4.12 Heat-treating Furnaces and Equipment

Two basic types of furnaces are used for heat treating: batch furnaces and continuous furnaces. Because they consume much energy, their insulation and efficiency are important design considerations, as are their initial cost, the personnel needed for their operation and maintenance, and their safe use.

Uniform temperature and accurate control of temperature–time cycles are important. Modern furnaces are equipped with various electronic controls, including computer-controlled systems, programmed to run through a complete heat-treating cycle repeatably and with reproducible accuracy. The fuels used are usually natural gas, oil, or electricity (for resistance or induction heating); the type of fuel affects the furnace's atmosphere. Unlike electric heating, gas or oil introduces combustion products into the furnace. Electrical heating, however, has a slower start-up time and is more difficult to adjust and control.

Batch Furnaces. In a *batch furnace*, the parts to be heat treated are loaded into and unloaded from the furnace in individual batches. The furnace basically consists of an insulated chamber, a heating system, and an access door or doors. Batch furnaces are of the following basic types:

1. A **box furnace** is a horizontal rectangular chamber, with one or two access doors through which parts are loaded.
2. A **pit furnace** is a vertical pit below ground level into which the parts are lowered.
3. A **bell furnace** is a round or rectangular box furnace without a bottom, and is lowered over stacked parts that are to be heat treated; this type of furnace is particularly suitable for coils of wire, rods, and sheet metal.
4. In an **elevator furnace**, the parts to be heat treated are loaded onto a car platform, rolled into position, and then raised into the furnace.

Continuous Furnaces. In this type of furnace, the parts to be heat treated move continuously through the furnace on conveyors of various designs.

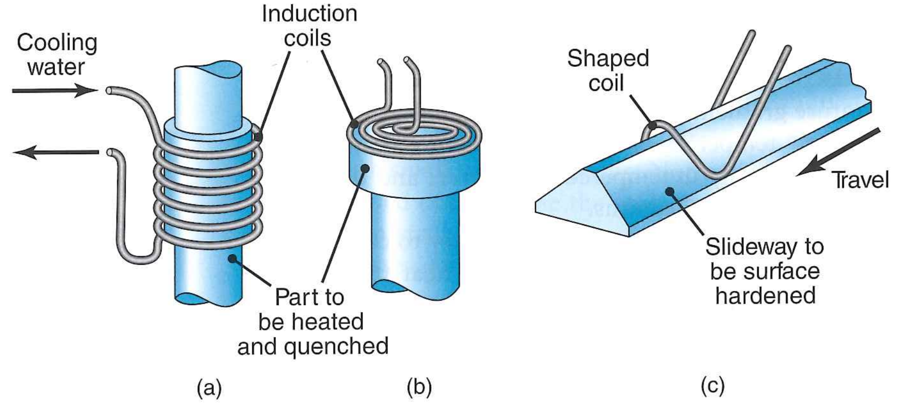

FIGURE 4.24 Types of coils used in induction heating of various surfaces of parts.

Salt-bath Furnaces. Because of their high heating rates and better control of uniformity of temperature, *salt baths* are commonly used in various heat-treating operations, particularly for nonferrous strip and wire. Heating rates are high because of the higher thermal conductivity of liquid salts as compared with that of air or gases.

Fluidized Beds. Dry, fine, and loose solid particles, usually aluminum oxide, are heated and suspended in a chamber by an upward flow of hot gas at various speeds. The parts to be heat treated are then placed within the floating particles, hence the term *fluidized bed*.

Induction Heating. In this method, the part is heated rapidly by the electromagnetic field generated by an *induction coil* carrying alternating current, which induces eddy currents in the part. The coil, which can be shaped to fit the contour of the part to be heat treated (Fig. 4.24), is made of copper or of a copper-base alloy. The coil, which is usually water cooled, may be designed to quench the part as well.

Furnace Atmospheres. The atmospheres in furnaces can be controlled so as to avoid oxidation, tarnishing, and decarburization of ferrous alloys heated to elevated temperatures. Oxygen causes corrosion, rusting, and scaling. Carbon dioxide, which has various effects, may be neutral or decarburizing, depending on its concentration in the furnace atmosphere. Nitrogen is a common neutral atmosphere, and a vacuum provides a completely neutral atmosphere. Water vapor in the furnace causes oxidation of steels, resulting in a blue color. The term **bluing** is used to describe formation of a thin, blue film of oxide on finished parts to improve their appearance and their resistance to oxidation.

QR Code 4.3 Demonstration of induction heating. (*Source:* Courtesy of GH Induction Atmospheres)

4.13 Design Considerations for Heat Treating

In addition to metallurgical factors, successful heat treating involves design considerations for avoiding such problems as cracking, distortion, and nonuniformity of properties throughout and among heat-treated parts. The rate of cooling during quenching may not be uniform, particularly in complex shapes having varying cross-sections and thicknesses, producing severe temperature gradients in the part.

Nonuniformity can lead to variations in contraction, resulting in thermal stresses that may cause warping or cracking of the part. Nonuniform cooling also causes residual stresses in the part, which then can lead to stress-corrosion cracking. The quenching method selected, the care taken during the operation, and the selection of a proper quenching medium and temperature also are important considerations.

As a general guideline for part design for heat treating.

- Sharp internal or external corners should be avoided, as otherwise stress concentrations at these corners may raise the level of stresses high enough to cause cracking.
- The part should have its thicknesses as nearly uniform as possible.
- The transition between regions of different thicknesses should be made smooth.
- Parts with holes, grooves, keyways, splines, and asymmetrical shapes may be difficult to heat treat, because they may crack during quenching.
- Large surfaces with thin cross-sections are likely to warp.
- Hot forgings and hot steel-mill products may have a *decarburized skin* which may not respond successfully to heat treatment.