The Processes are:

1. **Flame hardening**
2. **Induction hardening**
3. **Vacuum hardening**
4. **Plasma hardening**

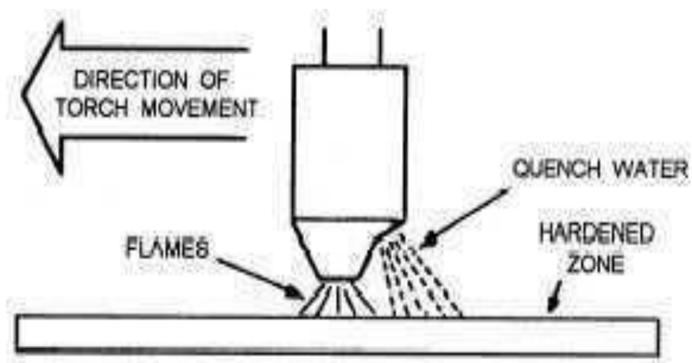
(Explain flame hardening and induction hardening.)

1. **FLAME HARDENING**

   Flame hardening is the process of selective hardening with a combustible gas flame as the source of heat for austenitising.

   Principle of flame hardening:

   - The surface to be hardened is heated to a temperature above its upper critical temperature, by means of a travelling oxy-acetylene torch.
   - Then it is immediately quenched by a jet of water issuing from a supply built into the torch-assembly.
   - Thus the surface hardening results when the austenitized surface is quenched by the water spray that follows the flame.



Suitability:

- The flame hardening technique is suitable for the **plain carbon steels with carbon contents ranging from 0.40% to 0.95% and low alloy steels.**

Advantages:

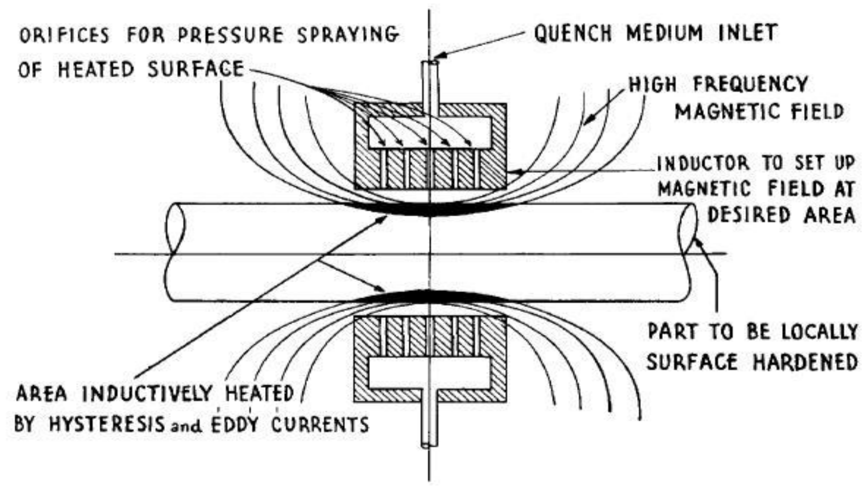
1. The process is more efficient and very economical for larger works.
2. As heating rate is high the surface of work remains clean.

Disadvantages:

1. very thin sections may get distorted excessively.
2. overheating may cause cracks.

2. INDUCTION HARDENING

- The heating in this process is done within a thin layer of metal surface by high frequency induced currents.
- A high frequency current is passed through the primary coil. This generates alternate magnetic field. This magnetic field induces eddy currents of the same frequency in the surface layer which heat the surface of the components.
- Within a short period of 2 to 5 minutes the temperature of surface layer comes to above the upper critical temperature of the steel.
- The component is quenched by water spray usually without removing the inductor coil. Due to fast heating and no holding time, Austenite is transformed in to fine grained Martensite.
- Induction hardening is commonly followed by low temperature tempering at 160 to 200 ^{o}C.
- Steels with carbon between **0.4 to 0.5%** are hardened by this method.



Advantages:

- Fast heating.
- No holding time.
- Increase the production rates.
- Low alloy steels are also surface hardened.
- Easy control the depth of hardening.

Disadvantages:

- High equipment cost.
- Irregular shapes cannot be used.
- High Maintenance cost.

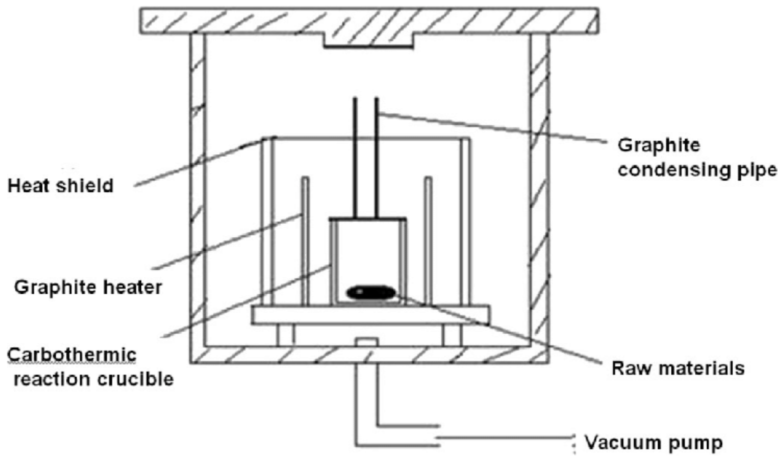
Applications:

- Cylinder liners, machine tool ways, pump shafts.

(Explain vacuum hardening and plasma hardening.)

3. VACUUM HARDENING

- Vacuum hardening is one of the methods to protect heated steel and metal parts from the negative influence of an air.
- A vacuum furnace is normally an electrically heated furnace in which vacuum is maintained during the process.
- Vacuum hardening is the hardening of components under a controlled partial pressure, during which temperatures of up to 1,300°C can be reached.
- Aims to create bright metallic work piece surfaces which render further mechanical processing unnecessary.



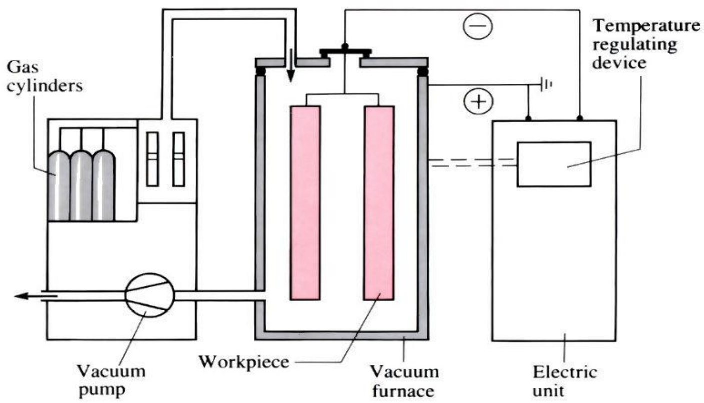
Advantages

- It comes out harder and resists corrosion better.
- It also has more tensile strength, shear strength, ductility, and elasticity.

4. PLASMA HARDENING

- Plasma technology is primarily for stainless steel and other low alloy steels which are not suitable for a “standard” heat treatment process.
- The process uses a Plasma discharge of Hydrogen and Nitrogen gases both to heat the steel surfaces and to supply nitrogen ions for nitriding.
- **PLASMA CARBURIZING PROCESS**, also called **ion carburizing**, making use of a high-voltage electrical field applied between the load and the furnace wall, producing activated and ionized gas species responsible for the carbon transfer to the work pieces.
- Plasma Nitriding is a surface hardening process, in which nitrogen is diffused in to the components surface.
- Plasma nitriding produces high surface hardness, good wear resistance, increased fatigue strength and toughness.

Gas plasmas are ionized gases formed by liberating electrons from gas molecules and atoms using external energy sources such as lasers or high electrical voltages.



(Define hardenability. Explain the method of determining hardenability.)

2.4 HARDENABILITY

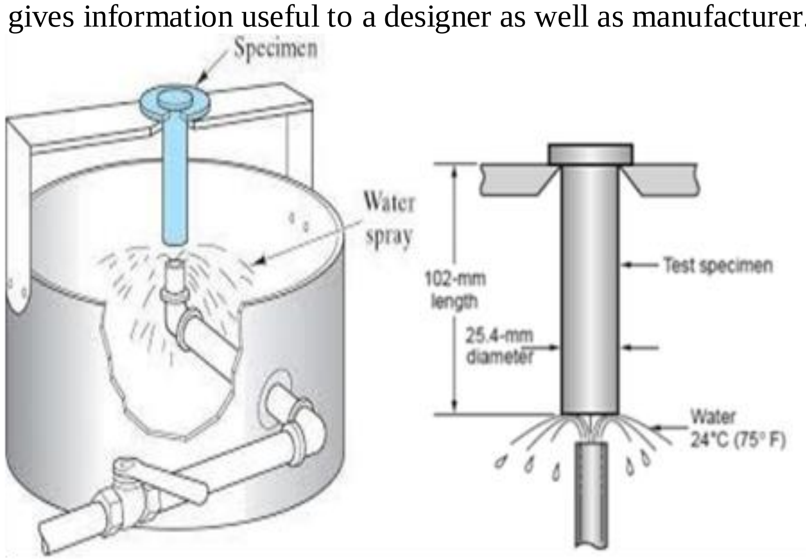
The hardenability of a metal alloy is the depth to which a material is hardened after putting it through a heat treatment process.

Factors affecting hardenability:

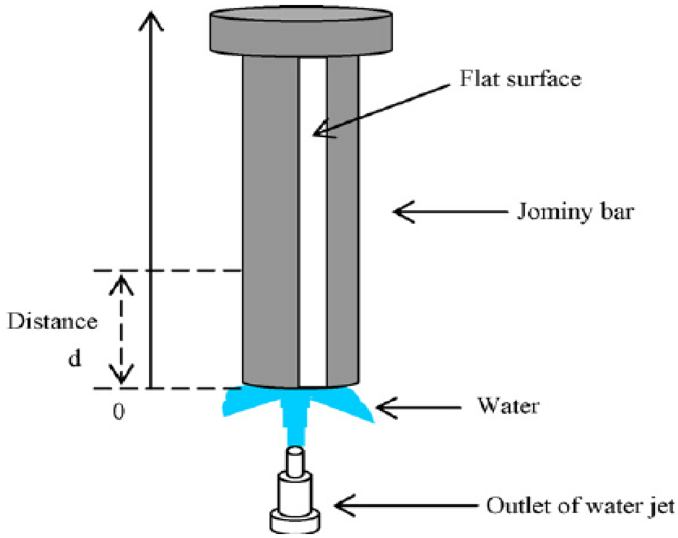
- The composition of the steel
- The austenitic grain size.
- The structure of the steel before quenching.
- The quenching medium and the method of quenching.

Determining hardenability (Jominy End Quench test):

1. **Importance of Jominy End Quench test**
    - It is relatively easy to perform.
    - It is excellent reproducibility.
    - It gives information useful to a designer as well as manufacturer.



2. **Process:**
    - Specimen of cylindrical shape of diameter 25.4mm (1inch) length of approximately 102mm.(4 inch) is heated in a furnace.
    - austenizing temperature (725°C -1330°C) is maintained for a prescribed time.
    - It is removed from furnace and placed in a fixture (stand like)
    - Lower end of specimen is quenched in a jet of water from nozzle.
    - cooling rate is high at thequenched end and reduces along the length of the specimen.
    - Hardness drops off rapidly a short distance from the quenched end.



- A flat 0.4mm deep flat surface is cut along the length of the bar.
- **Rockwell C hardness measurements** are taken at **1.5 mm intervals from quenched end** and hardness readings are taken.
    - Hardenability curves are plotted.