9

Surface Hardening

INTRODUCTION

In this chapter, those surface hardening processes are discussed in which there is no change in the chemistry of the surface of steel component to be surface hardened. These processes are flame hardening, induction hardening, laser hardening and electron beam hardening.

9.1 FLAME HARDENING

Flame hardening is the simplest form of surface hardening heat treatment. This process consists of heating the large work-piece, such as crank shaft, axle, large gear, cam, bending roller, or any other complicated cross-section, by an oxy-acetylene or oxy-fuel blow pipe, followed by spraying of jet of water as coolant. After hardening, reheating of the parts is carried out in furnace or oil bath at about 180–200°C for stress relieving. Such a treatment does not appreciably reduce the hardness at the surface. Hardness in flame hardened steel is due to martensitic and lower bainitic structure.

Overheating of work-piece should be avoided, otherwise, there is danger of cracking after quenching and excessive grain growth in the region just below the hardened surface. The carbon content required for flame hardening steels varies from 0.3 percent to 0.6 percent. High carbon steels can also be hardened by this process, but greater care is required to avoid cracking. Normally, case depth upto 3 mm can be achieved. A high rate of heating is essential for thin cases with proper adjustment of timing of application of flame. For good quality, strict control of heating time and fuel and oxygen consumption is essential.

There are four different methods which are used in general for flame hardening: (i) stationary, (ii) progressive, (iii) spinning, and (iv) progressive-spinning.

In the first, both burner and work-piece are stationary. Progressive hardening is carried out by using a burner combined with a waterspray, as shown in Figure 9.1(a). In this case, the burner moves over the large stationary work-piece. This is followed by quenching. In the spinning method, the work-piece is rotated, while the burner remains stationary. After heating, the flame is removed and quenching is carried out by a water jet. In the progressive-spinning method, the burner moves over a rotating work-piece [see Figure 9.1(b)]. In all the cases, rapid quenching is carried out after heating. There is little scaling, decarburization, or distortion in flame hardening. Since the heating and cooling are very fast, the core remains unaffected.

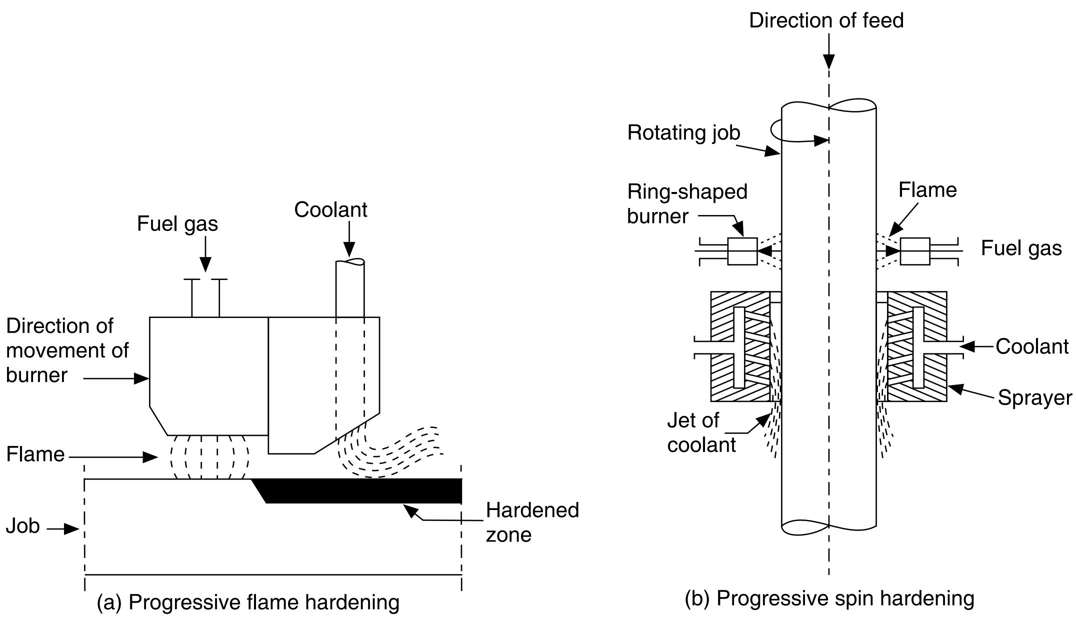

Figure 9.1 Schematic diagram illustrating two principles,

9.2 INDUCTION HARDENING

Induction hardening may be used for local surface heat treatment. Generally, it is used to surface harden crank shafts, cam shafts, gears, crank pins and axles. In this process, heating of the component is achieved by electromagnetic induction. A conductor (coil) carries an alternating current of high frequency which is then induced in the enclosed steel part placed within the magnetic field of the coil. As a result, induction heating takes place. The heat so generated affects only the outer surface of the steel component due to skin effect.

The degree of flow of current on the outer surface of a component depends on the frequency, resistivity and permeability of the component. For a given material, the last two factors depend on temperature. The depth to which the current, penetrates and raises the temperature is given by the following relation for steel components:

$$\text{In cold state (at 20°C)}, \; d_{20} = 20/\sqrt{f} \tag{9.1}$$

$$\text{In hot state (at 800°C)}, \; d_{800} = 500/\sqrt{f} \tag{9.2}$$

where d is the depth (mm) to which current flows and f is the frequency of current carried by the coil. This frequency is expressed in hertz. This relationship shows that the depth of hardening decreases with increase in frequency. In addition to direct heating of the skin by induced current, there is also some heating of the core due to conduction of heat. Hence, the overall depth of heating is greater than that given by Eqs. (9.1) and (9.2). Accordingly, the overall depth of penetration of heat (d_0, in mm) at 800°C is given by the relation

$$(d_0)_{800} = d_{800} + d_c \tag{9.3}$$

where d_c (mm) is the depth of penetration of heat due to conduction and is given by the relation

$$d_c = 0.2\sqrt{t} \tag{9.4}$$

where t is the heating time (seconds).

In induction hardening, the component is heated usually for a few seconds only. Immediately after heating, the surface is quenched by a jet of cold water. Due to quenching, a martensitic structure is formed, which makes the outer surface hard and wear resistant. Figure 9.2 shows the operation of induction hardening.

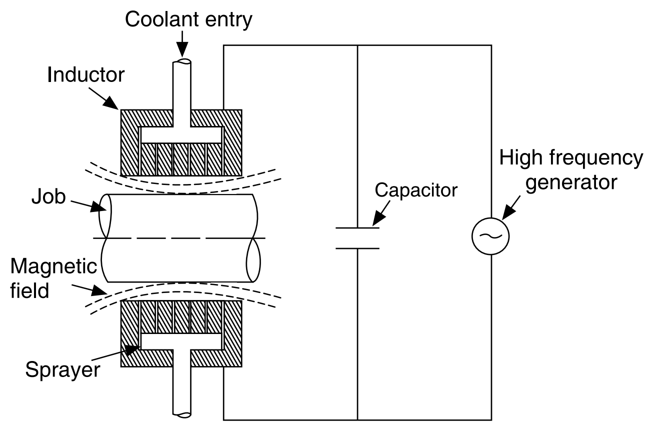

Figure 9.2 Diagrammatic representation of induction hardening process.

In hardening, temperature for plain carbon steel is about 760°C. For alloy steels, higher hardening temperatures are required. For example, for Cr-Mo steels the hardening temperature is about 800°C.

A striking feature of induction hardening (which is true of other surface hardening processes also) is that in this process the original toughness and ductility remain unaffected even after heat treatment.

Table 9.1 gives the process conditions for induction hardening of steels.

Table 9.1 Process Conditions for Induction Heating of Steels

Range of desired depth of hardening (mm)	Frequency required (Hz)	Range of power input required (kW)
0.5–1.1	450	15–19
1.1–2.3	450	8–12
1.5–2.3	10	15–25
2.3–3.0	10	15–23
3.0–4.0	10	15–22
3.0–4.0	3	22–25
4.0–5.0	3	15–22