

Electron Beam Machining

Topics

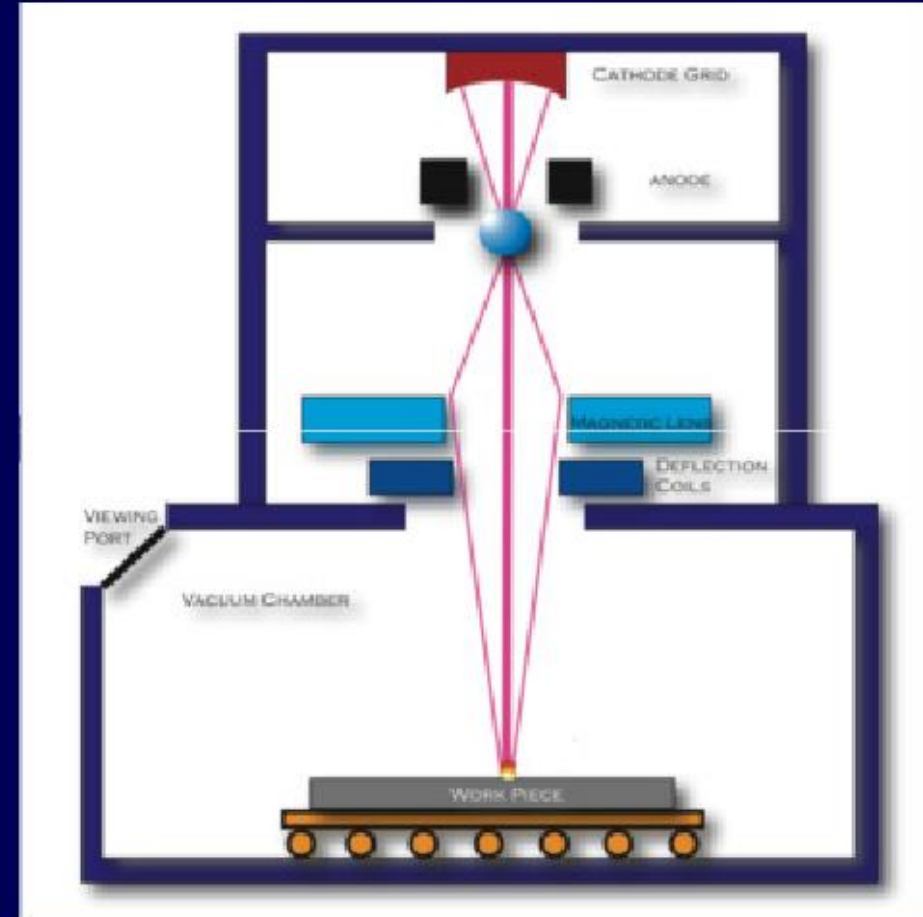
- Electron Beam welding/melting/machining
- Stereolithography (SLA)
- Selective Laser Sintering (SLS)
- Laser Engineering Net Shaping (LENS)

Videos

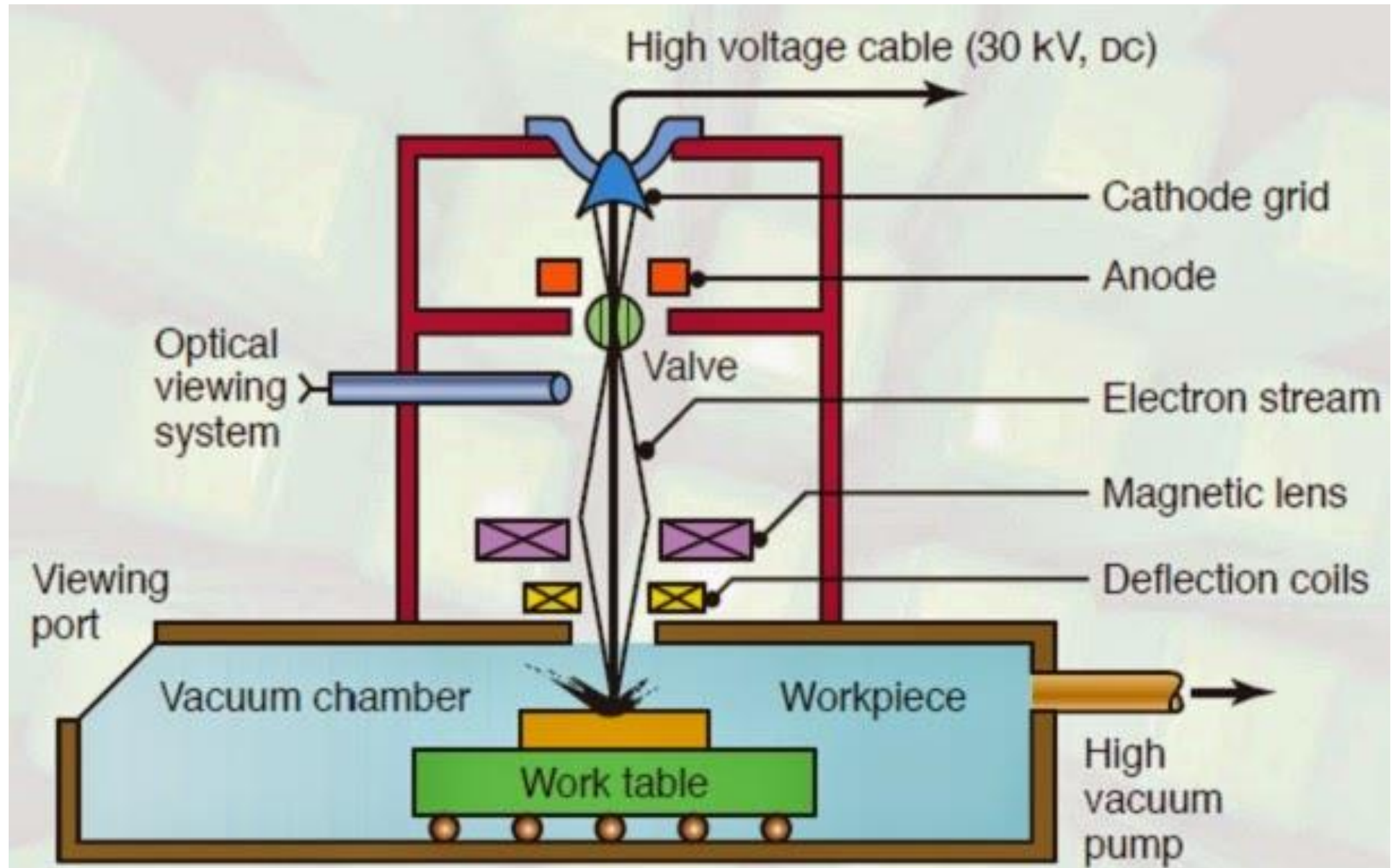
- <https://www.youtube.com/watch?v=uJQmFJCh7EM>
- <https://youtu.be/zX9tvdTEAEo>

Electron Beam Machining - Process

- A stream of electrons is started by a voltage differential at the cathode. The concave shape of the cathode grid concentrates the stream through the anode.
- The anode applies a potential field that accelerates the electrons.
- The electron stream is then forced through a valve in the electron beam machine.
- The beam is focused onto the surface of the work material, heating, melting, and vaporizing the material



Schematic Illustration of Electron-Beam Machining Process



- Electron Beam Machining (EBM) is a thermal process.
- Here a stream of high speed electrons impinges on the work surface so that the kinetic energy of electrons is transferred to work producing intense heating.
- Depending upon the intensity of heating the workpiece can melt and vaporize.
- The process of heating by electron beam is used for annealing, welding or metal removal.
- During EBM process very high velocities can be obtained by using enough voltage.
- 150,000 V can produce velocity of 228,478 km/sec focused on 10 – 200 μm diameter.
- Power density can go up to 6500 billion W/sq.mm. Such a power density can vaporize any substance immediately.
- Complex contours can be easily machined by manoeuvring the electron beam using magnetic deflection coils.
- To avoid a collision of the accelerating electrons with the air molecules, the process has to be conducted in vacuum. So EBM is not suitable for large work pieces.
- Process is accomplished with vacuum so no possibility of contamination.
- No effects on work piece because about 25-50 μm away from machining spot remains at room temperature and so no effects of high temperature on work.

Electron Beam Process Capability

- EBM can provide holes of diameter in the range of 100 μm to 2 mm with a depth up to 15 mm, i.e., with a l/d ratio of around 10.
- A wide range of materials such as steel, stainless steel, Ti and Ni super-alloys, aluminium as well as plastics, ceramics, leathers can be machined successfully using electron beam.
- As the mechanism of material removal is thermal in nature as for example in electro-discharge machining, there would be thermal damages associated with EBM.
- However, the heat-affected zone is rather narrow due to shorter pulse duration in EBM. Typically the heat-affected zone is around 20 to 30 μm .
- Some of the materials like Al and Ti alloys are more readily machined than steel.
- Number of holes drilled per second depends on the hole diameter, power density and depth of the hole as well as material type.

Advantages:

- Very small size holes can be produced.
- Surface finish produced is good.
- Highly reactive metals like Al and Mg can be machined very easily.
- EBM provides very high drilling rates when small holes with large aspect ratio are to be drilled.
- Can machine almost any material irrespective of their mechanical properties. As it applies no mechanical cutting force, work holding and fixturing cost is less.
- For the same reason fragile and brittle materials can also be processed. The heat affected zone in EBM is less due to shorter pulses.
- EBM can provide holes of any shape by combining beam deflection using electromagnetic coils and the CNC table with high accuracy.

Limitations:

- The primary limitations are the high capital cost of the equipment
- Must be done in a vacuum, very high specific energy consumption, expensive, slow, necessary regular maintenance applicable for any equipment using vacuum system.
- Maintaining perfect vacuum is very difficult.
- The entire process occurs in a vacuum chamber because a collision between an electron and an air molecule causes the electrons to veer off course.
- Material removal rate is very low compared to other unconventional machining processes.
- The machining process can't be seen by operator.
- Workpiece material should be electrically conducting.
- Moreover in EBM there is significant amount of non-productive pump down period for attaining desired vacuum.
- However this can be reduced to some extent using vacuum load locks.
- Though heat affected zone is rather less in EBM but recast layer formation cannot be avoided.

Applications:

- Used for producing very small size holes like holes in diesel injection nozzles, Air brakes etc.
- Used only for circular holes.
- Drilling fine holes, cutting contours in sheets, cutting narrow slots
- It is used for drilling synthetic jewels in the watch industry.
- Holes as small as 0.002 mm diameter can be produced in hard synthetic sapphires.
- Electron beam can be suitably used for welding small pieces of highly reactive and refractory metals.
- For making fine gas orifices in space nuclear reactors and turbine blades for supersonic aero engines, it is used
- Wire drawing dies, flow orifices could be produced by this process.
- Fine copper wire can be welded to in transistors.

MRR in EBM:

MRR power is $P = C.Q$

where

Q = area of slot or hole $\times$ speed of cutting = $A \times V$

Where power for 'Q' Where,

C = Specific power consumption

Thermal velocity acquired by an electron of the work material due to electron beam is

$$v_{th} = \sqrt{\frac{2k_B T}{m}}$$

Where, K_B = Boltzmann constant

m = mass of one atom of work.

T = rise in temperature