UNIT-V

Electron beam Machining.

working principle.

→ EBM is classified into two categories
Thermal type and Non thermal type.

→ ~~ea~~ thermal type. EBM process:-

→ In this 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 w/p is heated by the bombardment of these electrons in a localised area, to such a high temperature that it is melted and vaporized at a point of bombardment

Non thermal type EBM process:-

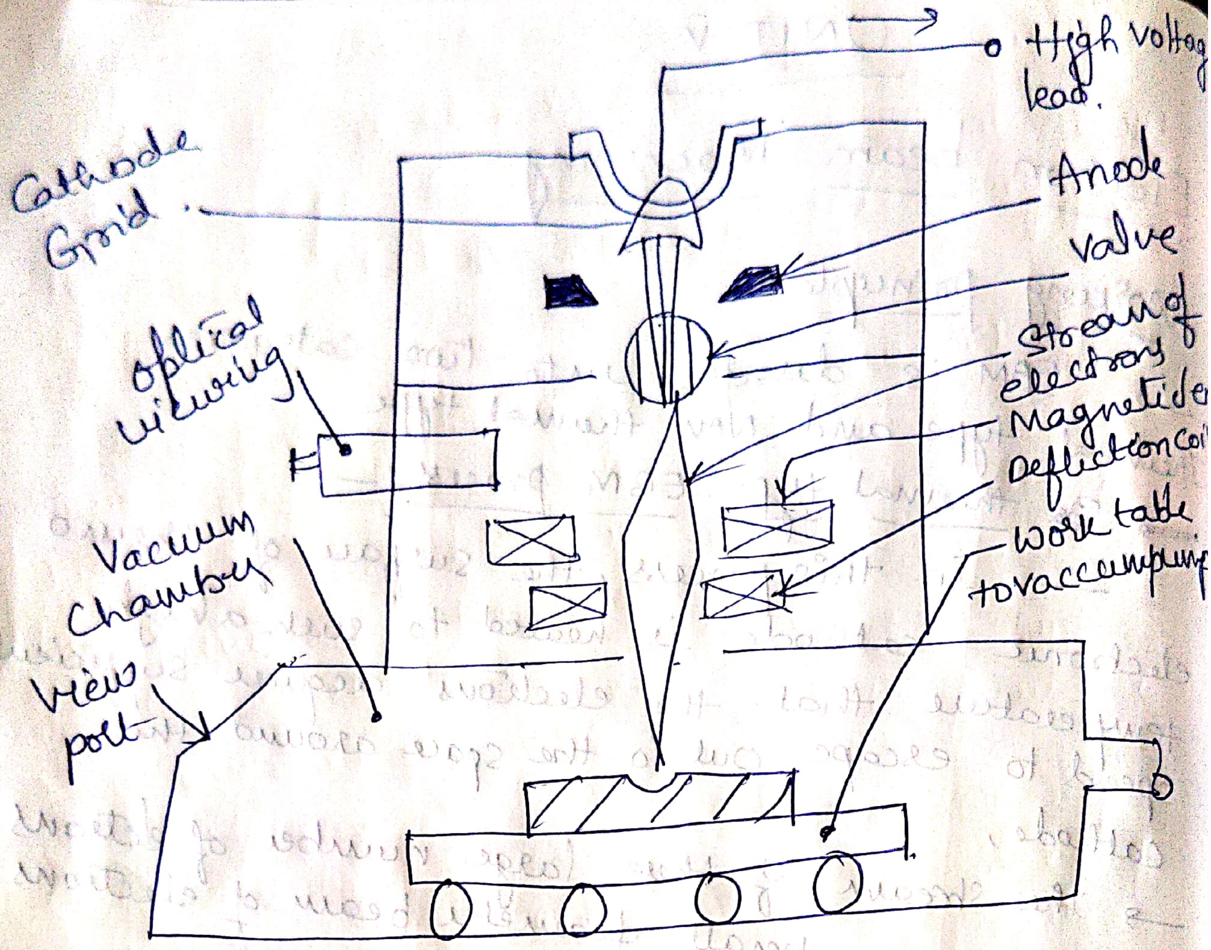
→ The electron beam is used to cause a chemical reactions.

~~Electron~~ Working:-

→ The high velocity beam of electrons strikes the w/p ~~strikes the~~ w/p

→ The kinetic energy of electrons ~~The K.E of e~~ converts into heat which is responsible for melting and vaporization of workpiece material

→ This process can produce any shape of hole, however round holes are usually drilled in



Schematic diagram

→ It can be machined electrically conducting as well as non conducting materials. metals, ceramics, plastics etc.

→ Before machining starts, vacuum is created in the machining chamber.

→ The dia, of the electron beam focussed on the work should be slightly smaller than the desired hole diameter.

→ As the electron beam strikes the workpiece, 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 w/p, also partly penetrates in the auxiliary backing material.

→ The backing material vapolizes and comes out of hole at a high pressure.
→ The molten material is also expelled along with the vapolized backing material.
→ In case of 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.
→ 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.

EBM Machining System

There are three important elements of EBM system, vaccumsystem, electron beam gun and power supply.

1) Electron beam Gun

→ It is called heart of electron beam machining. It is used to generate electron
→ It is simply a cathode ray tube which generates electron, accelerate them to sufficient velocity and focus them at small spot size. In this gun cathode is made by tungsten or tantalum.

2) Annular bias grid

→ It is next element in EBM, It is just after the electron gun. It is a anode which is connected by the negative bias, so the electron generated by the cathode do not diverge from its path and approach to the next element
→ when the electrons leave this section, the velocity of electron is almost haft the velocity of light

Magnetic lenses:-

→ After the anode, magnetic lenses are provided which shape the beam and does not allow to diverge electron or reduce the divergence of beam

→ These lenses allow to pass only convergent electron, thus a high focused beam is obtained.

→ They also capture low energy electron, thus increase the quality of beam.

Electromagnetic lenses and deflection coil:-

→ Electro magnetic lens is used to focus the electron beam at a spot.

→ They use to focus beam at a spot on w/p so a high intense beam reaches at work surface which produces more heat and improve machining

→ The deflecting coil does not allow to beam deflect and take care of all electrons moves in series thus form a high intense beam.

2) power supply:-

→ The power supply generates a voltage as high as 150kv to accelerate electrons.

→ The EBM gun of a powerful system is usually operated at about 12 kw and an individual pulse energy as 120 J/pulse.

→ The power density at the work surface is too high that is why it is capable to melt and vaporize the w/p material.

→ Thus material removal in EBM is basically due to vaporization.

3) Vacuum system & Machining chamber

→ The electron beam generation, it travel in the space, and resulting machining take place in a vacuum chamber

→ The vacuum does not allow rapid oxidation of incandescent filament and there is no loss of energy of electrons as a result of collision with air molecules

→ The vacuum in the chamber is of the order of 10^{4} – 10^{-5} torr.

<u>process parameters</u> :-

The important parameters in EBM process are beam current, duration of pulse, lens current and signals for the deflection of beam.

The values of these parameters during EBM are controlled with the help of a computer.

beam <u>current</u> :-

→ It varies from 100 μA to 1 A and it governs the energy/pulse being supplied to the w/p.

→ Higher the energy pulse more rapidly the hole can be drilled.

<u>duration of pulse</u> :-

→ pulse duration during EBM varies in the range of 50μs to 10ms depending upon the depth and diameter of the hole to be drilled.

→ Drilling using longer pulse duration results in a wider & deeper drilled hole.

→ It also affects HAZ as well as the thickness of the recast layer which is normally 0.025mm or less,

lens <u>current</u> :-

→ The working distance (i.e., the distance between the electron beam gun and the focal point) are determined and the focused beam size (diameter) are determined by the magnitude of lens current

Signal for the deflection of beam :

→ The shape of the hole along its axis (Straight, tapered etc) is determined by the position of the focal point below the top surface of the w/p.

→ To obtain the hole shape other than circular the movement of the beam can be programmed.

Material removal rate :-

The MRR at which the w/p material is vaporized can be calculated from equation

$$MRR = \eta \frac{P}{W}$$

Where, η = cutting efficiency.

P = power (J/s)

W = specific energy (J/cm³)

$$\text{Specific energy } (W) = C_{ps}(T_m - T_i) + C_{pl}(t_b - t_m) + H_f + H_v.$$

Where C_p = specific heat

T_m = melting temperature

T_i = initial temp of w/p.

T_b = boiling temp

H_f = latent heat of fusion.

H_v = latent heat of vaporization

Characteristics of the EBM process

→ This process can be used to machine both electrically conductive as well as non conductive materials (Ni, cu, Al, ceramics, leather, plastics etc)

→ In general performance of the EBM process is not significantly influenced by the properties (physical, mechanical & metallurgical) of w/p material.

→ This [illegible] small diameters holes (0.1 to 1.4mm) to a large depth (say, 10mm)

→ The geometry of the hole and depth of the hole to be drilled, determine the average machining rate.

→ No Mechanical force is applied on the Job, hence fragile (or brittle), thin, and low strength w/p's can be easily machined.

→ off-the axis holes (or inclined holes) can also be machined by this process.

Advantages :-

1) very accurate and precise holes can be machined.
2) Holes of very small diameters (up to 50 microns) can be drilled.
3) Narrow slots of width 25 μm can be easily machined.
4) No ~~tool~~ wear & cutting tool pressure.
5) cuts drill holes and cut slots in w/p's that cannot be done by other conventional processes.
6) Input energy can be precisely controlled, thus distortion can be reduced to a mini, when thin foils and thin walled hollow parts are machined.
7) There is no physical or metallurgical damage to the surface.
8) There is no physical or metallurgical damage to the surface.
9) Depth of surface layer affected due to machining is reduced to a minimum.
9) Fast speed of operation, One hole can be drilled in one sec, mainly it depends on the work material, its composition and thickness.

Disadvantages

→ All EBM operations must be done in Vacuum.

→ Size of the Vacuum chamber restricted to small medium size of w/p only.

→ Large part of the cycle time is spent on setting up the w/p in the chamber.

→ Material removal rate is very small, hence the process is economical only for relatively small cuts.

→ Equipment cost is high.

→ Require ~~high~~ ~~operator~~ skilled operator.

→ The process is applicable only for machining of thin parts (thickness 0.25 mm - 6.00 mm)

Applications

1) EBM is more popular in industries like aerospace, insulation, food processing, chemical, clothing etc.

2) This process is also used for drilling thousands of holes (dia < 1.00 mm) in very thin plates used for turbine engine combustor domes.

3) ~~Many~~ thousand holes in a cobalt alloy fibre spinning head of thickness around 5 mm are drilled by EBM

4) Holes in the filters and screens used in food processing industries are also made by this process

5) Making of fine gas orifices in space

nuclear reactors, holes in wire drawing dies, cooling holes in turbine blades, metering holes in injector nozzles of diesel engines.

6.) It is also used for pattern generation for integrated circuit fabrication.

Laser Beam Machining

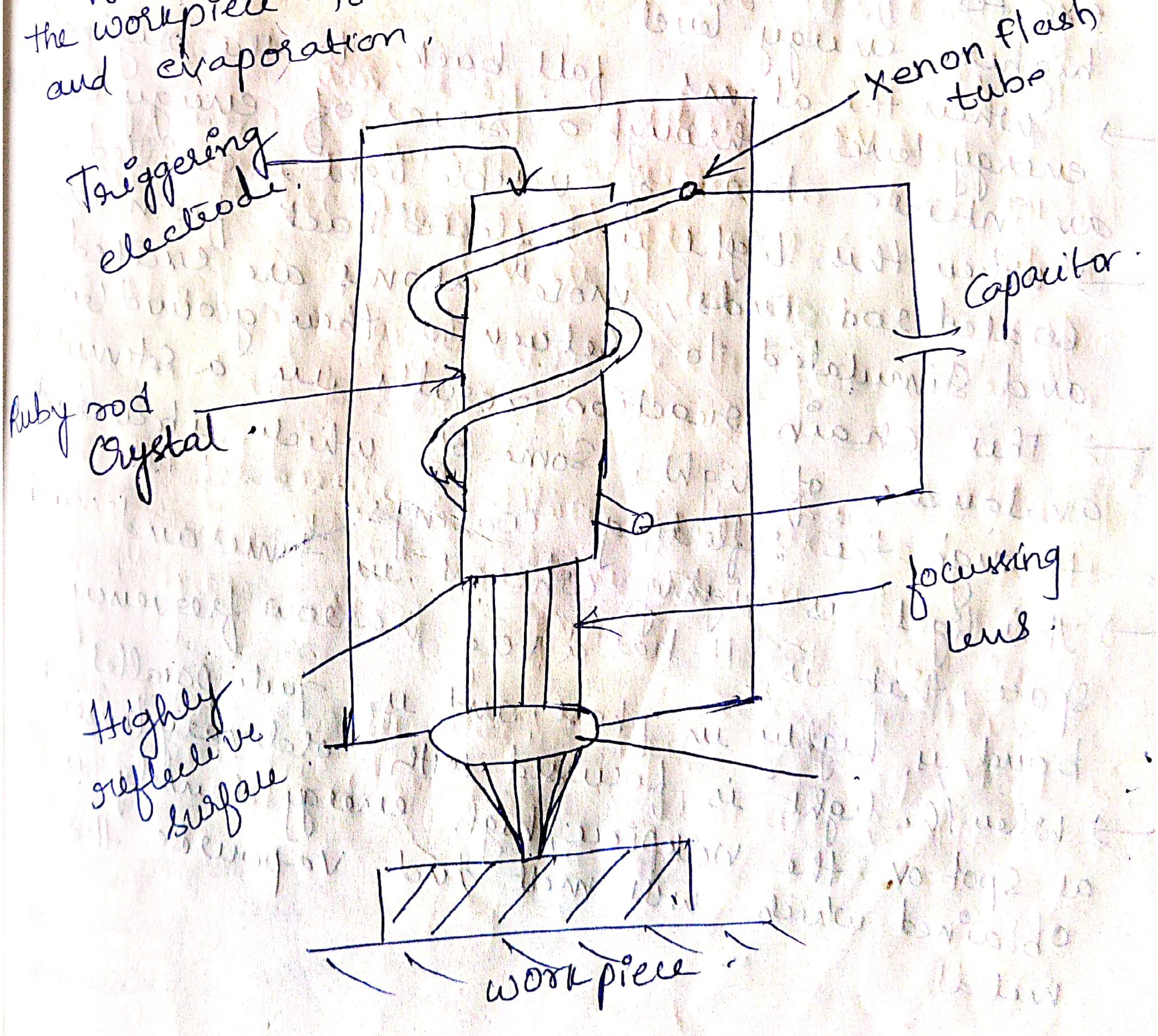
Introduction

→ The word laser is derived from the phenomenon Light Amplification by Stimulated Emission of Radiation.

→ LBM is similar to EBM, both utilize a high energy beam which can be focussed upon a small area.

Principle

In LBM, exceedingly high electromagnetic energy densities are focussed on the surface of the workpiece to remove metal by melting and evaporation.



→ There are many types of lasers used for different purposes eg: solid state, gas, liquid and semi conductor.

→ for machining and welding, high power lasers are required.

→ In general only the solid lasers can provide the required power levels.

→ The most commonly used solid state laser is the ruby laser.

→ figure shows a schematic view of LBM

→ The ruby crystal is doped with a small amount of chromium oxide.

→ The laser is pumped by a flash of high intensity light (A xenon filled flash lamp)

→ The xenon lamp is fired by discharging a large capacitor through it

→ The intense radiation from the lamp excites fluorescent impurity atoms to a higher energy level.

→ when the atoms fall back to the original energy level through a series of energy levels, an intense beam of visible light is emitted.

→ when this light is reflected back from the coated rod ends, more atoms are excited and stimulated to return to their ground level.

→ This chain reaction results in a stimulated avalanche of light, some of which is transmitted through the reflecting coatings.

→ This light is highly coherent in time and space, that is, it has a very narrow frequency band is highly in phase, and is quite parallel.

→ when the light is focussed with ordinary lenses at spot on the workpiece, high energy density is obtained which will melt and vapourise the metal.

→ It is a ... After discharge, the capacitor must be recharged.

→ power supply is : potential - 4.5 kV, current - 2A ;

→ The ruby laser works with maximum efficiency when kept at a very low temperature

→ for this, liquid nitrogen at -196°c is employed.

→ On the other hand, the light flash works best when warm.

→ for this, hot air is circulated over it. The vacuum chamber b/w the ruby crystal and the flash lamp acts as an insulator and enables the two temps to be maintained.

→ The flash lamp operates from 1 flash every 3 min to 12 flashes per min.

Thermal features :-

1) High temp Zone : The Laser beam generates an intense heat source focused on a small spot on the w/p, creating a high temp zone. This zone is typically several thousand degree celsius, depending on the laser power and material being processed

2) Rapid heating and cooling :- The laser beam rapidly heats the material, causing it to melt, vapolize, or even undergo ablation. Subsequently, as the Laser moves away, the material cools quickly due to its small thermal mass.

3) Non contact process :- since the machining is achieved through the focussed laser beam, there is no physical contact b/w the tool and the w/P, reducing the risk of contamination and wear associated with traditional cutting tools.

4) Energy concentration :- Laser beam can be focused to very small diameters, concentrating a significant amount of energy into a small area, which enhances the machining efficiency and allows for precise control over material removal.

Cutting speed and accuracy of cut

→ In LBM, cutting and accuracy are two critical factors that influence the efficiency and quality of the machining process.

→ The cutting speed, depends on factors such as laser power, beam dia, material properties and depth of cut

→ Higher cutting speeds lead to increased productivity and reduced manufacturing lead times.

→ Excessive cutting speeds can lead to issues such as excessive thermal damage, while too slow speeds may result in efficient material removal.

→ LBM is capable of achieving high levels of precision & accuracy due to focused nature of the laser beam

→ The narrow kerf width produced by the laser beam results in minimal material wastage and allows for tight nesting of parts, maximizing material utilization

→ LBM produces high quality cut edges with minimal burrs, HAZ & distortion, leading to superior S/F and dimensional accuracy

Advantages :-

1) Laser can weld through optically transparent material
2) No direct contact b/w two & w/p
3) Inaccessible areas can be readily machined.
4) Refractory metals can be easily worked with.
5) Machining of brittle, non metallic and hard materials are easy.
6) Machining can be carried out in any desired atmospheric environment
7) Extremely small holes can be drilled.
8) HAZ (heat affected zone) is relatively small and no thermal damage occurs on adjacent regions.
9) Laser can be used not only for removal of cylindrical sections but also for conical and rectangular sections.
10) The laser drilling machine is particularly suitably for drilling into dimensionally unstable materials.

Disadvantages :-

If large quantity of material is to be removed, than laser machining is not economical.
) Another limitation of the laser is that till now we are not in a position to bend the beam for cutting any desired contour
) High cost of the system.
) Over all efficiency of the system is low.
) Its use is practically limited to thin sheet plates or wire fabrication.
) Holes drilled may have a slight taper formation and may not be truly round.
) Durability and reliability of the system is limited.
) Limited life of flash lamp leads to high operational cost.

Applications :-

1) The laser is suitable for precision work.

2) Drilling of small holes of very small dimensions, (of 2 microns holes, which is not possible with other process). Such as fuel fillers, carburetor nozzles, hypodermic needles, hole for lock nut safety wires, jet engine blade cooling holes, diamond drawing dies etc.

3) It is used for marking or engraving so as to produce controlled surface patterns on a w/p, (company logos, part number, bar codes etc can be made)

4) It is used to vapourize foreign material clogged in electron microscopic apertures.