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Internal Assessment Test 3 – July 2023

Sub:	Nontraditional machining					Sub Code:	18ME64	Branch:	ME
Date:	05.07.2023	Duration:	1.30 hour	Max Marks:	50	Sem / Sec:	VI/A		OBE

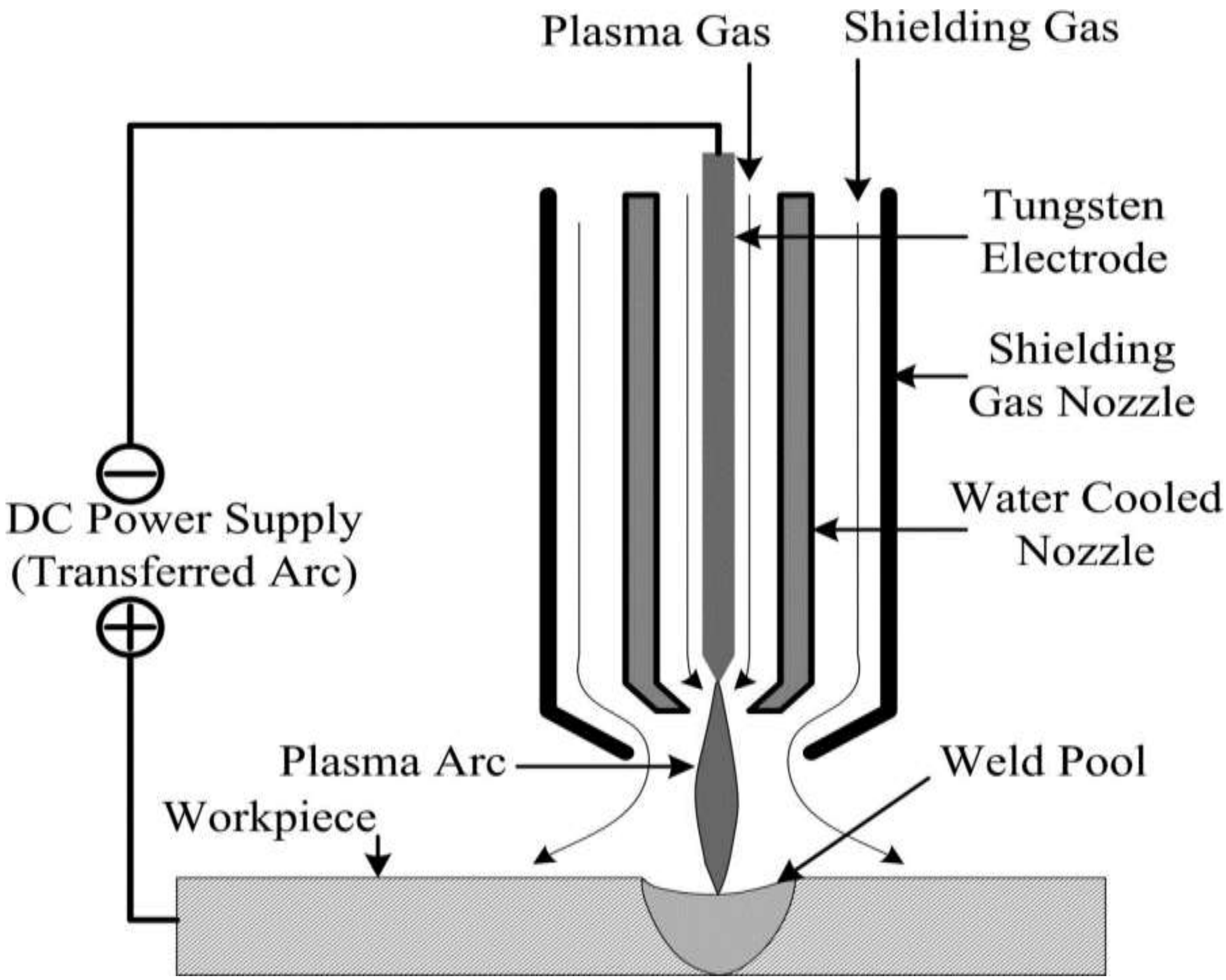
Answer any FIVE Questions

		MARKS	CO	RBT
1	Explain PAM with a neat sketch.	[10]	CO4	L2
2	Explain LBM with a neat sketch	[10]	CO5	L2
3	Explain EBM with a neat sketch	[10]	CO5	L2
4	Write short notes on a. Generation of Laser b. Laser materials c. Beam current in EBM d. Mechanism of material removal in LBM e. Mechanism of material removal in EBM	[10]	CO5	L2
5	Briefly discuss different types of plasma torch with neat sketch (any two types)	[10]	CO4	L2
6.	Briefly discuss advantages, limitations and applications of LBM and EBM process	[10]	CO5	L2

Scheme of Evaluation

Question number	Particulars	Marks distribution
1.	Sketch Working process Advantages and disadvantages	4 marks 4 marks 2 marks
2.	Sketch Working process Advantages and disadvantages	4 marks 4 marks 2 marks
3.	Sketch Working process Advantages and disadvantages	4 marks 4 marks 2 marks
4.	a. Generation of Laser b. Laser materials c. Beam current in EBM d. Mechanism of material removal in LBM e. Mechanism of material removal in EBM	2 marks each

5.	Each torch	5 marks each
6.	Advantages and disadvantages of LBM Advantages and disadvantages of EBM	5 marks 5 marks



- PAC system uses DC power source. PAC systems operate either on non-transferred arc mode or transferred arc mode (Fig. 9.1).
- In non-transferred arc mode, the thermal efficiency is low (65-75%) and power is transferred between the electrode and the nozzle. This non-transferred arc ionizes a high velocity gas that is streaming towards the work piece.
- The work piece may be electrically conductive or non-conductive.
- The torch is the holder of the consumable electrode and nozzle.
- Responsible for forming the arc and maintain it in a vortex
- Constant DC current source.
- Speed and cut thickness are determine by the amount of output current.
- High frequency generator circuit that produces a high AC Current.
- To start the arc, the AC current ionizes the cutting gas, which makes it conductive to allow the DC current to flow through it
- Plasma is the glowing, ionized gas that results from heating of a material to extremely high temperature.
- It is composed of free electrons dissociated from the main gas atoms.
- A gas in plasma state becomes electrically conductive as well as responsive to magnetism. Because of such behavior, plasma is also known as *a fourth state of matter*.

- The temperature of plasma can be of the order of 33,000°C.
- When such a high temperature source reacts with work material, the work material melts out and may even vaporize, and finally is cut into pieces.
- Many materials (say, aluminium, stainless steel, etc) have high thermal conductivity, large heat capacity, and/or good oxidation resistance. As a result, such materials cannot be cut by conventional techniques like oxy-fuel cutting.
- But these materials can be easily cut by plasma arc cutting (PAC).

Advantages

- Cuts any metal.
- 5 to 10 times faster than oxy-fuel.
- 150 mm thickness ability.
- Easy to automate.

Disadvantages

- Large heat affected zone.
- Rough Surfaces
- Difficult to produce sharp corners.
- Smoke and noise.
- Burr often results

1. Lasing process describes the basic operation of laser, i.e. generation of coherent beam of light by “light amplification” using “stimulated emission”.

- In the model of atom, negatively charged electrons rotate around the positively charged nucleus in some specified orbital paths.
- The geometry and radii of such orbital paths depend on a variety of parameters like number of electrons, presence of neighbouring atoms and their electron structure, presence of electromagnetic field etc. Each of the orbital electrons is associated with unique energy levels.
- At absolute zero temperature an atom is considered to be at ground level, when all the electrons occupy their respective lowest potential energy.
- The electrons at ground state can be excited to higher state of energy by absorbing energy from external sources like increase in electronic vibration at elevated temperature, through chemical reaction as well as via absorbing energy of the photon.
- Fig. 1 depicts schematically the absorption of a photon by an electron. The electron moves from a lower energy level to a higher energy level.
- On reaching the higher energy level, the electron reaches an unstable energy band. And it comes back to its ground state within a very small time by releasing a photon. This is called **spontaneous emission**.
- In operation, when the xenon flash tube is connected to a pulsed high voltage source, the inert gas *xenon* transforms the electrical energy into white light flashes (light energy).

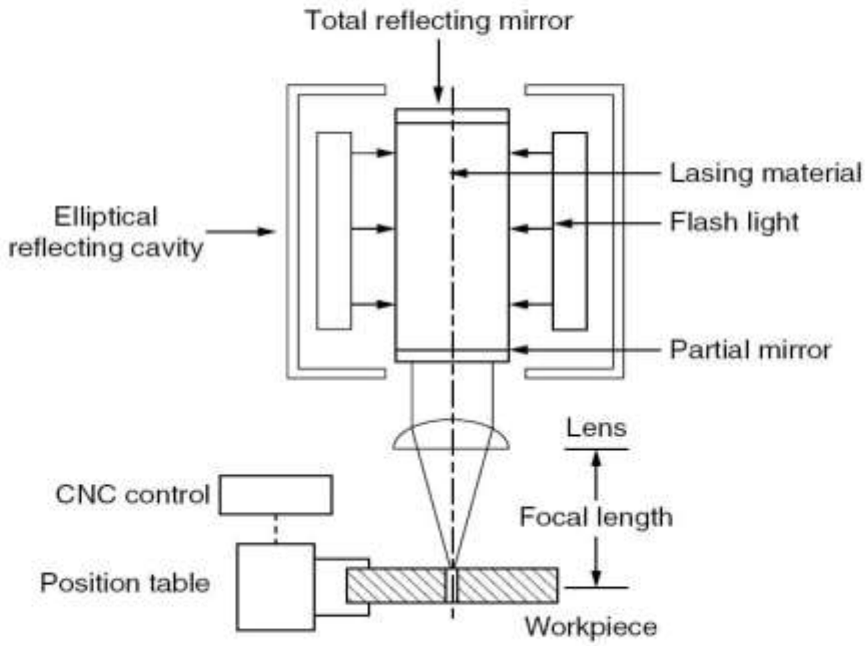
- Since the ruby crystal is exposed to the intense light flashes, the chromium atoms of the crystal are excited and jumped to a high-energy level.
- These chromium atoms immediately drop to an intermediate energy level with the evolution of heat and eventually drop back to their original state with the evolution of a discrete quantity of radiation in the form of *red fluorescent light.*
- As the red light emitted by one excited atom hits another excited atom, the second atom gives off red light, which is in phase with the colliding red light wave.
- The effect is enhanced as the silvered ends of the ruby crystal cause the red light to reflect back and forth along the length of the crystal.
- The chain reaction collisions between the red light wave and the chromium atoms become so numerous that, finally the total energy bursts and escapes through the tiny hole as a *laser beam.*
- The beam is focused with a simple lens to obtain high power densities in small areas of the work surface.
- The intense heat of the laser beam is used to melt and, or evaporate the work piece material being cut.
- A stream of gas, like oxygen, nitrogen or argon is often used to blow the molten metal through the cut, cool the work piece and minimize the heat affected zone.
- The type of gas used depends on the work piece material being cut.
- Oxygen is used for mild steel work pieces, nitrogen or oxygen for stainless steel; nitrogen for aluminum, and inert gas like argon for titanium metals.
- The table carrying the work piece can be moved in three dimensions with respect to the laser beam to obtain the desired profile of cut on the work piece.

Advantages OF LBM:

- Any material, including non-metals, and irrespective of their hardness and brittleness can be machined by laser.
- Apart from cutting, drilling and welding materials, lasers can also be used for marking, scribing, heat- treating of surfaces and selectively clad materials.

DISADVANTAGES OF LBM

- Costlier
- Low thermal efficiency
- Low metal removal rates
- Process is limited to thin parts
- High reflectivity materials are difficult to machine
- Difficult to drill exact round holes



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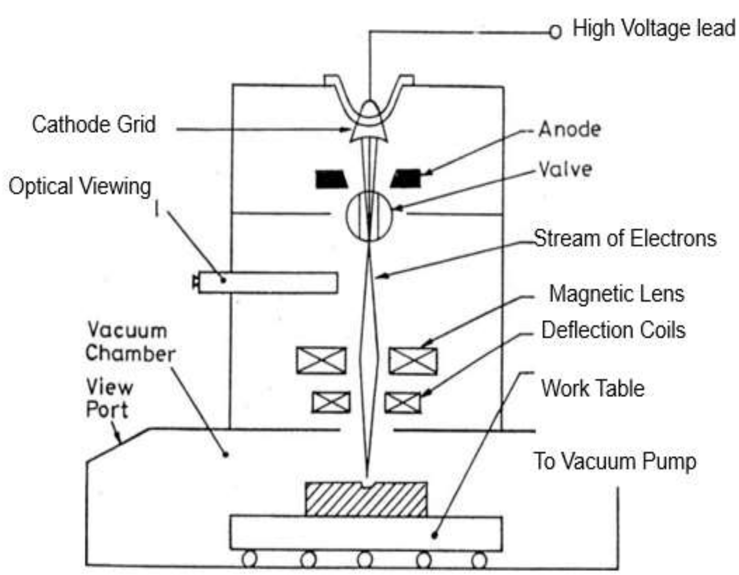

Schematic diagram of **EBM** system.

- There are three important elements of EBM system, viz
- Vacuum system,
- Electron beam gun
- Power supply.
- Electron beam machining (EBM) process is classified into two categories *'Thermal type'* and *'Non-thermal type'*.

- In the thermal type EBM process, the surface of thermo electronic cathode is heated to such a high temperature that the electrons acquire sufficient speed to escape out to the space around the cathode.
- The stream of these large number of electrons moves as a small diameter beam of electrons towards the anode.
- As a result, the work piece is heated by the bombardment of these electrons in a localized area, to such a high temperature that it is melted and vaporized at the point of bombardment.
- In the second type *(non-thermal* EBM) process, the electron beam is used to cause a chemical reaction.
- When the high velocity beam of electrons strikes the work piece, the kinetic energy of electrons converts into heat which is responsible for melting and vaporization of work piece material.
- This process can produce any shape of hole; however, round holes are usually drilled in metals, ceramics, plastics, etc.
- It can machine electrically conducting as well as non-conducting materials. Before machining starts, vacuum is created in the machining chamber.
- The diameter of the electron beam focused onto the work should be slightly smaller than the desired hole diameter.
- As the electron beam strikes the work-piece, the material gets heated, melted and partly vaporized.
- On the exit side of the hole, the *synthetic or organic backing material* is used.
- The electron beam after complete penetration into the work piece, also partly penetrates in the auxiliary backing material. The backing material vaporizes and comes out of hole at a high pressure.
- The molten material is also expelled along with the vaporized backing material.
- In case of a *non-circular hole* to be produced, the electron beam is deflected with the help of the *computer control,* along the perimeter of the hole to be produced.
- As an alternative method, the beam can be kept stationary but the work-table can be moved in the desired path with the help of CNC.

Advantages of EBM

1. This process can machine small diameter holes (0.1 to 1.4 mm) to a large depth (say, 10 mm) or in other words, a hole with high *aspect ratio* (up to 15:1).
2. This process can be used to machine both electrically conductive as well as non-conductive materials.
3. No mechanical force is applied on the job; hence fragile (or brittle), thin, and/or low strength workpieces can be easily machined. *Off-the-axis holes* (or inclined holes) can also be machined by this process.
4. EBM process is not significantly influenced by the properties (physical, mechanical and metallurgical) of workpiece material.

Limitations of EBM

1. Very high temperature gradient would result in *residual thermal stresses.*
2. Another limitation of the process is very high cost of the equipment.

3. The operator also should be skilled one.
4. The quality of the edges produced is determined by the thermal properties of the workpiece material and the pulse energy.
5. The heat affected zone (HAZ) depends upon pulse duration and the diameter of the hole being drilled.
6. Application of the process is possible only for specializeddrilling operations.
7. For deeper penetrations vacuum is essential.

4. a. Generation of Laser

- Lasing process describes the basic operation of laser, i.e. generation of coherent beam of light by "light amplification" using "stimulated emission".
- In the model of atom, negatively charged electrons rotate around the positively charged nucleus in some specified orbital paths.
- The geometry and radii of such orbital paths depend on a variety of parameters like number of electrons, presence of neighbouring atoms and their electron structure, presence of electromagnetic field etc. Each of the orbital electrons is associated with unique energy levels.
- At absolute zero temperature an atom is considered to be at ground level, when all the electrons occupy their respective lowest potential energy.
- The electrons at ground state can be excited to higher state of energy by absorbing energy from external sources like increase in electronic vibration at elevated temperature, through chemical reaction as well as via absorbing energy of the photon.
- On reaching the higher energy level, the electron reaches an unstable energy band. And it comes back to its ground state within a very small time by releasing a photon. This is called **spontaneous emission**.

b. Laser Materials

- Many materials can be used as the heart of the laser. Depending on the lasing medium lasers are classified as solid state and gas laser.
- Solid-state lasers are commonly of the following type
  - Ruby which is a chromium – alumina alloy having a wavelength of 0.7 μm
  - Nd-glass lasers having a wavelength of 1.64 μm.
  - Nd-YAG laser having a wavelength of 1.06 μm.

(Nd-YAG stands for neodymium-doped yttrium aluminium garnet; **Nd:$Y_3Al_5O_{12}$**)

- These solid-state lasers are generally used in material processing.
- The generally used gas lasers are:
  - Helium – Neon
  - Argon
  - CO_2 etc.
- Lasers can be operated in continuous mode or pulsed mode. Typically CO_2 gas laser is operated in continuous mode and Nd – YAG laser is operated in pulsed mode.

c. Beam current in EBM

- Beam current varies from 100 uA to 1A and it governs the energy/pulse being supplied to the workpiece.
- Higher the energy/pulse more rapidly the hole can be drilled. Pulse duration during EBM varies in the range of 50 us to 10 ms depending upon the depth and diameter of the hole to be drilled.
- Drilling using longer pulse duration results in a wider and deeper drilled hole. It also affects HAZ as well as the thickness of the recast layer which is normally 0.025 mm or less. The extent of both these effects should be minimum possible.

d. Mechanism of material removal in LBM

- As laser interacts with the material, the energy of the photon is absorbed by the work material leading to rapid substantial rise in local temperature. This in turn results in melting and vaporisation of the work material and finally material removal.
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e. Mechanism of material removal in EBM

- The diameter of the electron beam focused onto the work should be slightly smaller than the desired hole diameter.
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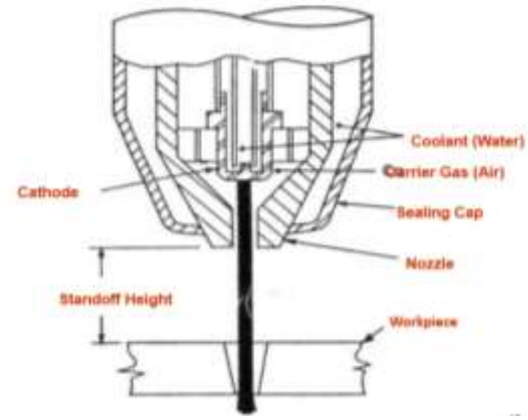
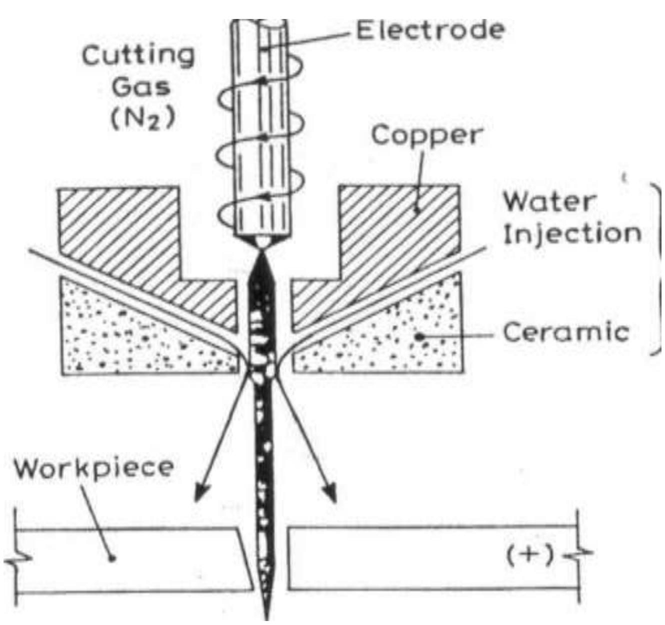
5. Air Plasma

- ➢ Air plasma torch uses compressed air as the gas that ionizes and does cutting.
- ➢ The air to be used should be uncontaminated.
- ➢ The nozzle of this torch may result in prematured failure because of double arcing i.e, arcing between the electrode and the nozzle, and between the nozzle and the work piece.
- ➢ Zirconium or hafnium are used as electrode material because of their higher resistance to oxidation.



Water injected torch

- Water (pressure =1.2 MPa) is injected (radially or swirling vertically) to constrict the plasma. A small quantity (about 10%) of water vaporizes. This thin layer of steam constricts the plasma and also insulates the nozzle. Nitrogen at about 1 MPa is used as the plasma.
- To avoid double arcing, the lower part of the nozzle is made of ceramic.
- Water constriction helps in reducing smoke, enhancing nozzle life, reducing HAZ, and limiting formation of oxides on the cut edges of the workpiece.
- Water muffler (a device that produces a covering of water around the plasma torch and extends down to the work surface) helps in reducing smoke and noise.
- Water mixed with a dye also absorbs part of the ultraviolet rays produced in PAC.
- In some cases, a water table is also used to reduce the level of noise and extent of sparks. Water below the workpiece quenches sparks and damps sound level.
- Underwater PAC systems are also available which effectively reduce the noise and smoke levels.



Constructional details of water-injected plasma torch

6. Advantages OF LBM:

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APPLICATIONS OF LBM

- Laser beam machining is used to perform precision micro- machining on all materials such as steel, ceramic, glass, diamond, graphite etc. it is used for cutting, drilling, welding of materials, marking, scribing, heat treating of surfaces and selectively clad materials.

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4. The quality of the edges produced is determined by the thermal properties of the workpiece material and the pulse energy.
5. The heat affected zone (HAZ) depends upon pulse duration and the diameter of the hole being drilled.
6. Application of the process is possible only for specialized drilling operations.

Applications of EBM

- EBM is more popular in industries like *aerospace, insulation*, *food processing, chemical, clothing, etc.*
- It is very useful in those cases where number of holes (simple as well as complex shaped) required in a work piece may range from *hundreds to thousands* (perforation of sheets, etc).
- This Process is also used for drilling thousands of holes (diameter < 1.00 mm) in very thin plates used for turbine engine combuston domes.
- Many thousand holes (diameter < 1.0 mm) in a cobalt alloy fiber spinning head of thickness around 5 mm are drilled by EBM.