26 HEAT TREATMENT OF METALS

Review Questions

26.1 Why are metals heat-treated?

Answer. Metals are heat-treated to effect metallurgical changes that beneficially alter properties.

26.2 Identify the important reasons why metals are annealed.

Answer. The purposes of annealing include to (1) control properties, (2) reduce brittleness and improve toughness, (3) recrystallize cold-worked metals, and (4) relieve stresses from prior metalworking.

26.3 What is the difference between *full annealing* and *normalizing*?

Answer. Full annealing is associated with ferrous metals; it involves heating the alloy into the austenite region, followed by slow cooling in the furnace to produce coarse pearlite. Normalizing involves similar heating and soaking cycles, but the cooling rates are faster. The steel is allowed to cool in air to room temperature, resulting in fine pearlite.

26.4 What is the most important heat treatment for hardening steels?

Answer. The most important heat treatment for steels is martensite formation by heating steel into the austenite region and quenching.

26.5 What is the mechanism by which carbon strengthens steel during heat treatment?

Answer. When steel containing carbon is heat-treated to increase strength and hardness, martensite is formed which is a hard and brittle non-equilibrium phase of steel. The extreme hardness of martensite results from the lattice strain created by carbon atoms trapped in the body-centered tetragonal structure, thus providing a barrier to slip.

26.6 What information is conveyed by the TTT curve?

Answer. The time-temperature-transformation (TTT) curve indicates what phases in the iron-carbon phase diagram will be produced under various conditions of cooling.

26.7 What are the four quenching media used in the quenching of steel to produce martensite?

Answer. The four quenching media are (1) brine—salt water, usually agitated; (2) fresh water— not agitated; (3) still oil; and (4) air.

26.8 What function is served by tempering?

Answer. Tempering is a heat treatment to reduce brittleness, increase ductility and toughness, and relieve stresses in the martensite structure.

26.9 Define hardenability.

Answer. Hardenability is the relative capacity of a steel to be hardened by transformation to martensite. It is a property that determines the depth below the quenched surface to which the steel is hardened, or the severity of the quench required to achieve a certain hardness penetration.

26.10 What is the name of the most common test for hardenability?

Answer. Jominy end-quench test.

26.11 Name some of the elements that have the greatest effect on the hardenability of steel.

Answer. Important hardenability elements are chromium, manganese, molybdenum, and nickel.

26.12 How do the hardenability alloying elements in steel affect the TTT curve?

Answer. The hardenability alloying elements operate by pushing the nose of the TTT curve to the right, thereby permitting slower cooling rates for conversion of austenite to martensite.

26.13 Define precipitation hardening.

Answer. Precipitation hardening is a heat treatment in which very fine particles (precipitates) are formed so that dislocation movement is blocked and the metal is thus strengthened and hardened.

26.14 What are the three processing steps in precipitation hardening?

Answer. The three processing steps in precipitation hardening are (1) solution treatment, in which the alloy is heated to a temperature above the solvus line into the alpha phase region and held for a period sufficient to dissolve the beta phase; (2) quenching to room temperature to create a supersaturated solid solution; and (3) precipitation treatment, in which the alloy is heated to a temperature to cause precipitation of fine particles of the beta phase.

26.15 What is the difference between *natural aging* and *artificial aging* in precipitation hardening?

Answer. Natural aging is performed at room temperature, whereas artificial aging is accomplished at an elevated temperature.

26.16 What is the name of the steel that can be precipitation-hardened?

Answer. Maraging steel.

26.17 How does carburizing work?

Answer. Carburizing adds carbon to the surface of low-C steel, thereby transforming the surface into high-C steel for greater hardening potential.

26.18 What are the two types of furnace technologies used in heat treatment?

Answer. Fuel-fired furnaces and electric furnaces.

26.19 Identify the selective surface-hardening methods.

Answer. The selective surface-hardening methods include flame hardening, induction hardening, high-frequency (HF) resistance heating, electron beam (EB) heating, and laser beam (LB) heating.