ENGINEERING MATERIALS

Lecture No. 2

Heat Treatment

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Heat treatment المعاملات الحرارية

Heat treatment is the process of heating (without to obtain the molten state) and cooling of metals to change their physical and mechanical properties (such as improving formability, machining, etc.), without letting it change its shape. It is an operation or combination of operations involving heating at a specific rate for a period of time and cooling at some specified rate .

Objectives of heat treatment

The major objectives are

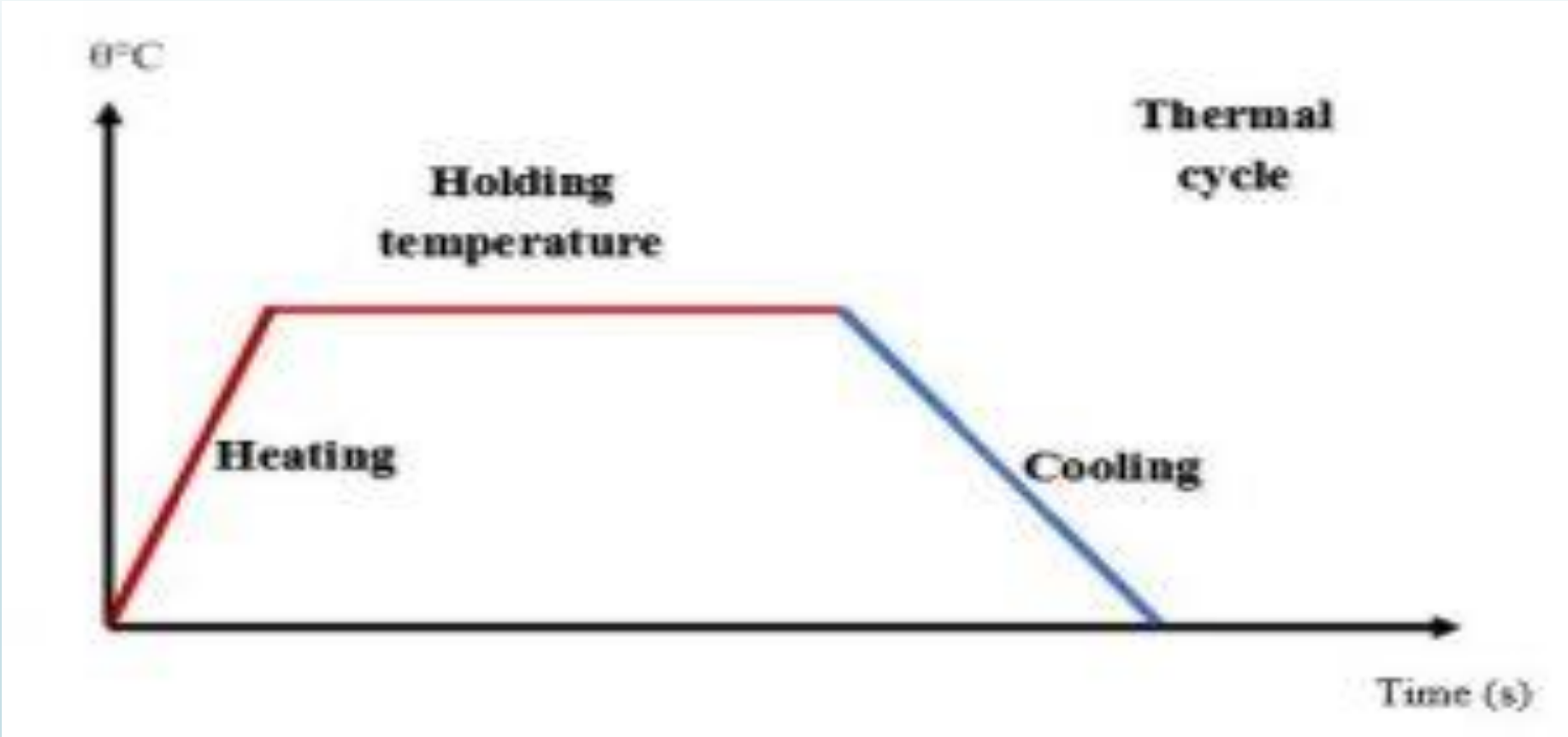
- To increase strength, harness and wear resistance
- To increase ductility and softness
- To increase toughness
- To obtain fine grain size
- To remove internal stresses induced by differential deformation by cold working, non-uniform cooling from high temperature during casting and welding
- To improve machinability.
- To improve cutting properties of tool steels.
- To improve surface properties.
- To improve electrical properties.
- To improve magnetic properties.

Stages of Heat Treatment:-

Stage -1 Heat the metal slowly to ensure a uniform temperature.

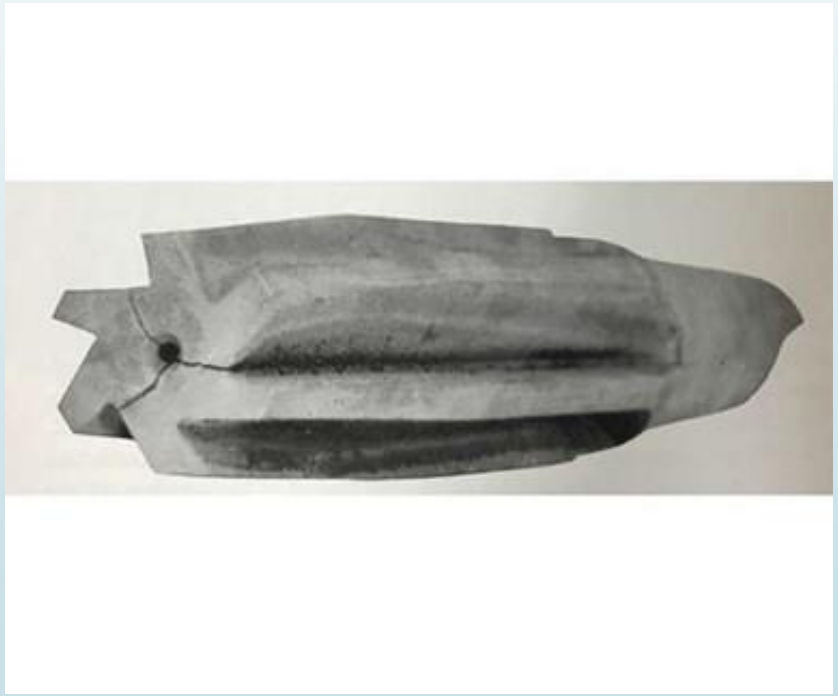
Stage - 2 Soak (hold) the metal at a given temperature for a given time.

Stage - 3 Cool the metal to room temperature.



Heating Stage

In the heating stage, the primary objective is to heat uniformly, and to attain and maintain uniform temperatures by slow heating. If the metal is heated unevenly, one section can expand faster than another, resulting in a distorted or cracked part.



Heating Stage

The appropriate heating rate will depend on several factors:-

1- The metal’s heat conductivity.

2- The metal’s condition. The heating rate for hardened (stressed) tools and parts Should be slower than the heating rate for unstressed.

3- A metal part’s size and cross section. To prevent warping or cracking, the large cross-sectioned parts must be heated slowly.

Soaking Stage

In the soaking stage, the objective is to hold the metal to the proper temperature until the desired internal structural changes take place. "**Soaking period**" is the term which use for the time that the metal is held at the proper temperature. The chemical analysis of the metal and the mass of the part will determine the appropriate soaking period. (Note: For steel parts with uneven cross sections, the largest section determines the soaking period.)

Cooling Stage

In the cooling stage, the objective is self-explanatory, but there are different processes to return a metal to room temperature, depending on the type of metal. To cool the metal and attain the desired properties, the metal is placed in direct contact with a **cooling medium** (a gas, liquid, solid, or a combination), and any cooling rate will depend on the metal itself and the chosen medium. Therefore, the choice of a cooling medium has an important influence on the properties desired. Cooling metal rapidly in air, oil, water, brine, or some other medium is called **quenching**.

Quenching

Quenching is usually associated with hardening since most metals that are hardened are cooled rapidly during the process. However, neither quenching nor rapid cooling always results in increased hardness. For example, a water quench is usually used to anneal copper, and some other metals are cooled at a relatively slow rate for hardening, such as air-hardened steels.

Generally, it should water-harden carbon steels, oil-harden alloy steels, and quench nonferrous metals in water.

Types of heat treatment:

Two types of heat treatment processes can be performed on nonferrous metalsالمعادن الغير حديدية . They are annealing and solution heat treatment. While there are five types of heat treatment processes can be performed on ferrous metals المعادن الحديدية. They are hardening, tempering, annealing, normalizing, and case hardening.

Hardening

A ferrous metal is normally hardened by heating the metal to the required temperature and then cooling it rapidly by plunging the hot metal into a quenching medium, such as oil, water, or brine. Most steels must be cooled rapidly to harden them. The hardening process increases the hardness and strength of metal, but also increases its brittleness.

Tempering

After hardening, steel is often harder than needed and too brittle for most practical uses, containing severe internal stresses that were set during the rapid cooling of the process. Following hardening, the steel is tempered to relieve the internal stresses and reduce brittleness.

Tempering consists of:

- Heating the steel to a specific temperature (below its hardening temperature)
- Holding it at that temperature for the required length of time
- Cooling it, usually in still air.

Annealing

The objective of annealing is the opposite of hardening. Metals are annealed to relieve internal stresses, soften them, make them more ductile, and refine their grain structures. Metal is annealed by heating it to a prescribed temperature, holding it at that temperature for the required time, and then cooling it back to room temperature. The rate at which metal is cooled from the annealing temperature varies greatly. Steel must be cooled very slowly to produce maximum softness, This can be done by burying the hot part in sand, ashes, or some other substance that does not conduct heat readily(packing), or by shutting off the furnace and allowing the furnace and part to cool together (furnace cooling).

Normalizing

Ferrous metals are normalized to relieve the internal stresses produced by machining, forging, or welding. Normalized steels are harder and stronger than annealed steels. Steel is much tougher in the normalized condition than in any other condition. Parts that will be subjected to impact and parts that require maximum toughness are usually normalized. Normalizing is achieved by heating the metal to a specified temperature (which is higher than either the hardening or annealing temperatures), soaking the metal until it is uniformly heated, and cooling it in still air.

Case hardening

Case hardening is an ideal heat treatment for parts which require a wear-resistant surface and a tough core, such as gears, cams, cylinder sleeves, and so forth. The most common case-hardening processes are carburizing and nitriding. During the case-hardening process, a low-carbon steel (either straight carbon steel or low-carbon alloy steel) is heated to a specific temperature in the presence of a material (solid, liquid, or gas) which decomposes and deposits more carbon into the surface of a steel. Then, when the part is cooled rapidly, the outer surface or case becomes hard, leaving the inside of the piece soft but very tough.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Thank you for listening

Tempering colors of steel