2.21. FLAME HARDENING

2.21.1. What is Flame Hardening ?

- ✓ Flame hardening is the process of selective hardening with a combustible gas flame as the source of heat for austenitizing.
- ✓ Flame hardening can be performed only on steels with a sufficiently high carbon content – at least 0.4% C (to allow hardening).

2.21.2. 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, as shown in Fig.2.33. 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.

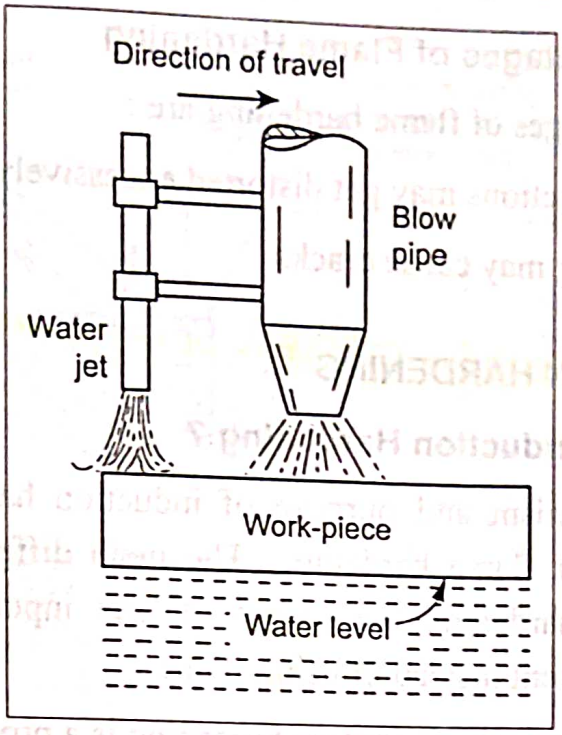

Fig. 2.33. Principle of flame-hardening

2.21.3. 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.

2.21.4. Applications

It is used to improve wear resistance and surface hardness of teeth of gears, wheels, sheaves, bushings, shafts, mill rolls, cams, spindles, hand tools, *etc.*

2.21.5. Advantages of Flame Hardening

The advantages of flame hardening are as follows :

1. There is practically no distortion of workpiece because only small section of steel is heated.
2. The process is more efficient and very economical for larger works.
3. As heating rate is high the surface of work remains clean.
4. It is more suitable for small quantities because it is versatile and equipment cost is less.

2.21.6. Disadvantages of Flame Hardening

The disadvantages of flame hardening are :

1. Very thin sections may get distorted excessively.
2. Overheating may cause cracks.

2.22. INDUCTION HARDENING

2.22.1. What is Induction Hardening ?

- ✓ The mechanism and purpose of induction hardening are the same as for flame hardening. The main difference is that in induction hardening the source of heat input is an induced electric current instead of using flame.
- ✓ In other words, the induction hardening is a process of selective hardening using resistance to induced eddy currents as the source of heat.

2.22.2. Suitability

The steels that can be hardened with this process are the same as those used in flame hardening.

2.22.3. Procedure

Induction heating is done by passing a high-frequency alternating current through a water-cooled coil or inductor around the workpiece. The cyclic magnetic field that is generated induces alternating currents that heat the workpiece, as shown in Fig.2.34.

The depth to which heating occurs varies inversely as the square root of the frequency, so that the higher the frequency used, the shallower the depth of heating. Typical frequencies used are : 3000 Hz for depths of 3 to 6 mm; and 9600 Hz for depths of 2 to 3 mm.

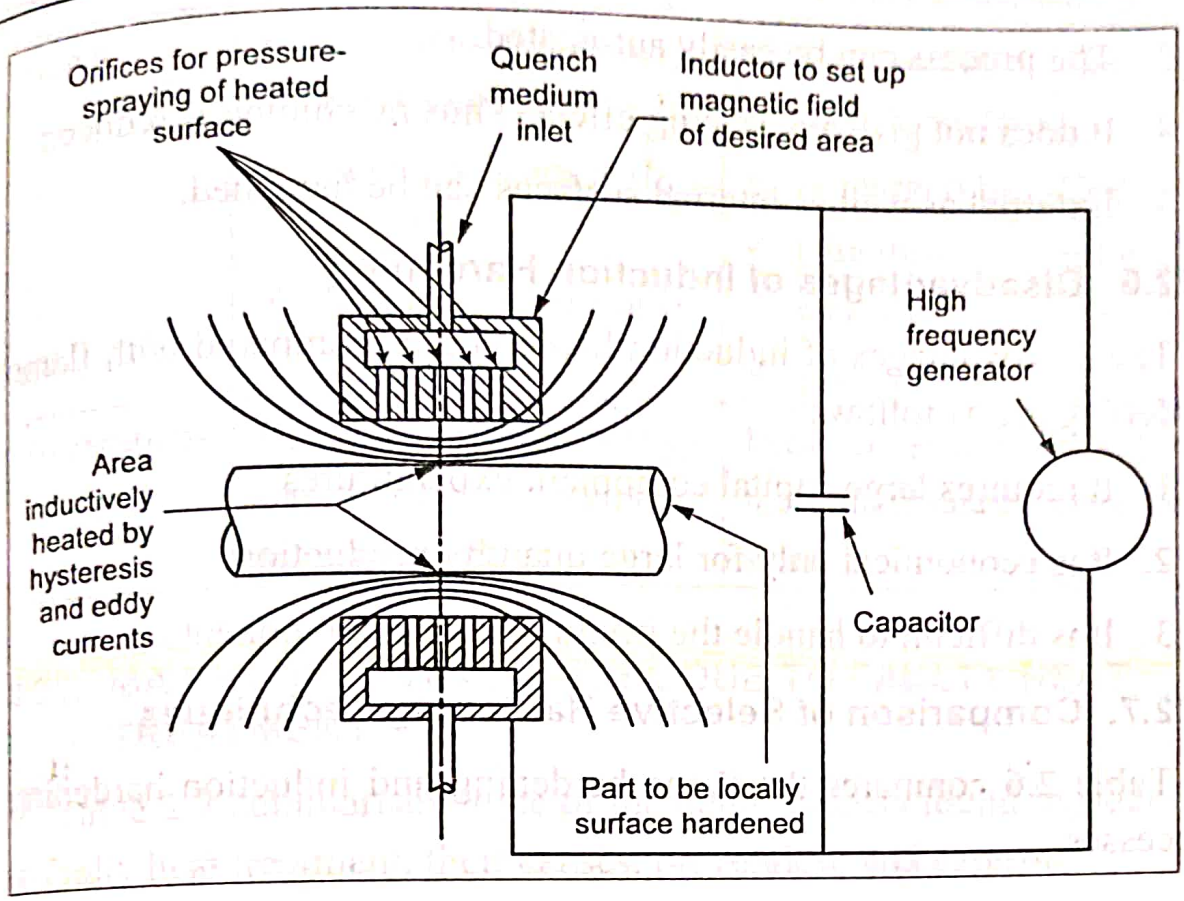

Fig. 2.34. The scheme of induction-hardening

As soon as the surface of the component has reached the necessary quenching temperature, the current is switched off, and the surface is simultaneously quenched by pressure jets of water, which pass through holes in the induction-block, as shown in Fig.2.34.

2.22.4. Applications

The induction hardening is employed for hardening the surfaces of gears, tool drivers, wrist pins, crank shaft bearing journals, cylinder liners, rail ends, machine tool ways, and pump shafts.

2.22.5. Advantages of Induction Hardening

The advantages of induction hardening over flame hardening are as follows :

1. Time required for heating in induction hardening is very less (in the order of 10 s).
2. The surface hardness and depth of hardness can be easily controlled.

3. The process can be easily automated.
4. It does not give any scaling effect. Thus machining is reduced.
5. External as well as internal surfaces can be hardened.

2.22.6. Disadvantages of Induction Hardening

The disadvantages of induction hardening as compared with flame hardening are as follows :

1. It requires large capital equipment expenditures.
2. It is economical only for large quantity production.
3. It is difficult to handle the irregular shape components.

2.11. MARTEMPERING (MARQUENCHING)

2.11.1. What is Martempering ?

- ✓ Martempering, also known as marquenching, is a interrupted cooling procedure used for steels to minimize the stresses, distortion and cracking of steels that may develop during rapid quenching.

2.11.2. Martempering Process

The martempering process consists of the following steps :

Step 1 : Austenitizing the steel, *i.e.*, heating the steel above its critical range to make it all austenite.

Step 2 : Quenching the austenitized steel in hot oil or molten salt at a temperature just slightly above the martensite start temperature (M_s).

Step 3 : Holding the steel in the quenching medium until the temperature is uniform throughout and stopping this isothermal treatment before the austenite-to-bainaite transformation begins.

Step 4 : Cooling at a moderate to room temperature (usually in air) to prevent large temperature differences between center and surface. Fig.2.27 shows a cooling path for the martempering process.

- ✓ The resulting microstructure of the martempered steel is untempered martensite.

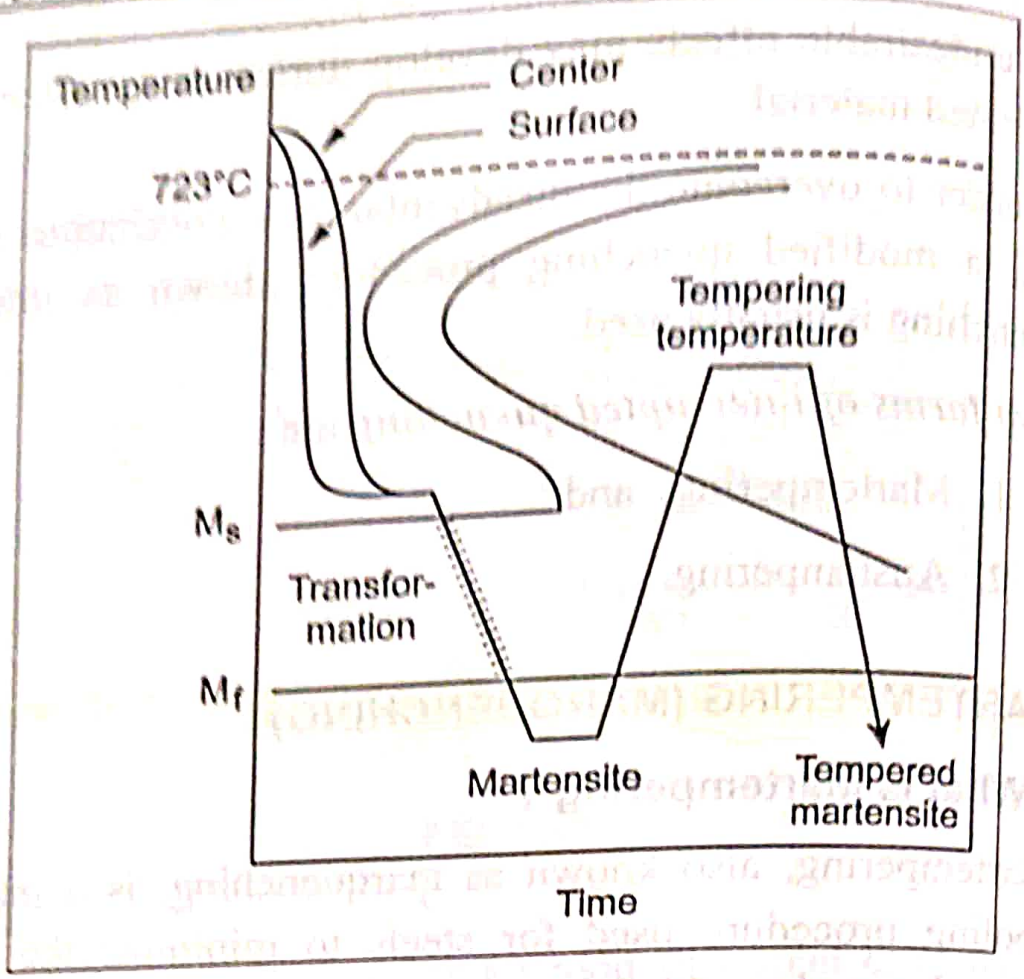

Fig. 2.27. Martempering process

✓ Now the untempered martensite structure is transformed into tempered martensite structure by the conventional tempering heat treatment processing rapid quenching.

Note Here it may be noted that despite the name of martempering, no tempering occurs. That's why this process is more appropriately called ***marquenching.***

2.11.3. Application

The martempering process is mostly used in alloy steels.

2.11.4. Advantages of Martempering

The main advantages of martempering are :

1. Minimised quenching stresses.
2. Minimised chances of formation of quenching cracks.
3. Less distortion or warping.

2.12. AUSTEMPERING (ISOTHERMAL QUENCHING)

2.12.1. What is Austempering ?

- ✓ Austempering is another type of interrupted quenching that forms bainite structure.
- ✓ The austempering is an isothermal heat treatment process, usually used to reduce quenching distortion and to make a tough and strong steels.

2.12.2. Austempering Process

The austempering process consists of the following steps :

Step 1 : Austenitizing the steel.

Step 2 : Quenching the austenitised steel in a molten salt bath at a temperature just above the martensite start temperature (M_s) of the steel.

Step 3 : Holding the steel isothermally to allow the austenite-to-bainite transformation to take place.

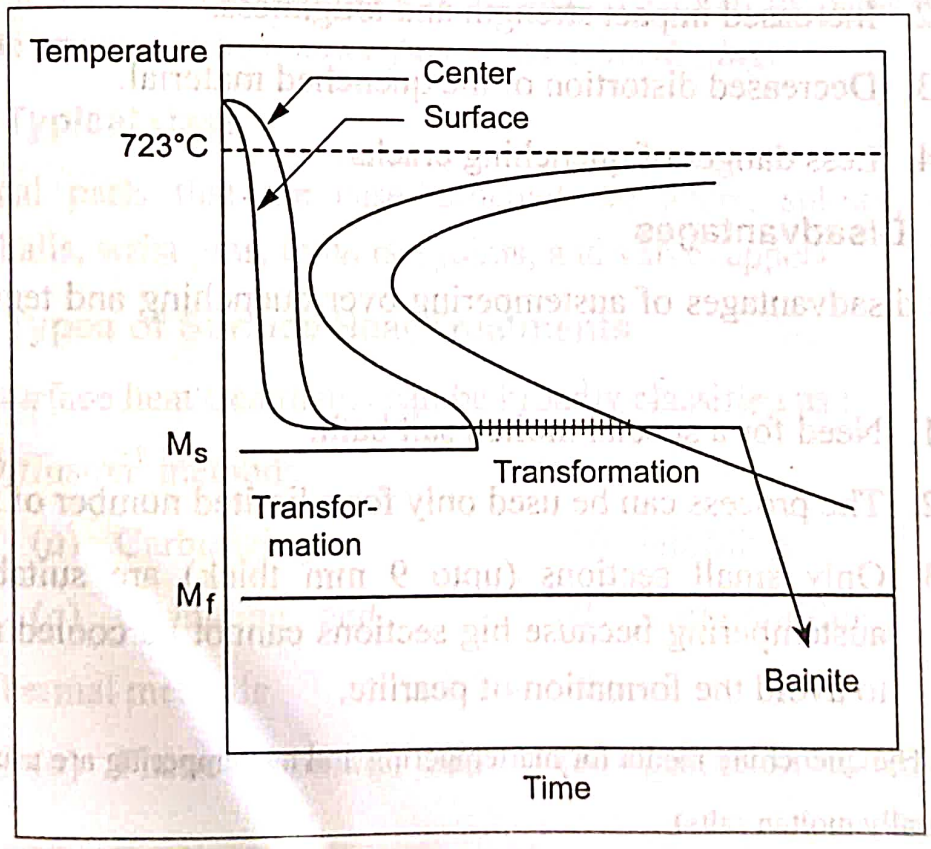

Fig. 2.28. Austempering process

Step 4 : Slow cooling to room temperature in air. Fig.2.28 shows a cooling path for the austempering process.

✓ The resulting microstructure of the austempering process is bainite. Unlike martempering, tempering is rarely needed after austempering.

Note Here, it may be noted that the process name 'austempering' is misleading since bainite is formed instead of martensite and there is no tempering.

2.12.3. Application

Austempering is widely applied on small tools, springs, retainers, automobile seat belt components, link chains, lawnmover blades and various machinery parts.

2.12.4. Advantages

The advantages of austempering are :

1. Improved ductility.
2. Increased impact strength and toughness.
3. Decreased distortion of the quenched material.
4. Less danger of quenching cracks.

2.12.5. Disadvantages

The disadvantages of austempering over quenching and tempering are :

1. Need for a special molten salt bath.
2. The process can be used only for a limited number of steels.
3. Only small sections (upto 9 mm thick) are suitable for austempering because big sections cannot be cooled rapidly to avoid the formation of pearlite.

Note The quenching media for martempering and austempering are usually the same (usually molten salts).