Part VI. Heat treatment

1 Hardness and hardenability: an inside view

In this part, we discuss the formation of microstructures and their evolution during heat treatment, aspects of practical heat treatment (such as furnaces, fixtures, atmosphere and quenching media), and some important heat treatment processes. The discussion is cursory. The interested reader should refer to Boyer and Dossett [1] for details on the practical aspects and Porter et al [2] for the phase transformations aspects.

1.1 Hardness and its measurement

Heat treatments are carried out to change the properties of materials by changing the microstructure of materials. The primary aim of majority of heat treatments is to change the mechanical properties of the given material; primarily, they are used either to harden (precipitation hardening, quenching, carburising, nitriding, etc) or soften (tempering, annealing, stress relieving, etc). Hence, in majority of cases, the success or failure of heat treatment is decided by the mechanical property measurements; more specifically, hardness is the typical quantity that is measured. Hence, in this module, we discuss some of the standard hardness measurements in a brief manner.

Hardness is the resistance of a material to plastic deformation. It also correlates with the other mechanical properties such as strength (direct) and ductility (inverse). Further, hardness tests are easy to perform, and, if needed, can be performed without having to discard the sample after testing. This is the reason why hardness tests are usually employed after heat treatment processes.

Hardness can be measured using indentors such as Brinell, Rockwell and Vickers; in each of these cases, by measuring the geometric parameters of the indent (area, depth of penetration, mean diameter, etc). It is also possible to apply very low loads and carry out indentation experiments; such tests are known as microhardness tests.

1.2 Hardenability

Hardenability is the ability for a material to harden; it refers not to the highest value of hardness that can be obtained but to the capacity (depth or thickness over which such high hardness values can be achieved) to harden. Thus, hardenability is intimately related to the cooling rate that can be achieved (especially in steels). Typically, hardenability is tested using hardness penetration diagram test (in which, the hardness of a hardened sample is plotted as a function of depth from the surface), and Jominy end quench test (in which one end of a sample is quenched and the hardness at equal intervals from the quenched end is measured and plotted).

1.2.1 Effect of alloying elements on hardenability

In steels, alloying elements are added to increase hardenability; this is achieved by delaying the time required to transform austenite into ferrite and pearlite (and thus shifting the nose of the C curve in the TTT diagram to longer times), which helps in the formation of martensites even with slower cooling rates.

The alloying elements delay the decomposition of austenite into ferrite and parlite by reducing either the nucleation or the growth.

The alloying elements in steel are distinguished into two types: namely, austenite stabilizers (Mn, Ni, Cu) and ferrite stabilizers (Cr, Mo, Si). Even though both these additions help hardenability, the mechanisms involved are different.

1.3 Supplementary information

In addition to heat treatments meant for hardening or softening a given material, there are also certain heat treatments such as homogenising and austenitizing, for example, which are used as the preliminary heat treatments for secondary heat treatments; and these secondary heat treatments are the ones which are used to achieve the desired microstructure.