4.10 Case Hardening

The heat-treatment processes described thus far involve microstructural alterations and property changes in the bulk of the component by means of *through hardening*. It is not always desirable to through harden parts, because a hard part lacks the required toughness for some applications. For example, a small surface crack could propagate rapidly through a part and cause sudden and total failure. In many cases, modification of only the *surface properties* of a part (hence, the term *surface* or *case hardening*) is desirable. This widely used method is particularly useful for improving resistance to surface indentation, fatigue, and wear. Typical applications for case hardening are gear teeth, cams, shafts, bearings, fasteners, pins, automotive clutch plates, tools, and dies.

Several case-hardening processes are available (Table 4.1):

1. **Carburizing** (gas, liquid, and pack carburizing)
2. **Carbonitriding**
3. **Cyaniding**
4. **Nitriding**
5. **Boronizing**
6. **Flame hardening**
7. **Induction hardening**
8. **Laser-beam hardening**

Basically, these are operations where the component is heated in an atmosphere containing elements (such as carbon, nitrogen, or boron) that alter the composition, microstructure, and properties of surface layers. For steels with sufficiently high carbon content, surface hardening takes place without using any of these additional elements; only the heat-treatment processes described in Section 4.7 are needed to alter the microstructures, usually by either flame hardening or induction hardening, as outlined in Table 4.1.

TABLE 4.1

Outline of Heat-treatment Processes for Surface Hardening

Process	Metals hardened	Element added to surface	Procedure	General characteristics	Typical applications
Carburizing	Low-carbon steel (0.2% C), alloy steels (0.08–0.2% C)	C	Heat steel at 870°C–950°C in an atmosphere of carbonaceous gases (gas carburizing) or carbon-containing solids (pack carburizing); then quench.	A hard, high-carbon surface is produced. Hardness = 55–65 HRC. Case depth = <0.5–1.5 mm. Some distortion of part during heat treatment.	Gears, cams, shafts, bearings, piston pins, sprockets, clutch plates
Carbonitriding	Low-carbon steel	C and N	Heat steel at 700°C–800°C in an atmosphere of carbonaceous gas and ammonia; then quench in oil.	Surface hardness = 55–62 HRC. Case depth = 0.07–0.5 mm. Less distortion than in carburizing.	Bolts, nuts, gears
Cyaniding	Low-carbon steel (0.2% C), alloy steels (0.08–0.2% C)	C and N	Heat steel at 760°C–845°C in a molten bath of solutions of cyanide (e.g., 30% sodium cyanide) and other salts.	Surface hardness up to 65 HRC. Case depth = 0.025–0.25 mm. Some distortion.	Bolts, nuts, screws, small gears
Nitriding	Steels (1% Al, 1.5% Cr, 0.3% Mo), alloy steels (Cr, Mo), stainless steels, high-speed tool steels	N	Heat steel at 500°C–600°C in an atmosphere of ammonia gas or mixtures of molten cyanide salts; no further treatment.	Surface hardness up to 1100 HV. Case depth = 0.1–0.6 mm and 0.02–0.07 mm for high-speed steel.	Gears, shafts, sprockets, valves, cutters, boring bars, fuel-injection pump parts
Boronizing	Steels	B	Part is heated using boron-containing gas or solid in contact with part.	Extremely hard and wear-resistant surface. Case depth = 0.025–0.075 mm.	Tool and die steels
Flame hardening	Medium-carbon steels, cast irons	None	Surface is heated with an oxyacetylene torch, then quenched with water spray or other quenching methods.	Surface hardness = 50–60 HRC. Case depth = 0.7–6 mm. Little distortion.	Gear and sprocket teeth, axles, crankshafts, piston rods, lathe beds and centers
Induction hardening	Same as above	None	Metal part is placed in copper induction coils and is heated by high frequency current; then quenched.	Same as above	Same as above

Laser beams and **electron beams** (Sections 27.6 and 27.7) are used effectively to harden small as well as large surfaces, such as gears, valves, punches, and engine cylinders. The depth of the case-hardened layer is usually less than 2.5 mm. These methods are also used for through hardening of relatively small parts. The main advantages of laser surface hardening are close control of power input, low part distortion, and the ability to reach areas that may be inaccessible by other means.

Because case hardening involves a localized layer, case-hardened parts have a *hardness gradient*. Typically, the hardness is maximum at the surface and decreases inward, the rate of decrease depending on the composition and physical properties of the metal and processing variables. Surface-hardening techniques can also be used for *tempering* (Section 4.11) and for modifying the properties of surfaces that have been subjected to heat treatment. Several other processes and techniques for surface hardening, such as shot peening and surface rolling, to improve wear resistance and other characteristics, are described in Section 34.2.

Decarburization is the phenomenon in which alloys lose carbon from their surfaces as a result of heat treatment or of hot working in a medium, usually oxygen, that reacts with the carbon. Decarburization is undesirable because it affects the hardenability of the surfaces of a part, by lowering its carbon content; it also adversely affects the hardness, strength, and fatigue life of steels, significantly lowering their endurance limit.