SREENIVASA INSTITUTE OF TECHNOLOGY AND MANAGEMENT STUDIES

(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

COURSE MATERIAL

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Unit-IV

THERMAL ENERGY BASED PROCESSES

UNIT-IV

THERMAL ENERGY BASED PROCESSES

Laser Beam Machining (LBM)

Laser is the term applied for phenomenon of amplification of light by stimulated radiation emission.

1 Construction

Fig. 2.19 shows the setup of laser beam machining, which consists of a stimulating light source (Xenon flash lamp) and a laser rod.

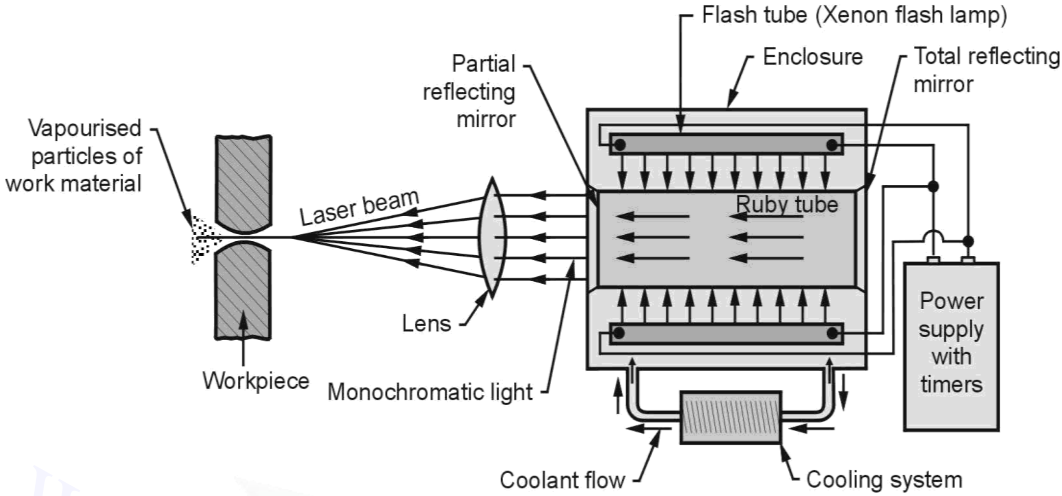

Fig. 2.19 : Laser beam machining

- Laser rod or laser tube consists of a pair of mirrors, which are placed at each end of a tube.
- Setup also consists of a flash tube /lamp (energy source), laser, power source, focussing source (lens) and cooling system.
- The whole setup is fitted inside an enclosure which has highly reflective surface inside it.
- The laser used in the process may be solid, liquid or gaseous type. The solid type carries reflective coatings at their ends and gaseous type produces continuous laser beams and is suitable for welding and cutting operations. Most commonly used laser is **Ruby**.

2.3.2 Working

- In operation, the optical energy (light) radiated from the flash lamp is focussed on the laser rod (tube), from where it is reflected with the help of mirrors and accelerated in its path.
- The reflected light is emitted in the form of a slightly divergent beam.
- A lens is placed in the path of this beam of light which converges and focuses the light beam on the component to be machined (workpiece).
- This impact of laser beam on the component melts the work material and due to this it vaporises. Hence it is also called as **thermal cutting process.**

2.3.3 Laser Machining System

Fig. 2.20 shows the different types of laser machining systems.

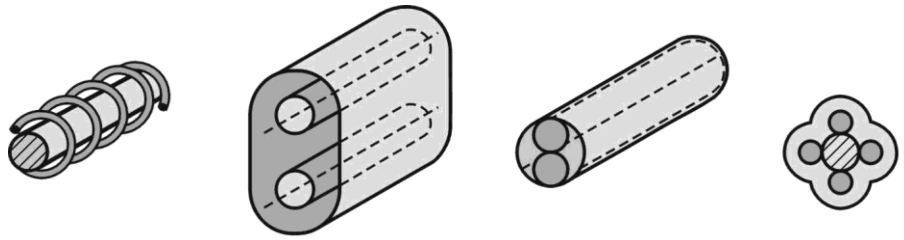

Fig. 2.20 : Laser machining systems

- Fig. 2.20 (a) is a spiral flash lamp in which a ruby rod is kept inside the lamp.
- Fig. 2.20 (b) shows a straight flash lamp and cylindrical mirror with elliptical cross-section.
- Fig. 2.20 (c) is another laser machining system in which circular reflecting cylinder is shown.
- Fig. 2.20 (d) shows four flash lamps arranged around the ruby rod.

2.3.4 Advantages of LBM

- In LBM process there is no direct contact between the tool and workpiece, hence tool wear does not exist.
- Easy machining of brittle, non-metallic and hard materials.
- Machining can be done in any environment.
- Extremely small holes can be drilled easily.
- Refractory materials can be easily worked.
- Also used for welding of dissimilar metals.

2.3.5 Disadvantages of LBM

- LBM is applicable only for thin sections and where a small quantity of material is removed.
- Holes drilled may have a slight taper formation, hence not suitable for large holes.
- Control of hole size is difficult.
- Safety precautions and procedures are to be followed.
- Durability and reliability of the system is limited.
- Limited life of flash lamp leads high operational cost.
- Initial cost and operating cost of system is quite high.
- Due to low production rate, efficiency of the system is low.
- Highly skilled operators are required.

2.3.6 Applications of LBM :

- LBM is mainly used for trimming of sheet metal, carbon resistors and plastic parts.
- It is used for drilling small holes in materials like tungsten, ceramics which are very hard.
- Cutting complicated profiles on thin films for making ICs (Integrated Circuits), engraving patterns on thin films LBM is used.
- LBM is also suitable for dynamic balancing of precise rotating components like watches.

2.4 Electron Beam Machining (EBM)

2.4.1 Principle :

- EBM process is used for machining of materials using high velocity beam of electrons. The component to be machined (workpiece) is held in vacuum chamber and beam of electrons is focused on to it magnetically.

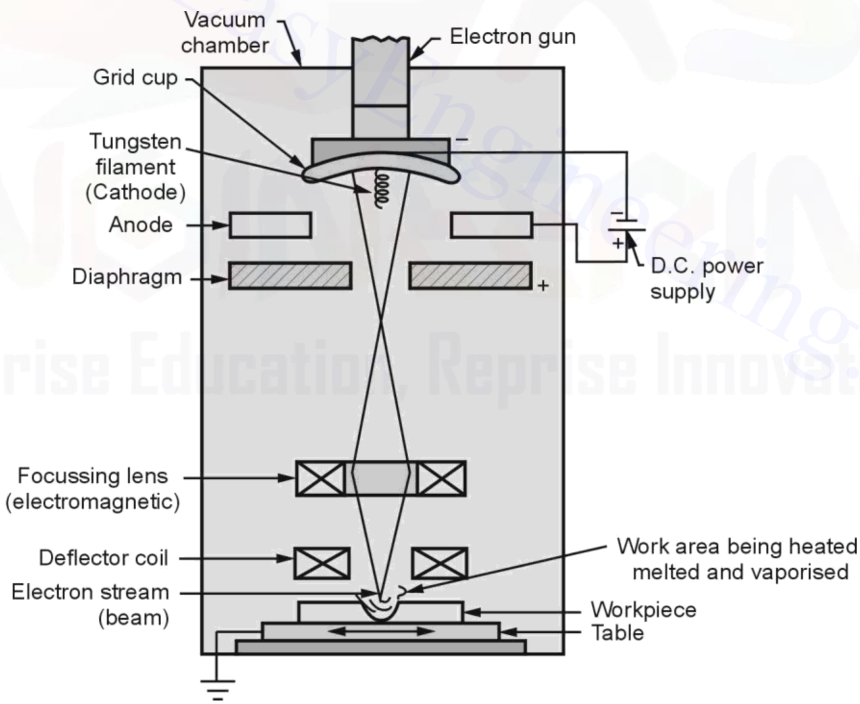

Fig. 2.21 : Electron beam machining

- When electrons strike the workpiece their kinetic energy is converted into heat energy and raises the temperature of workpiece. Due to high temperature, a small amount of workpiece material vaporises that means there is removal of metal from the workpiece.

2.4.2 Construction

- Fig. 2.21 shows the set up for Electron Beam Machining. The complete setup is enclosed in a vacuum chamber having vacuum of order 10^{-5} mm of Hg.
- The vacuum chamber carries a door, through which the component to be machined (workpiece) is placed on the table. After placing the component the door is sealed.
- The electron gun which is the main cause of emission of electrons consists of three main parts :

  (a) Tungsten filament (b) Grid cup (c) Anode.
- Tungsten filament acts as a cathode, as it is connected to negative terminal of D.C. supply and positive terminal is connected to anode as shown in Fig. 2.21.

2.4.3 Working

- As the current supply starts, the filament wire is heated to a temperature upto 2500°C in the vacuum. Due to this, electrons are emitted by filament, which is directed by the grid cup to travel downward.
- A potential difference of 50-150 kV is maintained between anode and filament. The velocity of electron passing through anode is 2/3 of light.
- This high velocity electron stream after passing through anode passes through tungsten diaphragm and then through the electromagnetic focussing coil.
- After passing through focussing coil (focussing lens) it precisely focus on the desired area of the component.
- The workpiece is kept on the table which can be traversed as per the requirement.
- When the high velocity beam of electrons impact on the workpiece, its kinetic energy is converted into heat energy.
- Due to high temperature, generated (heat) material from the workpiece is removed by vaporisation.
- Melting and vaporising of the metal takes only a fraction of second and turning off of the beam is necessary to conduct away the heat from the workpiece.

Need for vacuum :

- The electron beam should not collide with the molecules of gas and should not scatter.
- Electrons can travel from cathode to anode easily.
- There should be no loss of heat from cathode.
- To maintain high velocity of electron beam i.e. 2/3 of light.

2.4.4 Advantages of EBM

- Accurate and precise holes can be machined.
- It is a quicker process i.e. 1 hole in 1 second.
- Small diameter, narrow slots can be easily machined.
- It can machine any material i.e. metal or non-metal.
- Close dimension tolerances can be machined, as there is no tool wear as in case of EDM.
- There is no direct contact between tool and workpiece, hence damage of workpiece surface is avoided.
- It is a good technique for micro-machining.

2.4.5 Disadvantages of EBM

- Perfectly cylindrical deep holes can not be produced.
- High power consumption.
- As the process takes place in vacuum chamber and size of the chamber is limited, workpiece size is also limited.
- MRR is low.
- Initial investment is high.
- Highly skilled operator is required for the operation.

2.4.6 Applications of EBM

- EBM is used for producing precise holes in wire drawing dies.
- Used for machining operations like cutting, drilling or milling on varieties of materials, irrespective of hardness.
- Also suitable for micro-drilling operations (upto 0.002 mm) for thin orifices, injector nozzles for diesel engines.
- Also used for synthetic jewels drilling in watch industry.

2.5 Plasma Arc Machining (PAM)

The gases have property that when they are heated to temperatures above 5500 °C they are partially ionised and they exist in the form of a mixture of positively charged ions, neutral atoms and free electrons. This mixture is called as **Plasma**. Central part temperature of plasma is upto 11000 °C to 28000 °C and at that temperature the gas is completely ionised.

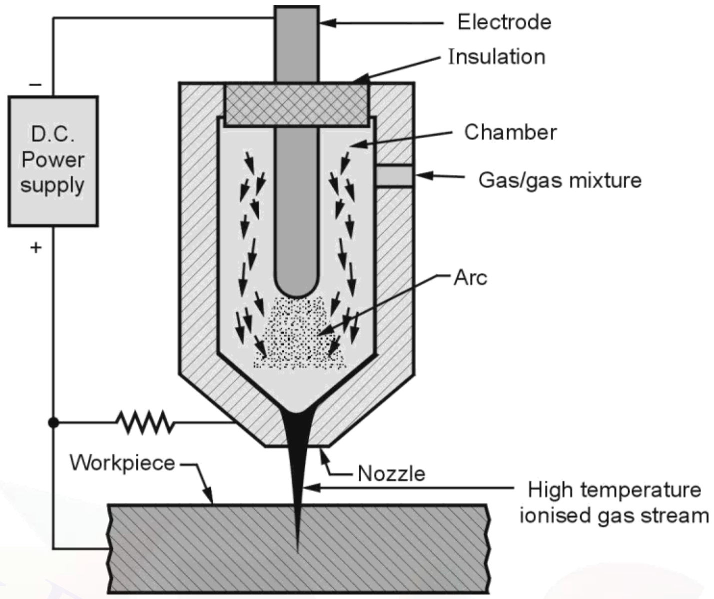

Fig. 2.22 : Principle of plasma arc machining

2.5.1 Construction

- Fig. 2.22 shows the general set-up for plasma arc machining or many times called as **Plasma Arc Cutting**.
- In this the Plasma-arc cutting torch carries an electrode which is generally made up of tungsten fitted in a small chamber.
- This tungsten electrode is connected to the negative terminal of a d.c. supply, hence acts as a **cathode** whereas positive terminal is connected to nozzle formed near the bottom of the chamber, hence acts as **anode**.
- Near the torch, small area is provided for supply of gas into the chamber. Also, while operation, electrode and nozzle should remain cool hence, water circulation is provided around the torch.

2.5.2 Working

- In PAM, as per Fig. 2.22 high velocity jet of high temperature ionised gas (plasma) is directed on the component (workpiece) surface with the help of a plasma cutting torch.
- This high velocity jet melts the metal of the workpiece and molten metal is thrown away from its path.
- The workpiece is heated due to continuous attack of electrons, which transfers heat energy of ionised gas to the work material.

Advantages of PAM

- PAM is a quicker process.
- A very high temperature is generated for machining.
- PAM is used to cut any metal.
- There is no contact between the workpiece and tool.
- Good surface finish and accuracy upto 5-10 microns can be obtained.
- High cutting rate upto 250-1700 m/min is available. (Gas flow rate is upto 2-10 m^3/hr).

Disadvantages of PAM

- As the temperature generated is very high, more precautions are required for the operator.
- Due to high temperature, work surface may undergo some metallurgical changes.
- Operator also requires protection from shielding and noise.
- Initial cost of the equipment is very high.

Applications of PAM

- PAM is used for profile cutting of alloy steel, stainless steel, aluminium and its alloys.
- PAM is used for turning and milling of difficult to machine materials.
- Also used for removing gates and risers from a casting.
- As PAM is also used under water, it is mostly used in shipyards, chemical industries and many times in nuclear plant also.
- PAM is used for cutting of hot extrusions.