Finish & Accuracy:

- If high precision or mirror-like finish is required → select processes like **USM, LBM, ECG**.

4. Material Removal Rate (MRR):

- Processes with high MRR are preferred for mass production; low MRR acceptable for precision work.

5. Production Volume & Cost:

- High-volume production may favor faster processes; cost of equipment and consumables also considered.

6. Environmental & Safety Considerations:

- Some processes produce toxic byproducts (ECM, PAM), others are environmentally friendly (WJM, AWJM).

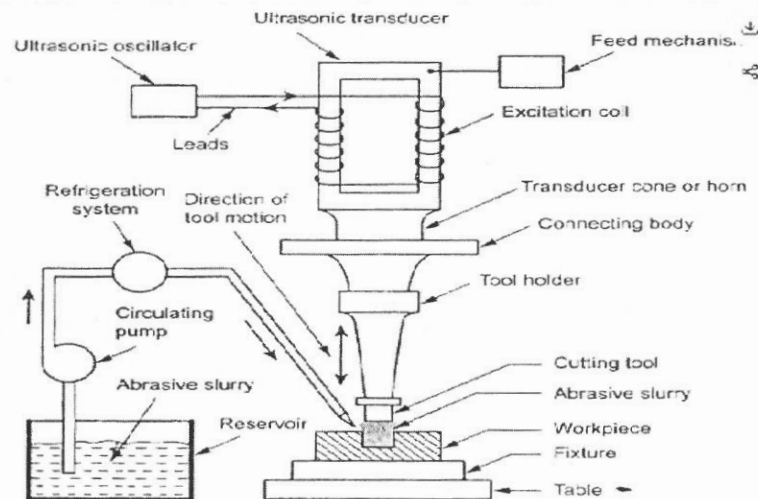
7. Tool Availability & Wear:

- Processes with less tool wear may be preferred for difficult-to-machine materials.

Factor	Influence on NTM Process Selection
Material properties	Hardness, brittleness, conductivity, heat sensitivity
Geometry & complexity	Micro-holes, thin walls, intricate shapes
Surface finish & accuracy	Precision and smoothness requirements
MRR	High or low material removal rate needed
Cost & production volume	Equipment cost vs production efficiency
Environmental & safety	Toxicity, heat generation, safety concerns
Tool wear & availability	Tool life considerations

3). Discuss Process Parameters influencing MRR & Surface Finish in Ultrasonic Machining (USM).(10M)

ans) Ultrasonic Machining (USM) is a non-traditional machining (NTM) process in which a tool vibrates at high frequency (20–40 kHz) while being pressed against the workpiece. A slurry of abrasive particles is fed between the tool and workpiece to remove material. It is suitable for hard and brittle materials like ceramics, glass, and hardened steels.



Key Process Parameters Affecting MRR and Surface Finish:

1. Amplitude of Tool Vibration:
 - Higher amplitude → more kinetic energy → higher MRR.
 - Too high → rough surface finish.
2. Tool Feed Rate:
 - Moderate feed → optimum MRR and smooth surface.
 - Excessive feed → chatter and poor surface finish.
3. Abrasive Particle Size & Concentration:
 - Larger particles → higher MRR; smaller particles → better surface finish.
 - High concentration → faster cutting, may increase surface roughness.
4. Applied Load on Tool:
 - Moderate load → effective cutting and high MRR.
 - Excessive load → tool wear or cracking of brittle workpiece.
5. Slurry Type & Viscosity:
 - Correct viscosity ensures efficient abrasive flow → consistent MRR.
 - Incorrect viscosity → uneven material removal and poor finish.

Summary Table:

Parameter	Effect on MRR	Effect on Surface Finish
Tool amplitude	↑ MRR	↑ Roughness if too high
Tool feed rate	Moderate → optimum MRR	Too high → poor finish
Abrasive size	Larger → ↑ MRR	Smaller → smoother finish
Abrasive concentration	↑ MRR	High conc. → rough surface
Slurry	Efficient → good MRR	Wrong → poor finish

Optimizing amplitude, feed rate, abrasive characteristics, load, and slurry ensures high MRR

Amplitude of tool vibration	Lower amplitude → smoother surface	Too high amplitude to deep micro-chipping.
Tool shape & condition	Sharp, precise tool → better finish	Worn tools can deteriorate surface quality.
Slurry concentration	Lower concentration → smoother surface	Too much abrasive can scratch the surface.

with good surface finish in USM.

- **High MRR:** Coarse abrasive, high amplitude, moderate force, low frequency.
- **Good Surface Finish:** Fine abrasive, high frequency, low amplitude, optimal slurry concentration.

In practice, a **trade-off** exists: increasing MRR often reduces surface quality, so parameters must be optimized according to the application.

Parameter	Effect on Surface Finish	Notes
vibration	smoother surface	due to deep micro-chipping.
Tool shape & condition	Sharp, precise tool → better finish	Worn tools can deteriorate surface quality.
Slurry concentration	Lower concentration → smoother surface	Too much abrasive can scratch the surface.

- **High MRR:** Coarse abrasive, high amplitude, moderate force, low frequency.
- **Good Surface Finish:** Fine abrasive, high frequency, low amplitude, optimal slurry concentration.

In practice, a **trade-off** exists: increasing MRR often reduces surface quality, so parameters must be optimized according to the application.

4). Explain the abrasive jet machining (ajm) process in detail with labelled diagram , process variables and metal removal mechanism.

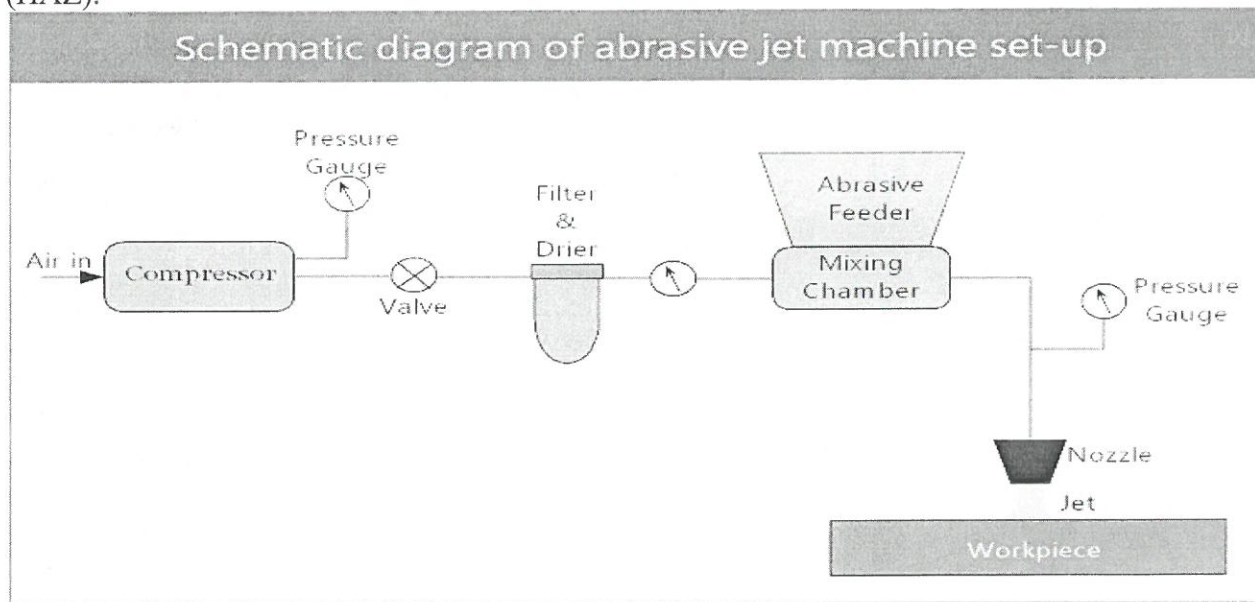
Ans) Abrasive Jet Machining (AJM) is an NTM mechanical process where high-velocity abrasive particles carried by a gas erode material from hard or brittle workpieces. Ideal for ceramics, glass, composites, and heat-sensitive materials.

AJM is ideal for hard or brittle materials where conventional machining is difficult.

Controlling particle size, flow, and gas pressure ensures efficient material removal and desired surface quality.

Working Principle:

- Compressed gas (air or nitrogen) carries fine abrasive particles through a nozzle.
- Abrasives strike the workpiece surface at high speed, causing erosion and micro-cutting.
- Material is removed gradually without thermal effects, leaving no heat-affected zone (HAZ).



Process Variables Affecting MRR:

1. Abrasive Particle Size: Larger → higher MRR; smaller → better surface finish.
2. Abrasive Type: Harder abrasives → faster cutting.
3. Abrasive Flow Rate: Higher → faster material removal.
4. Gas Pressure: Higher → higher particle velocity → higher MRR.
5. Nozzle Diameter: Larger → more particles → higher MRR.
6. Stand-off Distance: Optimal distance maximizes MRR; too close → nozzle wear, too far → reduced efficiency.
7. Traverse Speed: Slower → higher MRR; faster → lower cutting efficiency.

Metal Removal Mechanism:

- Erosion occurs due to impact and abrasion by particles.
- Leaves micro-cuts without causing heat damage.

Applications:

- Cutting/engraving glass, ceramics, composites
- Micro-machining for precision parts
- Surface cleaning, finishing, and deburring

5) Summarize the working principle of Abrasive Flow Finishing (AFF).

(a) Working Principle of Abrasive Flow Finishing (AFF)

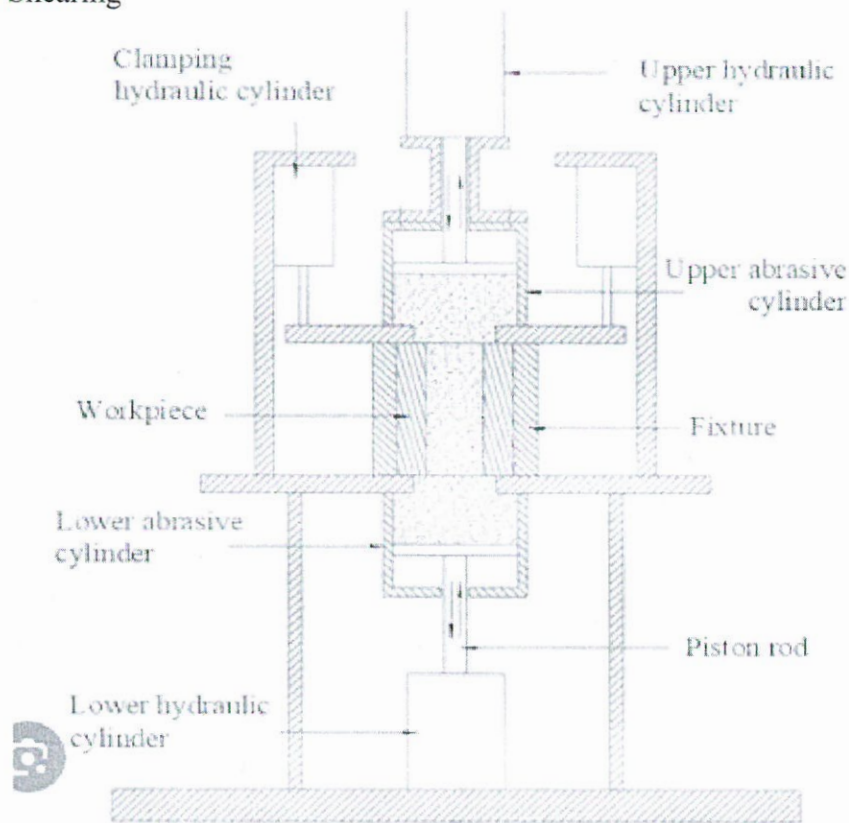
Abrasive Flow Finishing (AFF) is a **non-traditional machining process** used for improving surface finish, deburring, and polishing of complex internal and external surfaces.

Principle:

AFF operates on the principle of **material removal by the abrasive action of a flowing viscoelastic medium**. The abrasive particles embedded in the medium act as cutting tools.

Working:

- A semi-solid abrasive media (polymer + abrasive particles like SiC or Al₂O₃) is used.
- The media is **extruded under high pressure** through or across the workpiece.
- The abrasive particles remove material from surface irregularities through:
 - Micro-cutting
 - Ploughing
 - Shearing



- The process occurs in **reciprocating cycles**, ensuring uniform finishing.
- The media flows along the path of least resistance, finishing even **complex internal geometries**.
- Uniform surface finish
- Can machine inaccessible areas
- Simultaneous deburring and polishing
- No rigid tool required

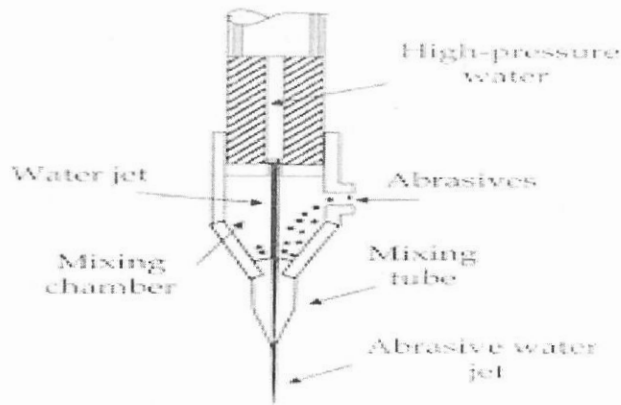
Applications:

- Aerospace components
- Automotive parts
- Dies and molds

Medical implants

5(b) Classify the factors influencing MRR in Abrasive Water Jet Machining (AWJM).(5M)

Abrasive Water Jet Machining (AWJM) is a hybrid NTM process in which high-pressure water mixed with abrasives cuts hard or brittle materials. It combines the advantages of Water Jet Machining (WJM) and abrasive erosion.



Factors Influencing MRR:

1. Abrasive Flow Rate:
 - More abrasives → higher MRR.
2. Water Jet Pressure:
 - Higher pressure → faster particle velocity → higher MRR.
3. Nozzle Diameter:
 - Larger diameter → higher particle flow → increased MRR.
4. Traverse Speed:
 - Slower → more material removed; faster → less cutting.
5. Stand-off Distance:
 - Optimal distance ensures maximum cutting efficiency. Too far → lower MRR; too close → nozzle wear.

Applications:

- Cutting hard metals, composites, ceramics
- Complex profiles and shapes
- Heat-sensitive materials without thermal damage

AWJM is a versatile, precise machining process. By controlling pressure, abrasive flow, traverse speed, and stand-off distance, desired MRR and surface quality can be achieved., while MRR in AWJM depends on a combination of **process, abrasive, and material parameters**, which must be optimized for efficient machining.

6) Relate the principle of Electro Stream Drilling (ESD) and Shaped Tube Electrolytic Machining (STEM) including advantages, disadvantages and typical applications(10M)

Ans) Both ESD and STEM are **non-traditional ECM-based processes** used for machining difficult materials.

- **ESD** is best suited for **deep, fine hole drilling with high aspect ratio**.
- **STEM** is preferred where **high precision and shape control** are required.

Their selection depends on the required **accuracy, geometry, and application**.

Both Electro Stream Drilling (ESD) and Shaped Tube Electrolytic Machining (STEM) are **Electrochemical machining (ECM) processes**.

They remove material by **anodic dissolution** using a flowing electrolyte and are widely used for producing **precision holes in hard, conductive materials**.

Electro Stream Drilling (ESD)

ESD works on the principle of **localized anodic dissolution** using a **high-velocity electrolyte jet**.

- Workpiece acts as **anode**
- Tool (fine tubular nozzle) acts as **cathode**
- High-speed electrolyte jet concentrates current, causing **intense localized material removal**

Working:

- Electrolyte is pumped through a fine nozzle at high velocity.
- A DC power supply creates a potential difference.
- The focused jet dissolves material and drills **deep, small-diameter holes**.
- Continuous flushing removes debris and heat.

Advantages:

- No tool wear
- Burr-free machining
- Can machine **hard and superalloy materials**
- High aspect ratio holes
- Good surface finish

Disadvantages:

- Only for electrically conductive materials
- Stray current effects reduce accuracy
- Electrolyte handling and disposal required
- High equipment cost

Applications:

- Turbine blade cooling holes
- Fuel injector nozzles
- Aerospace micro-hole drilling
- Medical components

2 Shaped Tube Electrolytic Machining (STEM)

STEM is based on **controlled anodic dissolution** using a **shaped tubular electrode** that defines the final geometry.

- Workpiece → Anode
- Shaped tube → Cathode
- Electrolyte flows through the tube to the machining zone

Working:

- Electrolyte is forced through a shaped tube electrode.
- The tool is fed towards the workpiece.
- Material is removed in the **exact shape of the tool end**.
- Provides high precision and controlled machining.

Advantages:

- High dimensional accuracy
- No tool wear
- Excellent surface finish
- Burr-free operation
- Suitable for complex shapes

Disadvantages:

- High initial and tooling cost
- Complex tool design
- Requires precise control of parameters
- Limited to conductive materials

Applications:

- Jet engine and turbine components
- Cooling holes with precise geometry
- Aerospace and nuclear industries
- Precision cavity machining

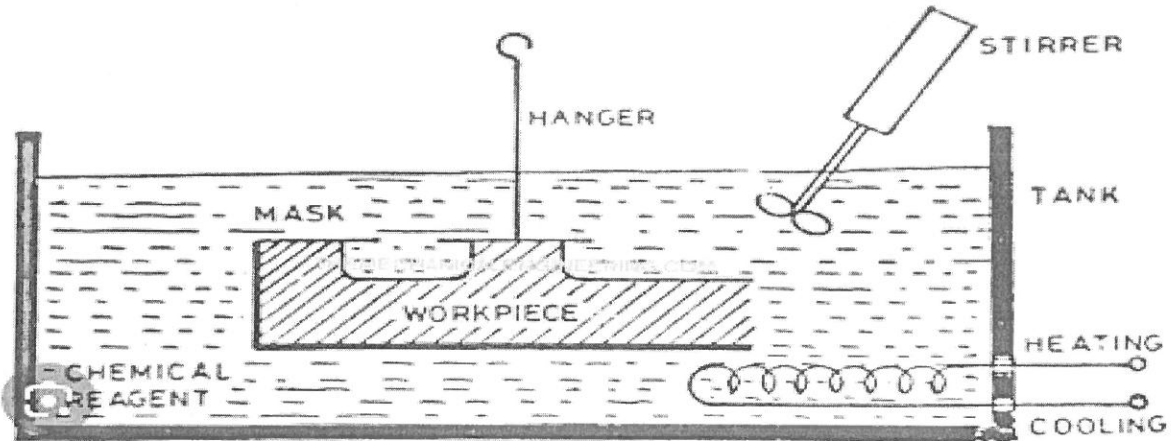
Relation / Comparison between ESD and STEM

Aspect	ESD	STEM
Basic Principle	ECM (anodic dissolution)	ECM (anodic dissolution)
Tool	Simple tube/nozzle	Shaped tubular electrode
Electrolyte Flow	High-velocity jet	Controlled internal flow
Accuracy	Moderate	High
Hole Type	Deep, small circular holes	Shaped/precision holes

Aspect	ESD	STEM
Control	Less control over shape	Excellent shape control
Application	Micro drilling	Precision machining

7a) Interpret the principle of Chemical Machining (CHM).(5)

Ans) Chemical Machining (CHM) is a **non-traditional machining process** in which material is removed from a workpiece by **controlled chemical dissolution** using an etchant. It is especially suitable for machining **thin sections, intricate shapes, and delicate components**.



The fundamental principle of CHM is based on the **selective removal of material through chemical reactions**. In this process, the workpiece is first cleaned thoroughly to remove contaminants such as oil, grease, and oxide layers. After cleaning, a **maskant (protective coating)** is applied on the surface to protect areas that are not to be machined. The desired pattern or area to be machined is then exposed by **removing the maskant selectively (scribing)**. The workpiece is subsequently immersed in or sprayed with a suitable **etchant (chemical solution)**. The exposed areas react with the etchant and undergo **chemical dissolution**, leading to material removal.

The depth of machining depends on factors such as:

- Etching time
- Concentration of the etchant
- Temperature of the solution

After achieving the required depth, the process is stopped, the maskant is stripped off, and the component is cleaned and finished.

Characteristics of CHM:

- No mechanical contact or cutting forces
- No tool wear
- Stress-free and burr-free surfaces
- Suitable for complex geometries
- Limited to relatively low material removal rates

Applications:

- Aerospace components (thin sheets, skins)
- Printed Circuit Boards (PCBs)
- Precision instruments
- Decorative and engraving works

7 b) Prepare short notes on maskants and etchants used in Chemical Machining.(5M)

Maskants are **chemically resistant protective coatings** applied on the workpiece surface to prevent unwanted areas from being etched.

Functions:

- Protect selected regions from chemical attack
- Enable selective and precise material removal
- Define the machining pattern

Desirable properties:

- High resistance to etchants
- Good adhesion to the work surface
- Easy application and removal
- Flexibility and durability
- Resistance to temperature and chemicals

Types of Maskants:

1. **Cut and Peel Maskants:**

- Rubber-based coatings
- Applied and then cut manually to expose areas

2. **Photographic Maskants (Photoresists):**

- Used for high-precision applications like PCBs
- Pattern transferred using light exposure

3. **Paint-type Maskants:**

- Applied using brush or spray
- Suitable for simple shapes
- **Advantages:**

- Accurate control over machining areas
- Reusable in some cases

Etchants

Etchants are **chemical solutions used to dissolve material** from the exposed portions of the workpiece.

Functions:

- React with the work material
- Remove material in a controlled manner
- Determine machining rate and surface finish

Desirable Properties:

- Uniform and controlled material removal rate (MRR)
- Minimal undercutting (sideways erosion)
- Chemical stability and reusability
- Safe handling and cost-effectiveness

Common Etchants and Applications:

- Ferric Chloride (FeCl_3) → Steel, copper
- Nitric Acid (HNO_3) → Copper, brass
- Sodium Hydroxide (NaOH) → Aluminum
- Hydrochloric Acid (HCl) → General-purpose etching

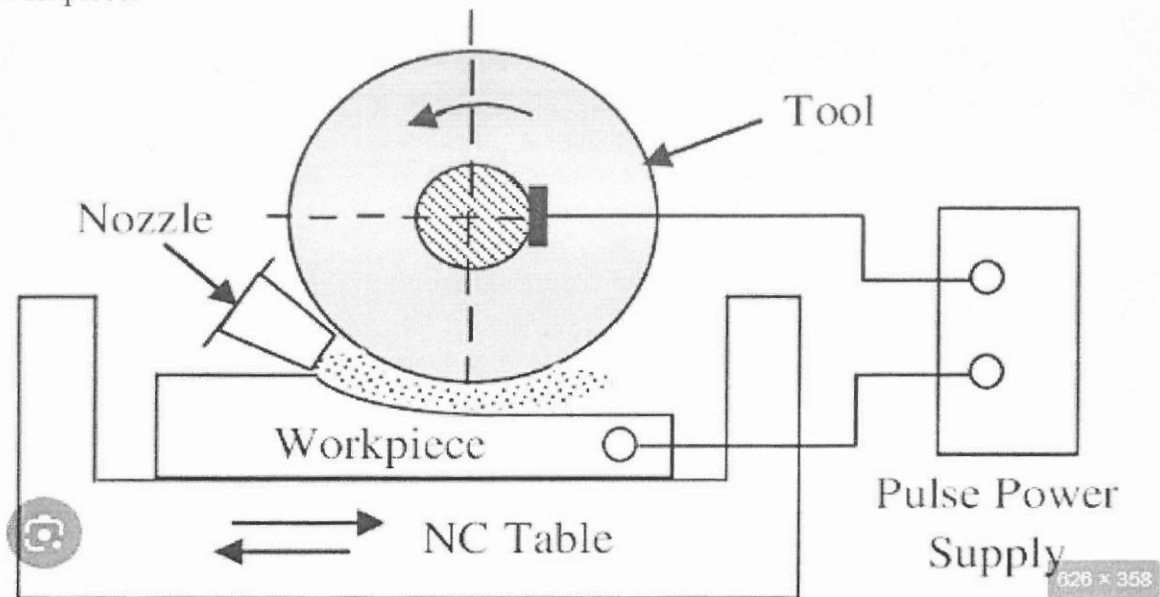
Factors Affecting Etching Process:

- Etchant concentration
- Temperature of solution
- Agitation or flow of etchant
- Time of exposure
- Material properties of the workpiece
- Chemical Machining is a **highly effective and precise machining process** for producing intricate shapes without inducing mechanical stresses. The proper selection of **maskants and etchants** plays a crucial role in achieving **accuracy, surface quality, and efficiency** in the CHM process.

8). **Interpret the Electric Discharge Grinding (EDG). Explain its working principle, advantages, limitations and applications.**

Ans) Electric Discharge Grinding (EDG) is a **non-traditional machining process** in which material is removed from an electrically conductive workpiece by **spark erosion** using a **rotating conductive grinding wheel**. It is a hybrid process combining **Electrical Discharge Machining (EDM)** and conventional grinding. Electric Discharge Grinding is an important **hybrid machining process** used for **precision machining of hard conductive materials**, offering good surface finish and accuracy, though limited by low MRR and high cost. EDG

works on the principle of **spark erosion** between a rotating grinding wheel (tool) and the workpiece.



- A **conductive grinding wheel** (metal-bonded abrasive wheel) acts as the electrode.
- The workpiece is also electrically conductive.
- Both are immersed in a **dielectric fluid** (kerosene or deionized water).
- When a voltage is applied, **controlled spark discharges** occur across a small gap.
- These sparks generate **intense heat (8000–12000°C)**, melting and vaporizing material from the workpiece.
- The rotating wheel helps in:
 - Removing debris
 - Maintaining uniform gap
 - Improving surface finish
 - Unlike conventional grinding, **material removal is mainly thermal**, not mechanical.

Construction

The EDG setup consists of:

- **Grinding Wheel (Tool):** Conductive metal-bonded abrasive wheel
- **Workpiece:** Electrically conductive material
- **Power Supply:** Pulsed DC supply
- **Dielectric Fluid:** Kerosene or deionized water
- **Servo Mechanism:** Maintains constant spark gap

Working Process

1. Workpiece and wheel are connected to the power supply.
2. A small gap is maintained between tool and workpiece.
3. Dielectric fluid is circulated continuously.
4. Pulsed voltage produces **spark discharges**.
5. Material is removed by **melting and vaporization**.
6. Debris is flushed away and the wheel rotation ensures smooth operation.

Advantages

- Can machine **very hard materials** (carbides, tool steels)
- **No mechanical contact**, hence no cutting forces
- Suitable for **thin and delicate components**
- Provides **good surface finish**
- Can produce **complex shapes and profiles**

Limitations

- Applicable only to **electrically conductive materials**
- **Low material removal rate (MRR)**
- High **equipment cost**
- Risk of **thermal damage** (recast layer, cracks)

- Requires careful parameter control

Applications

- Sharpening of **cutting tools**
- Machining of **dies and moulds**
- Finishing of **carbide parts**
- Aerospace and automotive components
- Machining of **intricate and precision components**

9a) Show the functions of dielectric fluid and its properties.

Ans) Functions of Dielectric Fluid (in EDM)

The dielectric fluid plays a vital role in the **Electrical Discharge Machining (EDM)** process:

1. **Insulation:**
Acts as an insulator until the breakdown voltage is reached, allowing controlled spark generation.
2. **Spark Conduction:**
Ionizes during machining and enables **spark discharge** between tool and workpiece.
3. **Cooling:**
Cools both the tool and workpiece, preventing excessive thermal damage.
4. **Flushing Action:**
Removes eroded particles (debris) from the spark gap.
5. **Quenching:**
Rapidly cools molten material to form a solid surface.
6. **Stabilizing the Process:**
Maintains consistent machining conditions and prevents arcing.

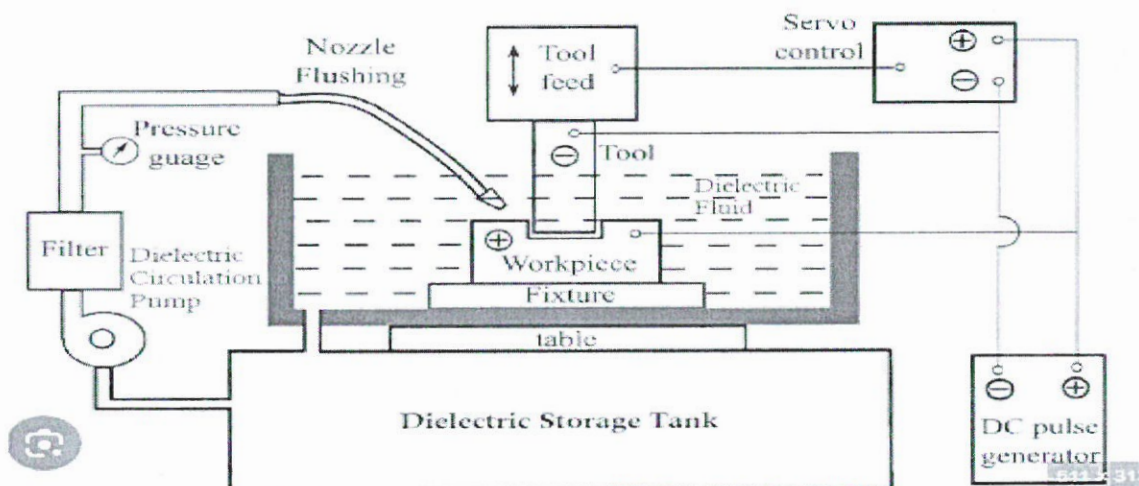
Properties of Dielectric Fluid

An ideal dielectric fluid should have:

- **High dielectric strength** (to withstand voltage before breakdown)
- **Low viscosity** (for easy flow and flushing)
- **Good cooling capacity**
- **High flash point** (safety against fire)
- **Chemical stability** (should not react with tool/workpiece)
- **Low volatility** (less evaporation loss)
- **Good insulation properties**
- **Non-toxic and economical**

9(b). What are the major process parameters in EDM and how do they affect machining?

ans) Proper selection and control of **EDM parameters and dielectric fluid** are essential for achieving **high MRR, good surface finish, and dimensional accuracy**



1. Discharge Voltage (V):

- Controls spark gap
- Higher voltage → larger gap, less accuracy

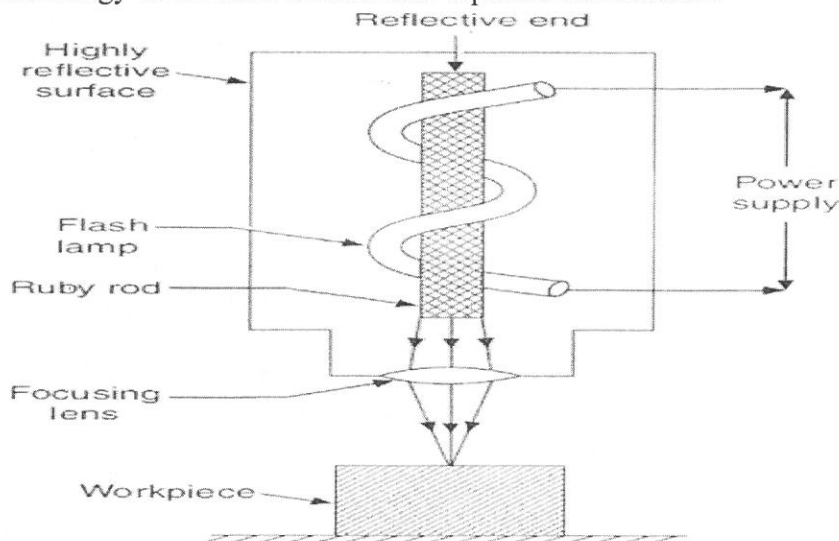
2. **Discharge Current (I):**
 - Controls spark energy
 - Higher current → higher **Material Removal Rate (MRR)** but poor surface finish
3. **Pulse ON Time (Ton):**
 - Duration of spark
 - Longer Ton → more material removal, rough surface
4. **Pulse OFF Time (Toff):**
 - Time between sparks
 - Helps in debris removal and cooling
 - Too short → unstable machining
5. **Duty Cycle:**
 - Ratio of Ton to total cycle time
 - Higher duty cycle → higher MRR
6. **Gap between Tool and Workpiece:**
 - Must be optimal for proper spark
 - Too small → short circuit
 - Too large → no spark
7. **Dielectric Pressure / Flushing Rate:**
 - Affects debris removal
 - Poor flushing → arcing and poor finish

Effect on Machining Performance

- **Material Removal Rate (MRR):**
Increases with higher current and pulse ON time
- **Surface Finish:**
Improves with lower current and shorter pulse duration
- **Tool Wear Rate (TWR):**
Increases with higher energy sparks
- **Dimensional Accuracy:**
Better at lower voltage and controlled gap

10) Illustrate the construction and working of Laser Beam Machining (LBM) with advantages, limitations and applications.(10M)

ans) Laser Beam Machining (LBM) is a non-conventional machining process that utilizes a high-energy laser beam to remove material from a workpiece. It is widely used for cutting, drilling, marking, and engraving hard materials with high precision. The process relies on the thermal energy of the laser to melt and vaporize the material.



Working Principle of Laser Beam Machining

LBM operates on the principle of converting electrical energy into light energy using a laser source. This laser beam is focused on the workpiece through a lens, generating

intense localized heat. The heat is sufficient to melt, vaporize, or ablate the material, allowing for precise machining.

Step-by-Step Working Mechanism:

1. A **laser source** (such as a ruby laser or CO₂ laser) generates a high-energy beam.
2. The **beam is amplified** and directed towards a **focusing lens**.
3. The **focusing lens converges** the laser beam onto a small spot on the workpiece.
4. The **intense heat energy** at the focal point **melts and vaporizes** the material.
5. The **vaporized material is expelled**, forming a precise cut or hole.
6. **Cooling mechanisms** or assist gases help in material removal and prevent overheating.

Process of Laser Beam Machining

The LBM process involves the following key steps:

1. **Material Preparation:** The workpiece is prepared, cleaned, and positioned under the laser.
2. **Laser Selection:** Depending on the material and application, an appropriate laser type (CO₂, Nd:YAG, fiber laser, etc.) is chosen.
3. **Focusing & Beam Control:** The laser beam is focused onto the workpiece using optical lenses.
4. **Material Interaction:** The laser interacts with the material, causing localized heating and vaporization.
5. **Machining Process:** Depending on the application, material removal occurs via melting, vaporization, or ablation.
6. **Final Finishing:** The machined surface is cleaned, and post-processing (if required) is performed.

Advantages of Laser Beam Machining

1. **High Precision & Accuracy:** LBM can create fine and intricate cuts with minimal material wastage.
2. **Non-Contact Process:** No physical contact between the tool and workpiece, reducing tool wear.
3. **Wide Range of Materials:** Can machine metals, ceramics, plastics, and composites.
4. **High Speed & Efficiency:** Faster than conventional machining processes for thin materials.
5. **Minimal Thermal Distortion:** Localized heating reduces thermal deformation.
6. **Automation Compatibility:** Can be integrated with CNC and robotic systems.
7. **Clean & Eco-Friendly:** No cutting fluids required; minimal material waste.

Applications of Laser Beam Machining

1. **Aerospace:** Cutting of turbine blades, precision drilling of cooling holes.
2. **Automotive:** Engraving, welding, and cutting of intricate components.
3. **Electronics:** Circuit board drilling, micro-machining.
4. **Medical:** Cutting surgical instruments, stents, and dental implants.
5. **Textile & Leather:** Fabric engraving and pattern cutting.
6. **Jewelry & Art:** Fine engraving and decorative design work.

Disadvantages of Laser Beam Machining

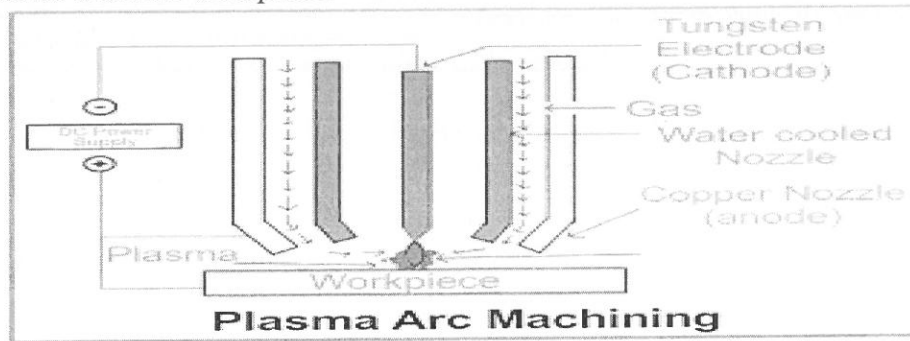
1. **High Initial Cost:** Expensive setup and maintenance costs.
2. **Limited Material Thickness:** Inefficient for very thick materials.
3. **Heat-Affected Zone (HAZ):** May cause microstructural changes in the material.
4. **Slow for Some Materials:** Metals with high reflectivity (e.g., copper, aluminum) are harder to machine.
5. **Health Hazards:** Requires protective measures due to harmful laser emissions.
6. **Energy Consumption:** High-power lasers consume significant energy.

11 a) Illustrate the working of Plasma Arc Machining (PAM). (5M)

ans) Plasma arc machining involves the removal of metal through the precise concentration of ionised gas at an extraordinarily high temperature (ranging from 11,000°C to 30,000°C) onto the workpiece. This high-velocity jet of superheated gas effectively melts and eliminates the material, allowing for efficient and accurate metal removal.

Working Principle of Plasma Arc Machining: The Plasma Arc Machining (PAM) process harnesses ionised plasma as a medium to transfer intense heat. This ionised plasma is

generated by passing gas through an electric arc formed between a cathode and anode. The resulting high-temperature plasma jet swiftly melts the metal, facilitating efficient material removal from the workpiece.



The different parts of Plasma Arc Machining are:

Plasma Gun

The Plasma Gun employs various gases, such as nitrogen, hydrogen, argon, or gas mixtures, to create plasma. It consists of a chamber housing a tungsten electrode connected to the negative terminal, while the plasma gun's nozzle links to the positive terminal of a DC power supply. Supplying the required gas mixture to the gun initiates a strong arc between the anode and cathode. This collision of electrons and gas molecules results in ionisation, generating substantial heat within the plasma.

Power Supply

Utilising a DC Power Supply, the plasma gun's two terminals are developed, creating a significant potential difference between the cathode and anode. This high potential difference ensures the generation of a robust arc, effectively ionising the gas mixture and transforming it into plasma.

Cooling Mechanism

To manage the heat generated during the process and as hot gases continuously exit the nozzle, a Cooling Mechanism is integrated into the plasma gun. This mechanism typically employs a water jacket, which envelops the nozzle, efficiently dissipating excess heat through a water jet.

Workpiece

Plasma arc machining offers the versatility to work on various materials. Different metals, including aluminium, magnesium, carbon, stainless steel, and various alloy steels, can be effectively processed using this precise and adaptable machining technique.

Construction of Plasma Arc Machining

The plasma arc cutting torch comprises a chamber with a tungsten electrode firmly fitted within. This tungsten electrode functions as the cathode and connects to the negative terminal of the DC power supply. For the process of plasma arc machining, a specialised plasma gun is essential, featuring its own chamber. Inside this chamber resides another tungsten electrode, also acting as a cathode and linked to the DC power supply's negative terminal. Positioned at the chamber's base is a copper nozzle functioning as the anode and connected to the positive terminal of the DC power supply.

The remaining portion of the chamber is constructed from insulating material to serve as an insulator. Gas is introduced into the chamber through a small passage located on the right side. Remarkably, both the cathode and anode maintain their coolness despite the hot gases flowing through them, owing to effective water cooling. A well-designed water circulation system surrounds the torch, ensuring efficient cooling during operation.

Working of Plasma Arc Machining

- When DC power is applied to the circuit, a potent arc emerges between the cathode (electrode) and the anode (nozzle). Subsequently, gas is introduced into the chamber, selected from options like hydrogen, nitrogen, argon, or a mixture tailored to the specific metal being worked upon. The gas is then heated to extraordinarily high temperatures, ranging from 11,000°C to 28,000°C, utilising the arc formed between the cathode and anode. As the arc interacts with the gas, electrons collide with gas molecules, causing them to dissociate into individual atoms.

- Due to the arc's intense heat, certain atoms lose their electrons, leading to ionisation, thereby transforming the gas into plasma—an electrically charged state. This ionised gas releases a significant amount of thermal energy. Directed towards the workpiece with high velocity, the plasma jet benefits from the electric arc in several ways. It further elevates the ionised gas's temperature, almost aligns the beam in parallel, and enhances the gas's velocity.
- Upon reaching the workpiece, the plasma jet efficiently melts the material, while the high-velocity gas effectively blows away the molten metal. This process of plasma arc machining effectively removes material from the workpiece, demonstrating its remarkable utility in various industrial applications.

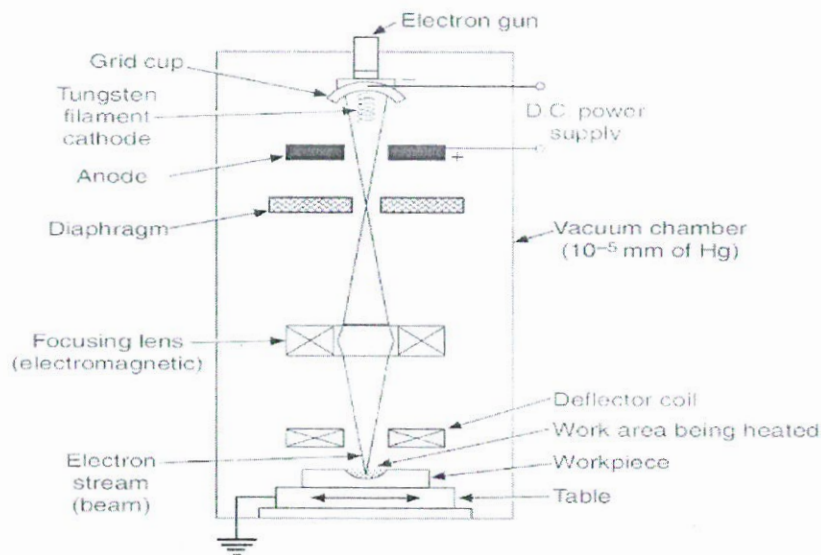
Applications

- Cutting of stainless steel, aluminum, copper
- Used in shipbuilding and aerospace industries
- Profile cutting of thick plates
- Welding applications

11(b). Articulate the theory of material removal in Electron Beam Machining (EBM). (5M)

Electron Beam Machining (EBM) is an advanced, non-conventional machining process that utilizes a high-velocity electron beam to remove material from a workpiece. It is widely used for precision micromachining, drilling, and cutting applications in industries where high accuracy and fine details are required. EBM is particularly effective for hard, brittle, and heat-sensitive materials, making it a preferred choice for aerospace, automotive, medical, and semiconductor industries.

Electron Beam Machining (EBM) is a thermal material removal process where a focused beam of high-energy electrons is directed onto a workpiece. The kinetic energy of the electrons is converted into thermal energy upon impact, melting and vaporizing the material to achieve precise machining.



1. **Electron Gun:** Generates high-velocity electrons using a tungsten filament cathode.: Operates under high vacuum conditions.
2. **Grid Cup:** Controls the flow of electrons from the cathode to prevent unwanted emissions.
3. **Anode:** Accelerates and directs the electron beam toward the workpiece.
4. **Diaphragm:** Eliminates stray electrons to refine the beam.
5. **Focusing Lens (Electromagnetic):** Condenses the electron beam to a fine point for high precision.
6. **Deflector Coil:** Adjusts the position of the beam to control machining location.
7. **Workpiece Table:** Holds and moves the workpiece accurately for machining.

8. **Vacuum Chamber:** Maintains a high vacuum ($\sim 10^{-5}$ mm of Hg) to prevent electron scattering and oxidation.

Working Principle of Electron Beam Machining

The working principle of EBM is based on the conversion of kinetic energy from high-speed electrons into heat energy upon striking the workpiece. The heat generated melts and vaporizes the material, forming a small hole or cut.

Step-by-Step Working of Electron Beam Machining

1. **Generation of Electron Beam:** The electron gun generates a beam of high-velocity electrons using a tungsten filament as a cathode.: A high-voltage DC power supply energizes the electrons.
2. **Acceleration of Electrons:** The electrons are accelerated to nearly half the speed of light using a high-voltage potential difference (typically 50 kV to 200 kV). The anode attracts and aligns the electrons into a coherent beam.
3. **Focusing the Electron Beam:** The beam passes through a diaphragm to eliminate stray electrons. An electromagnetic focusing lens concentrates the beam to a very small diameter, increasing energy density.
4. **Deflection and Positioning:** Electromagnetic deflection coils guide and position the beam on the workpiece to ensure accurate machining.
5. **Material Removal by Vaporization:** The electron beam impacts the workpiece in a vacuum chamber, where its kinetic energy transforms into thermal energy. The intense localized heating causes material to vaporize instantly, forming a hole or cut.
6. **Workpiece Movement and Machining Control:** The workpiece can be moved precisely using CNC-controlled tables for complex machining operations.
7. **Final Machined Product:** The resulting cut or drilled hole is highly precise, with minimal heat-affected zones and negligible tool wear.

Advantages of Electron Beam Machining

1. **High Precision and Accuracy:** EBM can achieve micro-level machining with high dimensional accuracy.
2. **No Mechanical Contact:** Since EBM is a non-contact process, there is no tool wear, reducing maintenance costs.
3. **Ideal for Hard and Brittle Materials:** Works efficiently on materials like tungsten, ceramics, titanium, and superalloys.
4. **Minimal Heat-Affected Zone (HAZ):** The high energy density and short interaction time minimize thermal damage to the surrounding material.
5. **Excellent Surface Finish:** Produces smooth and clean cuts without burr formation.
6. **Ability to Machine Small and Thin Materials:** Suitable for micro-machining and delicate components.
7. **No Need for Cutting Tools:** Eliminates the cost of cutting tools and tool replacement.

Applications of Electron Beam Machining

1. **Aerospace Industry:** Machining of turbine blades, fuel injector nozzles, and precision components.
2. **Automotive Industry:** Fabrication of fuel injection parts and lightweight structural components.
3. **Medical Industry:** Precision cutting of surgical tools and stents.
4. **Semiconductor Industry:** Micromachining of electronic components and micro-holes.
5. **Nuclear Industry:** Machining of radioactive and high-temperature materials.
6. **Defense and Military:** Manufacturing of missile components, jet engine parts, and advanced weaponry.

Disadvantages of Electron Beam Machining

1. **High Initial Cost:** Requires expensive vacuum systems, high-voltage generators, and electron guns.

2. **Vacuum Requirement:** The entire process must take place in a vacuum chamber, limiting large-scale applications.
3. **Limited to Conductive Materials:** Cannot be used for non-conductive materials like plastics and certain ceramics.
4. **Slow Machining Speed:** The process is slower compared to traditional machining methods like laser cutting.
5. **Skilled Operator Required:** Needs highly trained personnel for operation and maintenance.
6. **Small Workpiece Size Limitation:** Only feasible for small or medium-sized components due to vacuum chamber constraints.