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Internal Assessment Test 3 – JULY. 2022

Sub:	Nontraditional machining				Sub Code:	18ME641	Branch:	ME
Date:	09.07.22	Duration:	90 min's	Max Marks: 50	Sem / Sec:	VI/A&B		OBE

Answer any FIVE FULL Questions

		MARKS	CO	RBT
1	Explain the different types plasma torch with neat sketch	[10]	CO4	L2
2	Briefly explain generation of laser and different types of lasing materials used in LBM	[10]	CO5	L2
3	Explain with neat sketch the working of Plasma arc machining and also mention its advantages and disadvantages	[10]	CO4	L2
4	List the advantages, limitations and applications of EBM	[10]	CO5	L2
5	Explain with neat sketch the working of Laser beam machining	[10]	CO5	L2
6.	Explain with neat sketch the working of Electron beam machining process	[10]	CO5	L2

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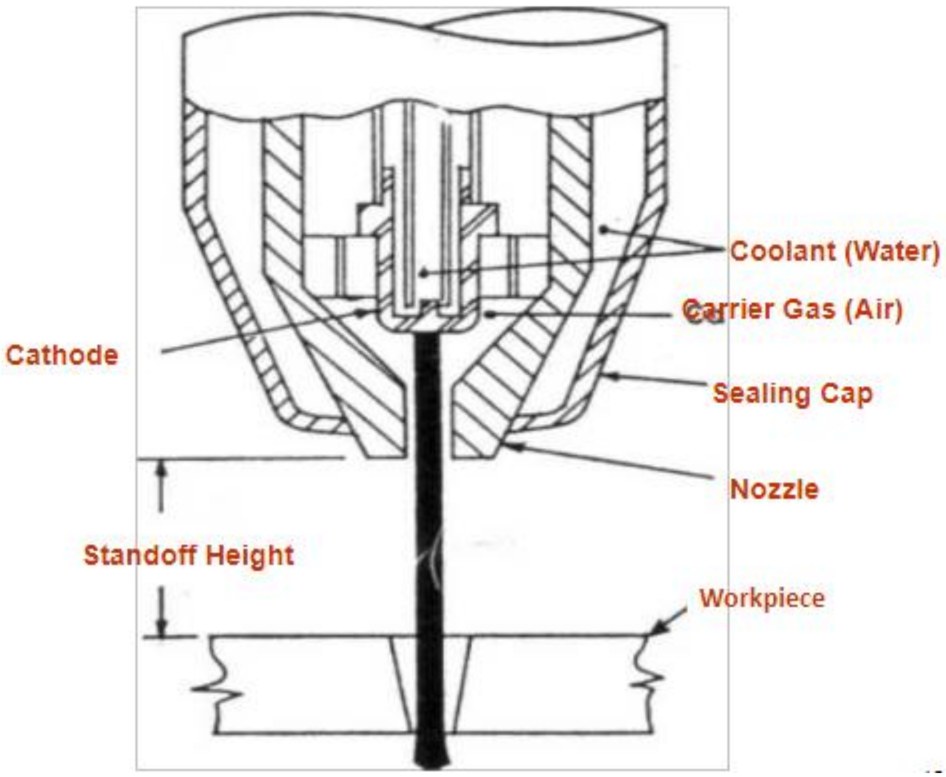
Scheme of Evaluation

Question number	Particulars	Marks distribution
1.	Sketch Working process	5 marks 5 marks
2.	Generation of laser Lasing materials	5 marks 5 marks
3.	Sketch Working process Advantages and disadvantages	4 marks 4 marks 2 marks
4	Advantages Limitations Applications	3 marks 3 marks 4 marks
5.	Sketch Working process Advantages and disadvantages	4 marks 4 marks 2 marks
6.	Sketch Working process Advantages and disadvantages	4 marks 4 marks 2 marks

1. There are many torch designs which are practically used, for example
   - Air plasma
   - oxygen injected
   - dual gas
   - water injected plasma torch.

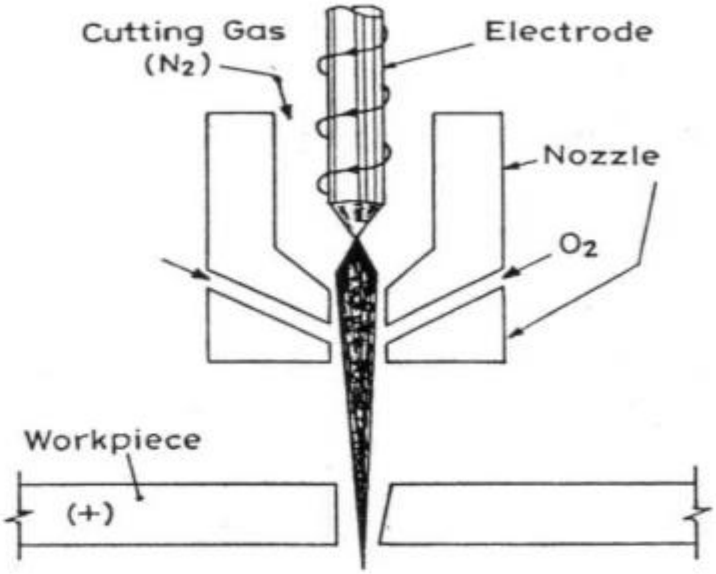
Air plasma

- 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.



Oxygen injected

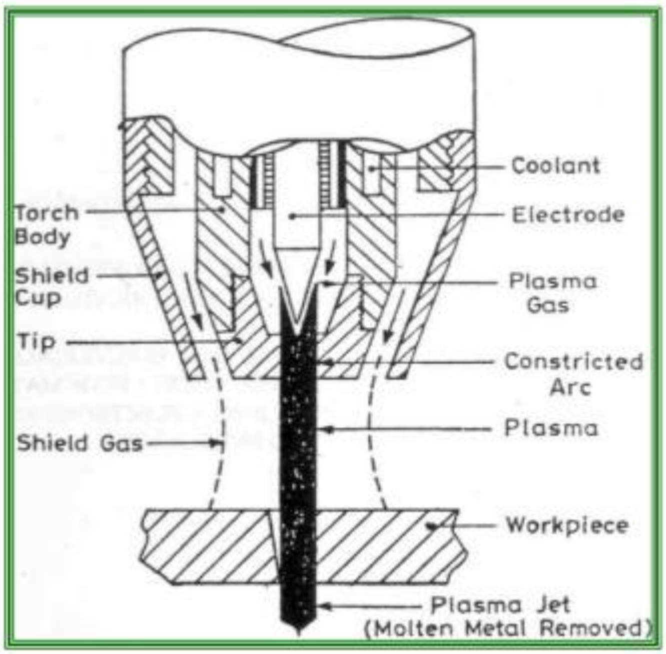
- To avoid oxidation of electrode (or to enhance the life of the electrode), oxygen injected torch (Fig. 9.3) uses nitrogen as the plasma gas.
- Oxygen is injected downstream of the electrode. However, it lowers down the nozzle life. This torch gives high MRR and poor squareness of the cut edges. It is commonly used for mild steel plate cutting.
- The presence of oxygen in the air helps in increasing MRR in case of oxidizable materials like steel.



Schematic diagram of oxygen-injected torch construction.

Dual gas system

It uses one gas (nitrogen) as the plasma gas while another gas as the shielding gas (0_2, $C0_2$, argon-hydrogen, etc). Secondary or shielding gas is chosen according to the material to be cut. Secondary gas system helps in maintaining sharp corners on the top side of the cut edges.

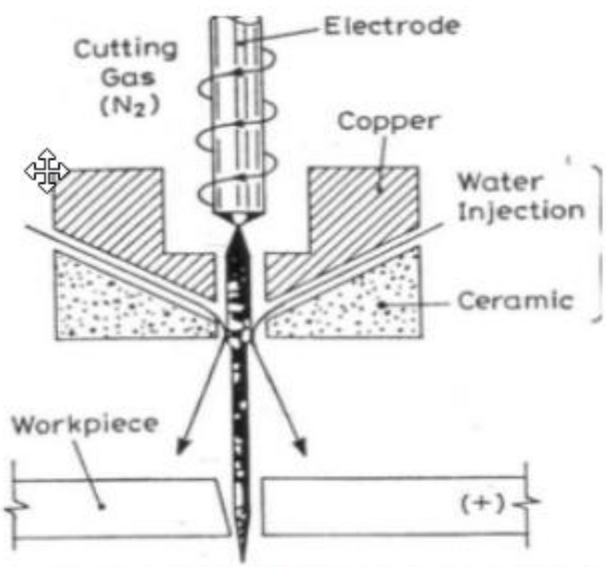


Constructional details of dual gas plasma torch

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

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

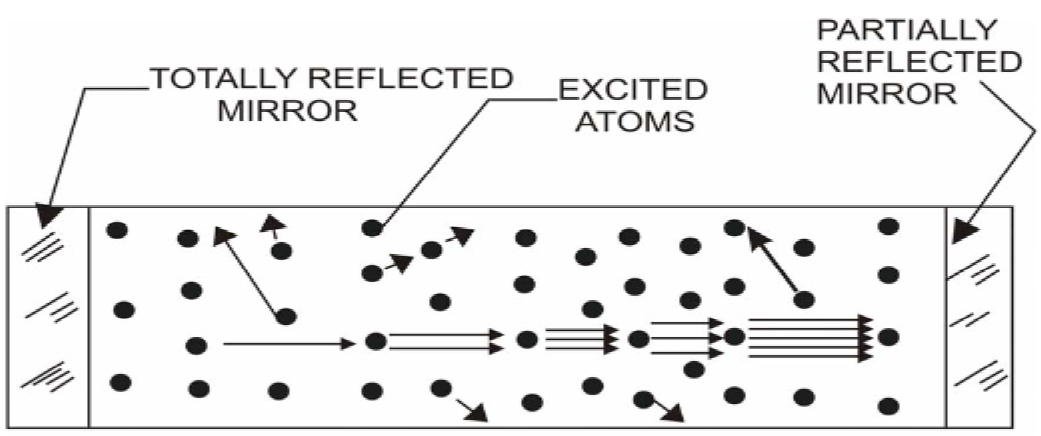


Fig. 3 schematically shows working of a laser.

Fig. 3 Lasing Action

- There is a gas in a cylindrical glass vessel. This gas is called the lasing medium.

- One end of the glass is blocked with a 100% reflective mirror and the other end is having a partially reflective mirror. Population inversion can be carried out by exciting the gas atoms or molecules by pumping it with flash lamps.

- Then stimulated emission would initiate lasing action. Stimulated emission of photons could be in all directions.

- Most of the stimulated photons, not along the longitudinal direction would be lost and generate waste heat. The photons in the longitudinal direction would form coherent, highly directional, intense laser beam.
- 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.

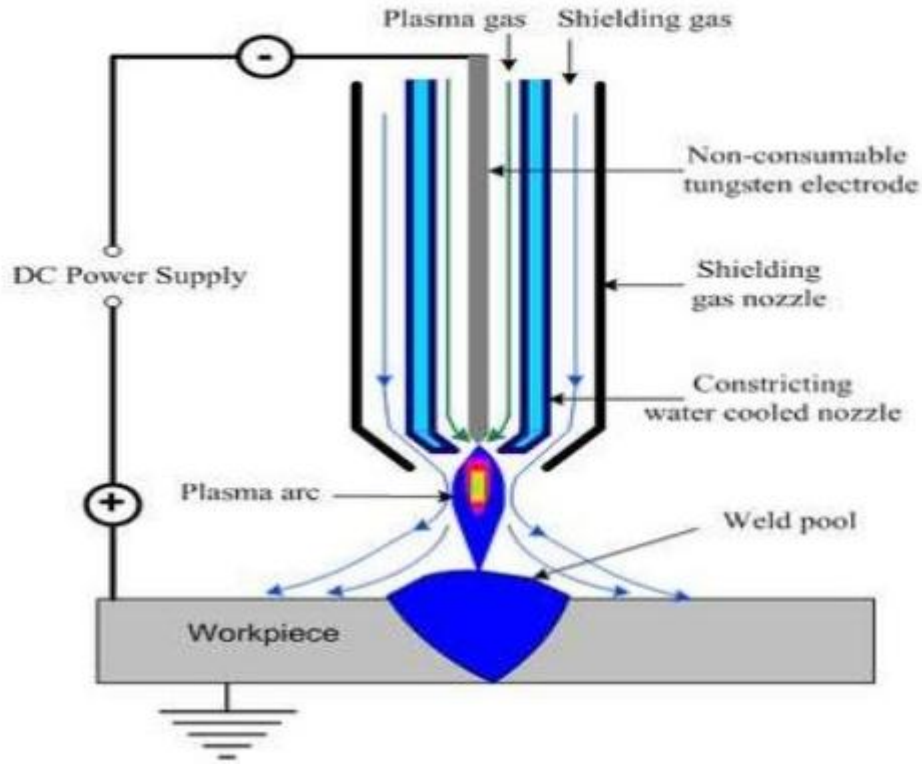
  Lasing materials

- 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.

3. Principle of Plasma Arc Machining
   - A high frequency spark is used to initiate a pilot arc between the tungsten electrode (cathode) and the copper nozzle (anode) both of which are water cooled.
   - Pilot arc is then cut off and the external arc generates a plasma jet which exists from the nozzle at high velocity.
   - Plasma jet heats the workpiece by striking with electrons and by transfer of energy from high temperature, high energy gas.
   - The heat is effective in cutting the workpiece upto thickness of 50mm.
     Construction
   - The equipment can be used to machine a wide range of materials and thickness by suitable adjustments of power level, gas tight, gas flow rate, speed.
   - The direct current is supplied to the tungsten electrode (cathode) from the power supply.
   - The tungsten electrode is heated to a very high temperature and generates high frequency spark.
   - A high frequency spark initiates a pilot arc between the tungsten electrode (cathode) and the copper nozzle (anode).
   - Gas is supplied to the ceramic chamber through plasma gas inlet at high velocity. Due to the heat liberated from the tungsten electrode gas is heated to a very high temperature. The collision between atoms increases and results with ionization.
   - Increase in collision causes pilot arc to cut off and the external arc generates a plasma jet which exit from the nozzle at high velocity. Plasma jet strikes the work piece and heats the surface. The heat produced melts the workpiece and the velocity gas stream blows the molten metal away.

PLASMA ARC MACHINING



Mechanism of Material removal

- The metal removal in plasma arc machining is basically due to the high temperature produced.
- The heating of workpiece is as a result of anode heating, due to direct electron bombardment plus convection heating from the high temperature plasma that accompanies the arc.
- The heat produced is sufficient to raise the workpiece temperature above its melting point and the high velocity gas stream effectively blows the molten metal away.
- Under optimum conditions, upto approximately 45% of the electrical power delivered to the torch is used to remove metal from the workpiece.
- Plasma arc cutting was primarily employed to cut metals that form a refractory oxide outer skin.
- The arc heat is concentrated on a localized area of the workpiece and it raises it to its melting point.
- The quality of cut is affected by the heat flow distribution; uniform heat supply throughout the thickness of the material produces a cut of excellent quality.

Advantages:

- Any material, regardless of its hardness and refractory nature can be efficiently and economically machined.
- Faster cutting speeds due to high velocity and high temperature of cutting gas.
- Requires minimal operator training.
- Process variables such as type of gas, power, cutting speed, etc, can be adjusted for each metal type.
- As there is no contact between tool and work piece a simply supported workpiece is adequate.

Disadvantages:

- High equipment cost.

- The high temperature, high velocity impinging gas causes metallurgical alterations in the workpiece material.
- Shielding and noise protection adds additional equipments and also burden on the operator's precautions.

4. **Advantages of EBM**

- EBM can effectively cut very thin holes of large aspect ratio. It can cut almost any programmable hole shape.
- It can use for machining of both metal and non-metal.
- EBM is precise and distortion free. It can achieve micro finishing.
- EBM does not apply direct force/ pressure on workpiece, so brittle and fragile material can be machined without the danger of fracture.
- It is used to the machining of highly reactive metals under vacuum.
- EBM can be used to cut holes and slots in metal, ceramic, plastic etc.

EBM limitations

- EBM is expensive; it involves high capital cost. Maintenance cost is also high.
- Vacuum must be provided to reduce contamination.
- The EBM requires a vacuum. The time need for evacuating chamber is also included in the time of manufacturing.
- Since EBM is done in a vacuum, there is a limit to the size of components to be handle.
- Even though the shorter pulse reduces the heat effecting zone, there is still some thermal effect may remain in the machined edges.
- The metal removal rate is very low when compared to other methods.
- A highly skilled operator is required.

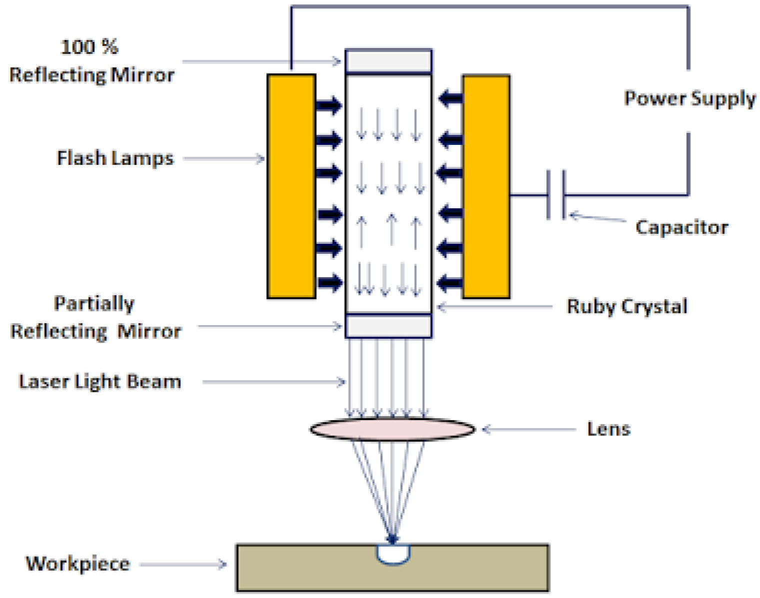
EBM applications

EBM now found application in many industrial equipments. Special characteristics of EBM, such as high-resolution long depth of field, make them suited for specific application. Other special characterises are their extraordinary high energy, controllability and compatibility with high vacuum. It also has the ability to catalyse many chemical reactions. EBM is used to cut and hole making on thin material. Hole drilling is the main application of EBM (e.g. wire drawing dies, making of the fine gas orifice). It can cut thin hole and slots in metals, plastics and ceramics of any hardness. It finds application in food, chemical, aerospace, textile, and automobile industries.

5. **Laser Beam Machining (LBM)** is a form of machining process in which laser beam is used for the machining of metallic and non-metallic materials. In this process, a laser beam of high energy is made to strike on the workpiece; the thermal energy of the laser gets transferred to the surface of the workpiece. The heat so produced at the surface heats melts and vaporizes the materials from the workpiece. Light amplification by stimulated emission of radiation is called **LASER**.

It works on the principle that when a high energy laser beam strikes the surface of the workpiece. The heat energy contained by the laser beam gets transferred to the surface of the workpiece. This heat energy absorbed by the surface heat melts and vaporizes the material from the workpiece. In this way the machining of material takes place by the use of laser beam.

The various main parts used in the laser beam machining are



1. A pumping Medium: A medium is needed that contains a large number of atoms. The atoms of the media are used to produce lasers.
2. Flash Tube/Flash Lamp: The flash tube or flash lamp is used to provide the necessary energy to the atoms to excite their electrons.
3. Power Supply: A high voltage power source is used to produce light in flashlight tubes.
4. Capacitor: Capacitor is used to operate the laser beam machine at pulse mode.
5. Reflecting Mirror: Two types of mirror are used, first one is 100 % reflecting and other is partially reflecting. 100 % reflecting mirror is kept at one end and partially reflecting mirror is at the other end. The laser beams comes out from that side where partially reflecting mirror is kept.

Working of Laser Beam Machining

A very high energy laser beam is produced by the laser machines. This laser beam produced is focused on the workpiece to be machined.
When the laser beam strikes the surface of the workpiece, the thermal energy of the laser beam is transferred to the surface of the w/p. this heats, melts, vaporizes and finally removes the material from the workpiece. In this way laser beam machining works.

Advantages

- It can be focused to a very small diameter.
- It produces a very high amount of energy, about 100 MW per square mm of area.
- It is capable of producing very accurately placed holes.
- Laser beam machining has the ability to cut or engrave almost all types of materials, when traditional machining process fails to cut or engrave any material.
- Since there is no physical contact between the tool and workpiece. The wear and tear in this machining process is very low and hence it requires low maintenance cost
- This machining process produces object of very high precision. And most of the object does not require additional finishing
- It can be paired with gases that help to make cutting process more efficient. It helps to minimize the oxidation of w/p surface and keep it free from melted of vaporized materials. Produces a very high energy of about 100 MW per square mm of area.
- It has the ability to engrave or cut almost all types of materials. But it is best suited for the brittle materials with low conductivity.

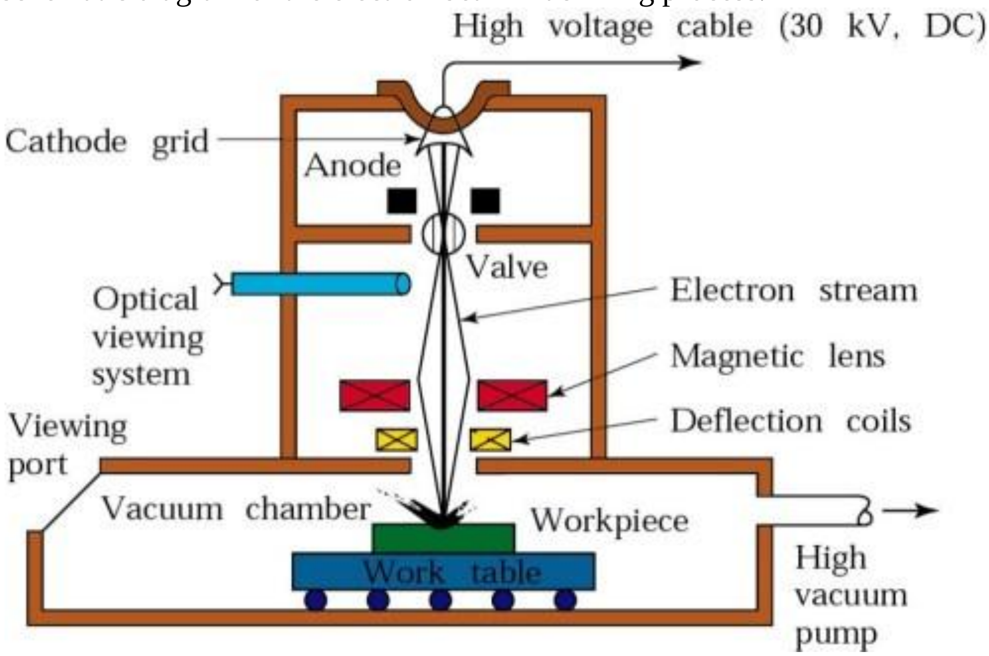
Disadvantages

- High initial cost. This is because it requires many accessories which are important for the machining process by laser.
- Highly trained worker is required to operate laser beam machining machine.

- Low production rate since it is not designed for the mass production.
- It requires a lot of energy for machining process.
- It is not easy to produce deep cuts with the w/p that has high melting points and usually cause a taper.
- High maintenance cost.

6. **Electron Beam Machining (EBM)**

The source of energy in electron beam machining is high-velocity electrons, which strikes the surface of the workpiece and generate heat. Electrons escape from the hot surface and a voltage of 50 to 200 kV helps to accelerate them. These high energy electrons possess high energy density generally in the order of 10ˆ4 kW/mm². Thin and high energy stream strikes the workpiece. As a result, the kinetic energy of the electrons is converted to heat energy. This heat energy is more than sufficient to melt and even vaporize any material. Electrons can penetrate only a few atomic layers of the metals and can melt metal up to a depth of 25 mm. The electron beam traveling at a speed of ¾ of the velocity of the sound is focused on the material to be machined. To focus the electron beams electro-static or electromagnetic lenses are used. Generally, electron beam machining is done in a high vacuum chamber to avoid the unnecessary scattering of the electrons. The following figure shows the schematic diagram of the electron beam machining process.



Schematic illustration of the electron-beam machining process. Unlike LBM, this process requires a vacuum, so workpiece size is limited to the size of the vacuum chamber.

For observing the process of machining an optical viewing system consisting of lens and prism is also incorporated. The beam can be controlled very accurately and focused on width as small as 0.002 mm. The electrons on impingement over the workpiece heat it up and raise its temperature to a value as high as 5000°C. Due to this the material melts and vaporizes locally.

Recent developments have made it possible to machine outside the vacuum chamber. In this arrangement, the necessary vacuum is maintained within the electron gun proper by removing gases as soon as they enter. The full vacuum system is more costly, but it has the advantage that no contaminating gases are present and the electron gun can be located at a considerable distance from the workpiece.

Advantages of EBM

- Very hard, heat resistant materials could be machined or welded easily
- No physical or metallurgical damage results in the workpiece.
- Close dimensional tolerance could be achieved since there is no cutting tool wear.

- In electron beam welding there is virtually no contamination and close control of penetration is possible.
- Holes as small as 0.002 mm diameter could be drilled.

Disadvantages of Electron Beam Machining Method

- The equipment costs high and operator of high skill is required for carrying out operations.
- The power consumption is exceedingly high
- It is not very suitable for sinking deep holes if the sides must be parallel. In other words, it is not possible to have perfectly cylindrical deep holes by this method.
- Unless special care is taken the bottom of a through hole would become cone-shaped.
- It is most suitable for machining operation where much less material is to be removed. The material removal rate being of the order of a fraction of a milligram per sec.
- The electron beam operation can be carried out only in a vacuum.