Heat Treatments

HEAT TREATMENTS of METALS

- Heat treatment simply is a combination of heating and cooling operations, timed and applied to a metal or alloy in the solid state in a way that, will produce desired properties.

- All basic heat-treating processes for steel involve the transformation of austenite.

- By varying the manner in which, carbon steels are heated and cooled, different combinations of mechanical properties for steels can be obtained.

HEAT TREATMENTS of METALS

There are a few purposes of simple heat treatments.

1. Eliminating cold work
2. Controlling dispersion strengthening
3. Improving machinability

BASIC HEAT TREATMENTS

- QUENCHING
- ANNEALING
    a) Full Annealing
    b) Process (Stress Relief) Annealing
- NORMALIZING
- SPHERODIZING
- TEMPERING
- MARTEMPERING
- AUSTEMPERING

QUENCHING

- Quenching is a heat treatment in which the steel is heated up to austenite (γ) region and then rapidly cooled in water or oil.

- The hardening of steel requires the formation of martensite phase. This can be accomplished by quenching. Martensite is a meta-stable phase consisting of super-saturated interstitial solid solution of carbon in BCC or BCT iron.

- Quenching in water gives higher hardness than quenching in oil.

ANNEALING

There are two types of annealing processes applied to commercial plain-carbon steels.

a) Full Annealing

In full annealing, hypoeutectoid and eutectoid steels are heated in the austenite region, about 40 °C above the upper-critical line, held the necessary time and then slowly cooled to room temperature, usually in the furnace. Resulting microstructure is consisting of small grains of pro-eutectoid ferrite and small areas of coarse lamellar pearlite.

For hypereutectoid steels, the material will be heated to the two-phase (γ+Fe_3C) region 40 °C above the eutectoid temperature.

ANNEALING

Heating above this temperature coarsen the austenitic grains, which on cooling will transform to large pearlitic areas. The microstructure of full annealed hypereutectoid steels will consist of coarse lamellar pearlite areas surrounded by a network of pro-eutectoid cementite. Because the excess cementite network is brittle, annealing should never be a final heat treatment for hypereutectoid steels.

b) Process Annealing

This process is sometimes called as stress relief annealing. This treatment is carried out at a temp. below the eutectoid temperature usually between 550-650 °C for hypoeutectoid steels.

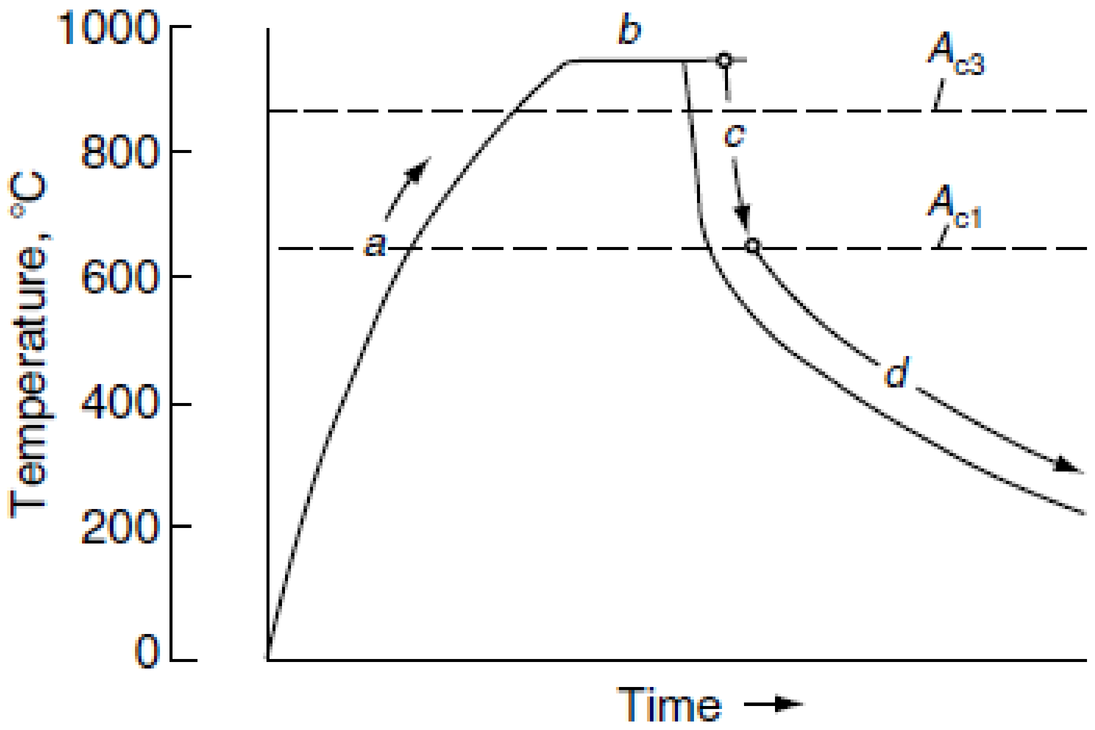
NORMALIZING

In this heat treatment steel is heated in the austenite region and then cooled in still air. The microstructrue of normalized plain carbon steels consists of pro-eutectoid ferrite and fine pearlite.

The aim of the normalizing process is:

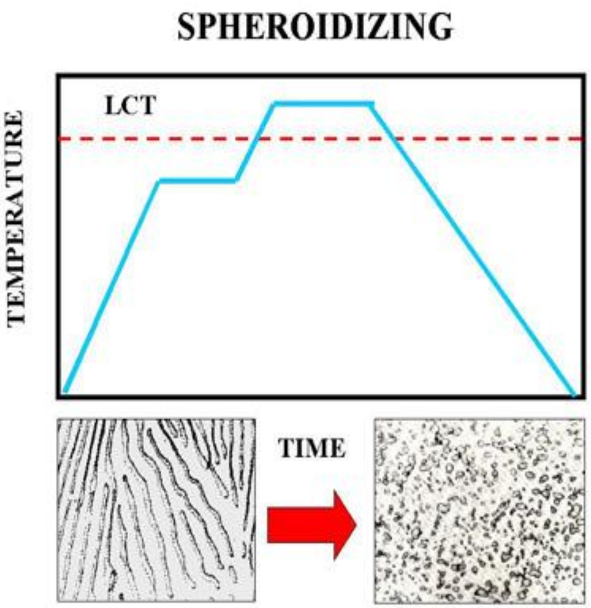
1. To refine the gain structure
2. To increase the strength of the steel
3. To reduce compositional segregation in castings or forgings and provide a more uniform structure.

Heating and Cooling Curve in Normalizing Heat Treatment

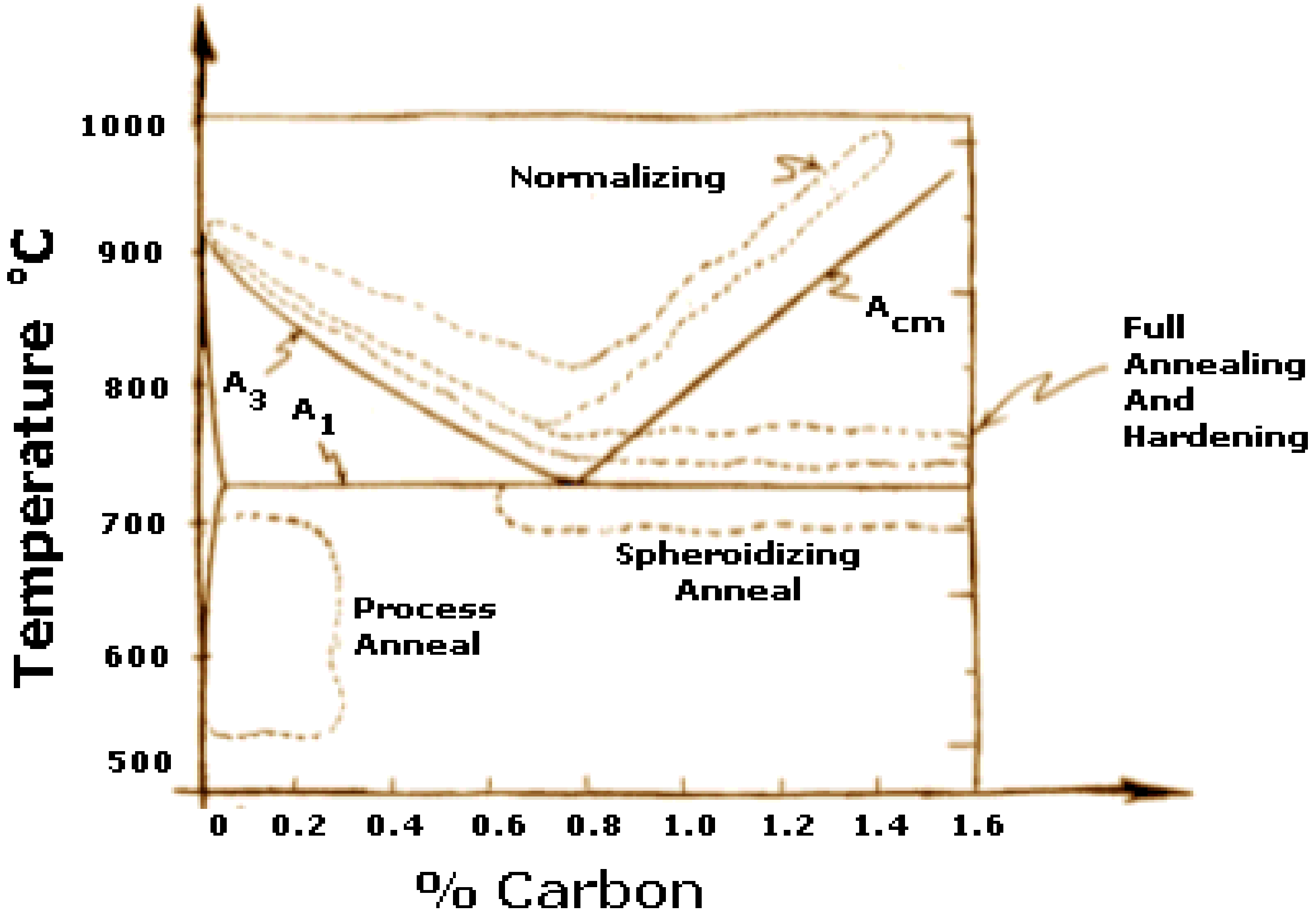


SPHERODIZING

High carbon hypereutectoid steels, which contain a large amount of Fe_3C, have poor machining characteristics. During the spherodizing treatment, which requires several hours at about 30 C below the eutectoid temperature, the Fe_3C changes into large spherical particles in order to reduce boundary area. The microstructure, known as spherodite, has a continuous matrix of soft machinable ferrite.



Positions of Heat Treatments on Iron-Iron-Carbide Phase Diagram



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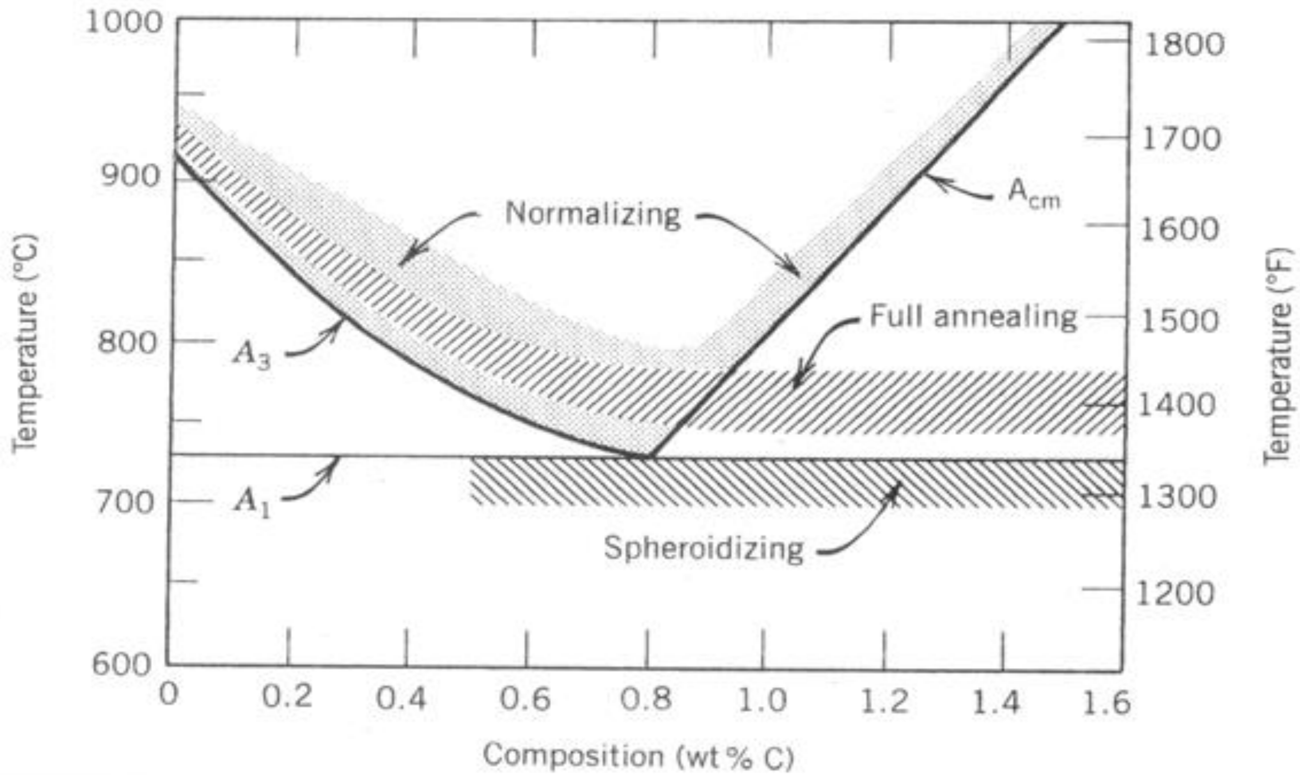

The iron–iron carbide phase diagram in the vicinity of the eutectoid, indicating heat treating temperature ranges for plain carbon steels.

TEMPERING

Tempering is the process of heating the martensitic steel at a temperature below the eutectoid temperature to make it softer and more ductile. Three stages of tempering are distinguished:

First stage: The quenched steel is heated to a temperature below 200 °C. In this temperature range a very small sized precipitate, called ε carbides, forms.

Second stage: It takes place at the temperature interval of 230-280 °C to transform the retained austenite to bainite.

TEMPERING

Third stage: It takes place at the temperature interval of 260-360 °C. Epsilon (ε) carbide changes to cementite plate, producing a structure of ferrite and cementite.

MARTEMPERING

This is a modified quenching procedure, sometimes called as Marquenching. It is used for steels to minimize distortion and cracking that may develop during uneven cooling of the heat-treated material. The martempering process consists of:

a) Austenitizing the steel
b) Quenching it in hot oil or molten salt at a temperature just above or below M_s (martensite start) temperature.
c) Holding the steel in the quenching medium until the temperature is uniform throughout and stopping this treatment before the austenite to bainite transformations begins.

MARTEMPERING

d) Cooling at a moderate rate to room temperature to prevent large temperature difference.

The microstructure of martempered steel is martensite, but the steel shows an improved ductility and no tempering is necessary because martensite has been formed without the production of high thermal stresses.

AUSTEMPERING

Austempering is an isothermal heat treatment which produces a bainite structure in some plain carbon steels. In this process the steel is first austenitized, then quenched in molten salt bath at a temperature just above M_s temp., held isothermally to allow austenite to bainite transformation to take place and then cooled to room temperature.

Provides an alternative procedure to quenching and tempering for increasing the toughness and ductility of some steels. The final structure is consisting of bainite.

AUSTEMPERING

Advantages of austempering over quenching and tempering are:

1. Improved ductility and impact resistance
2. Decreased distortion of quenched material.

Disadvantages are:

1. The need for special salt bath.
2. Can be applied to only limited number of steels.

CARBURIZING

This is the oldest and the cheapest method to produce material with very hard surface. In this process, a low carbon steel is placed in an atmosphere that contains carbon monoxide at austenite region.

$$Fe + 2\,CO \text{ ---------> } Fe_c + CO_2$$

This process is reversible. That is, the carbon can be removed from the surface of the steel. This process is now called as decarburizing.

DECARBURIZING

Decrease in content of carbon in metals is called decarburization. It is based on the oxidation at the surface of carbon that is dissolved in the metal lattice.

In heat treatment processes iron and carbon usually oxidize simultaneously. During the oxidation of carbon, gaseous products (**CO** and **CO_2**) develop. In the case of a scale layer, substantial decarburization is possible only when the gaseous products can escape.