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# Objective



- Describe the basic mechanism of welding in EBW.
- The working principle of EBW.
- Schematic diagram of EBW.
- Identifying the major equipments.
- Identifying the process parameters.
- Identifying the welding characteristics.
- Advantages, limitation & applications.

# Introduction



- Welding is an art of joining metals by heating. The process of joining may also take place by other means of riveting or by fastening nut and bolts.
- If a joint can be disassembled then joining method is called temporary joining method. If the formed cannot be disassembled without breaking it then the joint is called permanent joint.
- Normally in welding operation joining of metal pieces is done by raising their temperature to the fusion point so that they form a sort of pool of molten metal at the ends to be joined, sometimes, the pool is supplemented with a filler metal (wire or rod) which normally has almost same compositions as that of the work pieces. This way the pool forms a homogeneous mixture. It is allowed to get solidified to have a permanent joint.

# History



- Until the end of the 19th century, the only welding process was [forge welding](#), which [blacksmiths](#) had used for centuries to join iron and steel by heating and hammering. [Arc welding](#) and [oxyfuel welding](#) were among the first processes to develop late in the century and [electric resistance welding](#) followed soon after.
- Welding technology advanced quickly during the early 20th century as World War I and World War II drove the demand for reliable and inexpensive joining methods.
- Following the wars, several modern welding techniques were developed, including manual methods like [shielded metal arc welding](#), now one of the most popular welding methods, as well as semi-automatic and automatic processes such as [gas metal arc welding](#), [submerged arc welding](#), [flux-cored arc welding](#) and [electro-slag welding](#).

# Conti.....



- Developments continued with the invention of [laser beam welding](#), [electron beam welding](#), [electromagnetic pulse welding](#) and [friction stir welding](#) in the latter half of the century.
- Today, the science continues to advance. [Robot welding](#) is commonplace in industrial settings, and researchers continue to develop new welding methods and gain greater understanding of weld quality.

# Electron beam welding



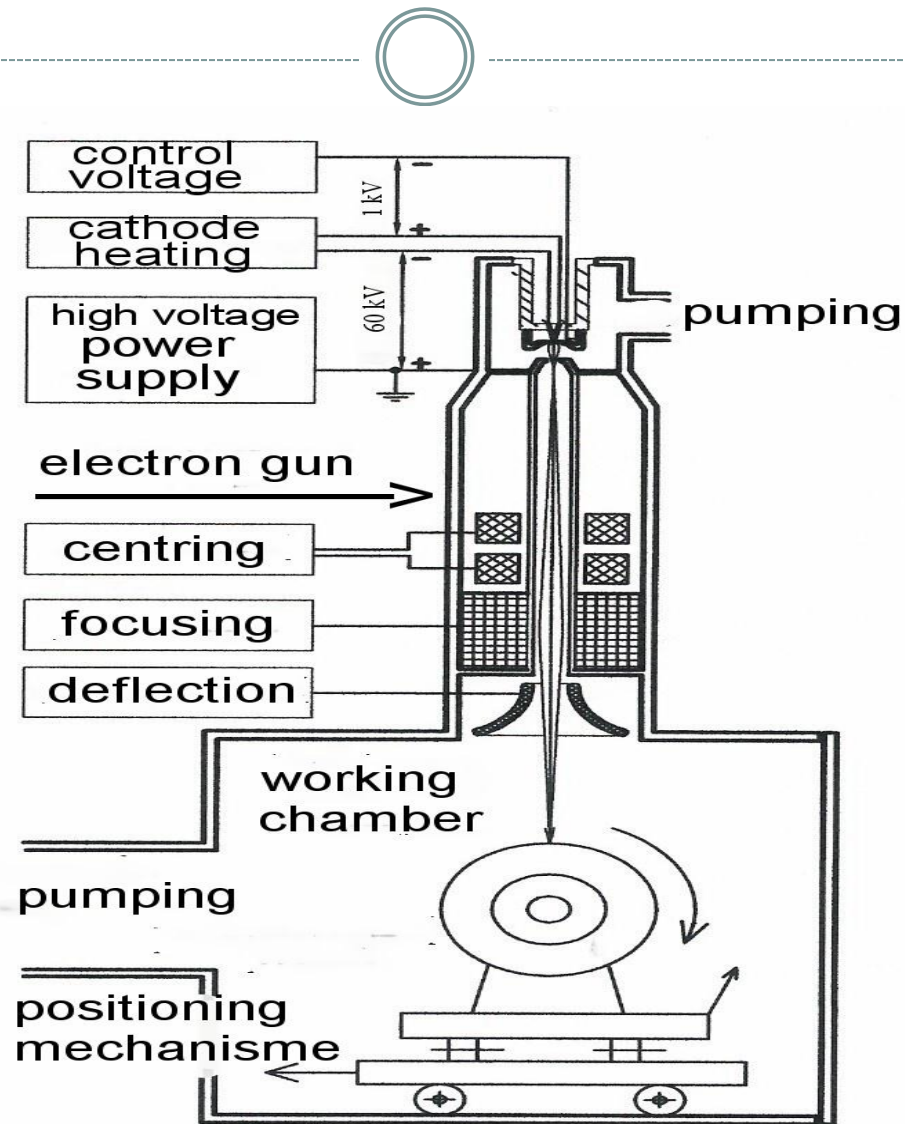
- **Electron beam welding (EBW)** is a fusion welding in which coalescence is produced by heating and consequently melting the work piece due to impingement of the concentrated electron beam of high kinetic energy on the work piece.
- As the electron beam impinges the work piece, the kinetic energy of the electron beam gets converted into thermal energy resulting in melting and even evaporation of the work material.

# Principle of EBW



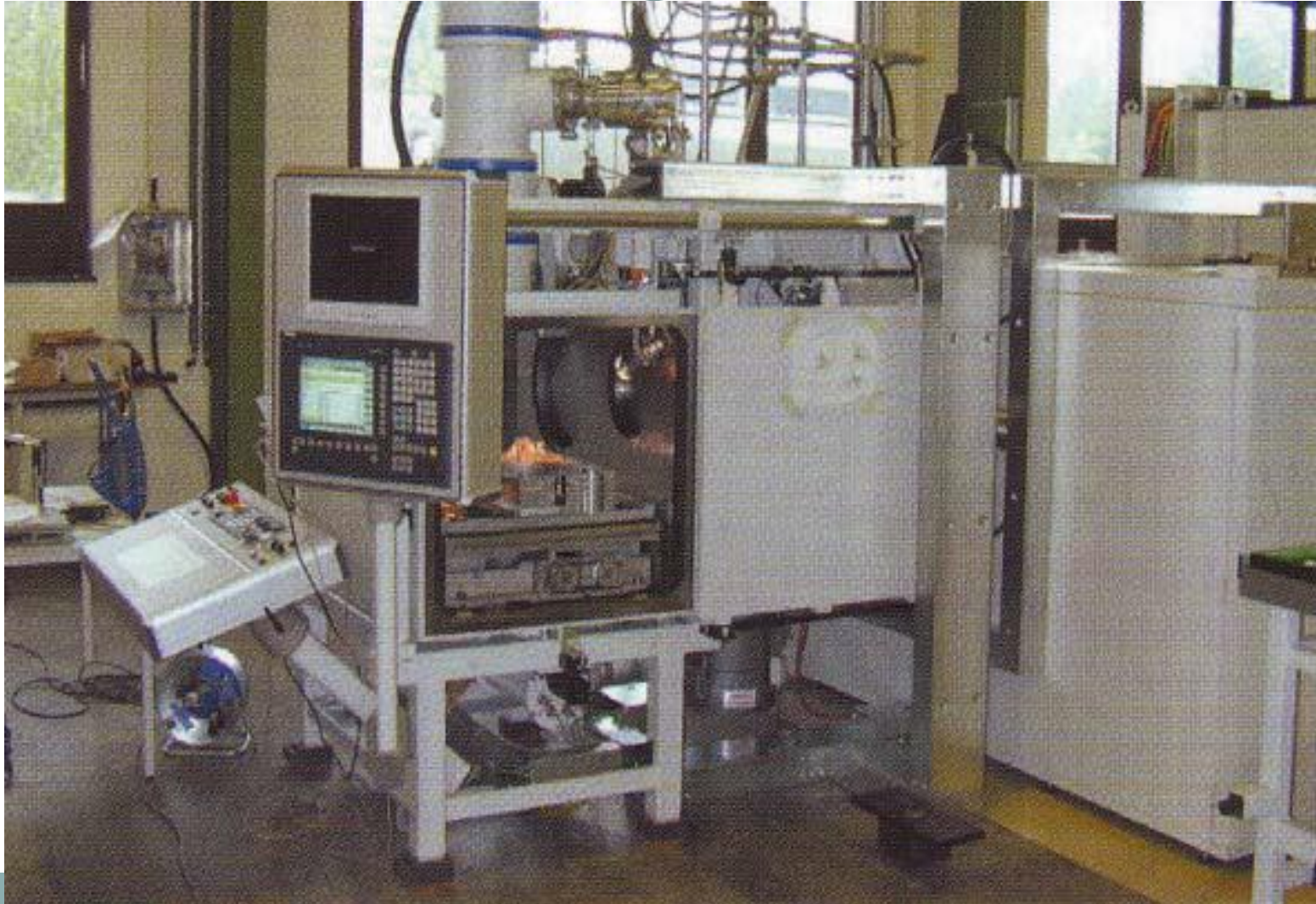
- In general, electron beam welding process is carried out in vacuum.
- In this process, electrons are emitted from a heated filament called cathode. These electrons are accelerated towards the anode by applying high potential difference.
- The high potential difference is in the range of 30-175kV between cathode and anode.
- The higher the potential difference, the higher would be the acceleration of the electrons.
- The electrons get the speed in the range of 50000 to 200000km/s.

# Diagram of EBW





# Today's EBW machine



# Major equipments of EBW



The major equipments of Electron beam welding are as follows

- Electron gun
- Power supply
- Vacuum chamber
- Work piece handling device

# Working



- The work accelerated gun accelerates the electrons by providing potential difference between the work piece and the cathode.
- In the self accelerate gun, electrons are accelerated by applying potential difference between the cathode and the anode.
- The anode and cathode are enclosed within the gun itself.
- The control of electron density is better in this type of electron gun.
- It has the following parts

## **Emitter/Filament:-**

- It generates the electrons or the beam of electrons on direct or indirect heating.

## **Anode:-**

- It is a positively charged element near the cathode across which a high voltage is applied to accelerate the electrons.
- The potential difference for high voltage equipment ranges from 70 to 150 kV and for low equipment the range is between 15-30 kV.

## **Electron focusing unit:-**

The unit has two parts

1. Electron focusing lens and
  2. Deflection coil
- Electron focusing lens focuses the beam into work area.
  - The focusing of the electrons can be carried out by deflection of beams.
  - The electro-magnetic lens contains a coil encased in iron.

- As the electrons enter into the magnetic field, the electron beam path is rotated and refracted into a convergent beam.
- The extent of spread of the beam can be controlled by controlling the amount of DC voltage applied across the deflection plates.

### **Electron gun power supply:-**

- It consists of mainly the high voltage DC power supply source, emitter power supply source, electro-magnetic lens and deflection coil source.
- In the high voltage DC power supply source, the required load varies from 3-100kW.
- It provides power supply for acceleration of electrons.
- The potential difference for high voltage equipment ranges from 70-150kV and for low voltage equipment 15-30kV
- The current level ranges from 50-1000mA.

- In emitter power supply, AC or DC current is required to heat the filament for emission of electrons.
- However, DC current is preferred as it affects the direction of the beam.
- The amount of current depends upon the diameter and the type of the filament.
- The current and voltage varies from 25-70A and 5-30V respectively.
- The power to the electromagnetic lens and deflection coil is supplied through a solid state device.

# Vacuum chamber



- In the vacuum chamber, required low pressure is created by vacuum pump.
- It consists of a roughing mechanical pump and a diffusion pump.
- The pressure ranges from 100kPa for open atmosphere; 0.13-13Pa for partial vacuum; 0.13-133 Mpa for hard vacuum.
- As the extent of vacuum increases, the scattering of the electrons in the beam increases.
- It causes increase in penetration.

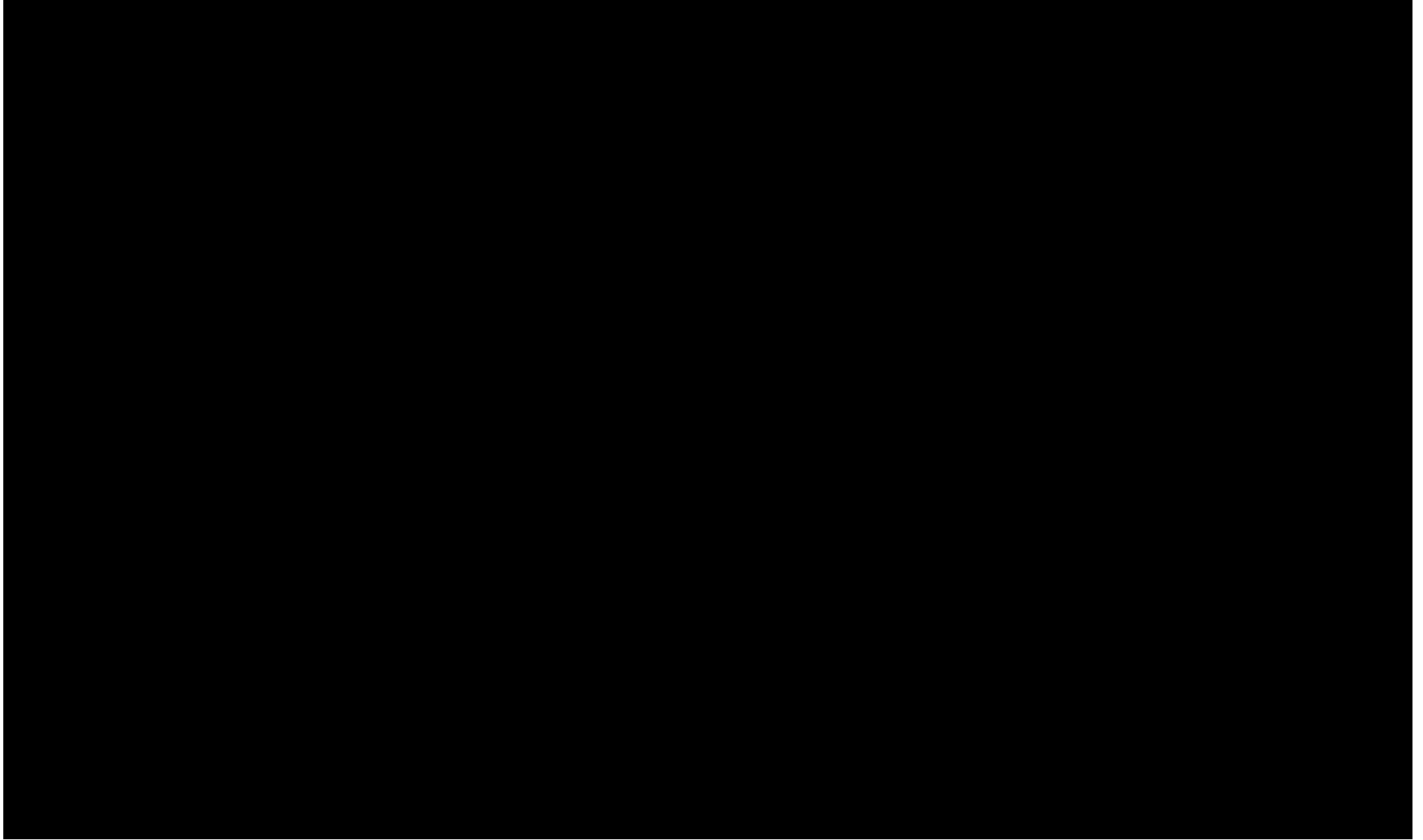
# Work piece handling device



- Quality and precision of the weld profile depends upon the accuracy of the movement of the work piece.
- There is also provision for the movement of the work piece to control the welding speed.
- The movements of the work piece are easily adaptable through computer numerical control.



# EBW Video



# Advantages



- Minimal distortion.
- Narrow melt zone (MZ) and narrow heat affected zone (HAZ).
- Deep weld penetration from 0.05 mm to 200 mm (0.002” to 8”) in single pass.
- Vacuum process yields in clean and reproducible environment.
- Natural welding process for oxygen greedy materials such as titanium, zirconium and niobium.

# Limitations



- High equipment cost.
- Work chamber size constraints.
- Time delay when welding in vacuum.
- High weld preparation costs.
- X-rays produced during welding .
- Rapid solidification rates can cause cracking in some materials.
- Too much dependence on operator skill to keep the process under control.

# Applications



- Electron beam welding process is mostly used in joining of refractive materials like columbium, tungsten, ceramics and etc which are used in missiles.
- In space shuttle applications, where in reactive materials like beryllium, zirconium, titanium, etc are used.
- It is used in high precision welding for electronic components, nuclear fuel elements, special alloy jet engine components and pressure vessels for rocket plants.
- It is particularly useful in joining dissimilar materials.



Bronze/Steel, 30 mm



Stainless, 2 mm



Copper, 35 mm

# Case studies



- Safety requirements for aviation components call for high standards for the welding process. One of the most advanced electron beam welding machines is currently used by Rolls-Royce for welding titanium components of Trent jet engines.
- The ring of vanes (ROV) for a front bearing housing is a structural component of a Trent jet engine. It is assembled from individual vanes and panels which are joined using electron beam welding. Due to the size and complexity of the part and due to thermal expansion during the welding process manual positioning of the joints was required in the past. Key to the automation is a sophisticated scanning process where the joint in between two vanes is scanned. Because of poor light conditions at the joint the scanning parameter have to be adjusted during the scan. Result is a sharp and clear image of the joint which is the basis for an automatic positioning routine.

# Conti....



- Using the advanced pro-beam seam tracking system the positioning process was automated resulting in a significant reduction of processing time. At the same time the quality of the welds could be improved since it no longer depends on the skills of the operator.
- The machine is operated with a HV electron beam generator. A CNC controlled 5 axis mechanical manipulator positions the part relative to the electron beam. Powerful vacuum equipment evacuates the process chamber to the process vacuum of  $7 \times 10^{-4}$  within less than 15 minutes.

*EB welded front bearing housing for Trent 700*



*Universal EB welding chamber type K640 with Trent 700 ring of vanes*

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