Heat-Treatment

- **Heat treatment** a combination of operations involving heating and cooling of metals at a specific rate in the solid state by changing a property or combination of properties, such as mechanical, physical, magnetic, or electrical leading to modification in the molecular arrangement causing the metal to be produced either soft or hard.
- It involves the use of heating or chilling, normally to extreme temperatures, to achieve a desired result such as hardening or softening of a material
- It applies only to processes where the heating and cooling are done for the specific purpose of altering properties intentionally

Heat-Treatment Objective :

To achieve a desired degree of properties such as hardness and softens. So, the metal would be more useful, serviceable, and safe for definite purpose.

However, It is very important to note that the major general reasons for heat treatments based on their types are related to:

- Improve strength, ductility, toughness
- Obtain fine grain size
- Remove internal stresses
- Increase impact and wear resistance.

There are **two types of heat treatment processes**, the **softening** and **hardening**

- **Softening Purpose**: includes **annealing**, **normalizing, tempering** to reduce strength or hardness, Remove residual stresses, Improve toughness, Restore ductility, or Refine grain size.
- **Hardening Purpose**: includes **quenching** and **case hardening** processes.

To Increase the strength and wear properties by providing sufficient amount of carbon in the alloy content.

Note:

When an annealed part is allowed to cool in the furnace, it is called a "full anneal" heat treatment.

When an annealed part is removed from the furnace and allowed to cool in air, it is called a "normalizing" heat treatment.

Heat Treatment stages

The heat treatment for any metal involve three stages:

1-Heating rate:

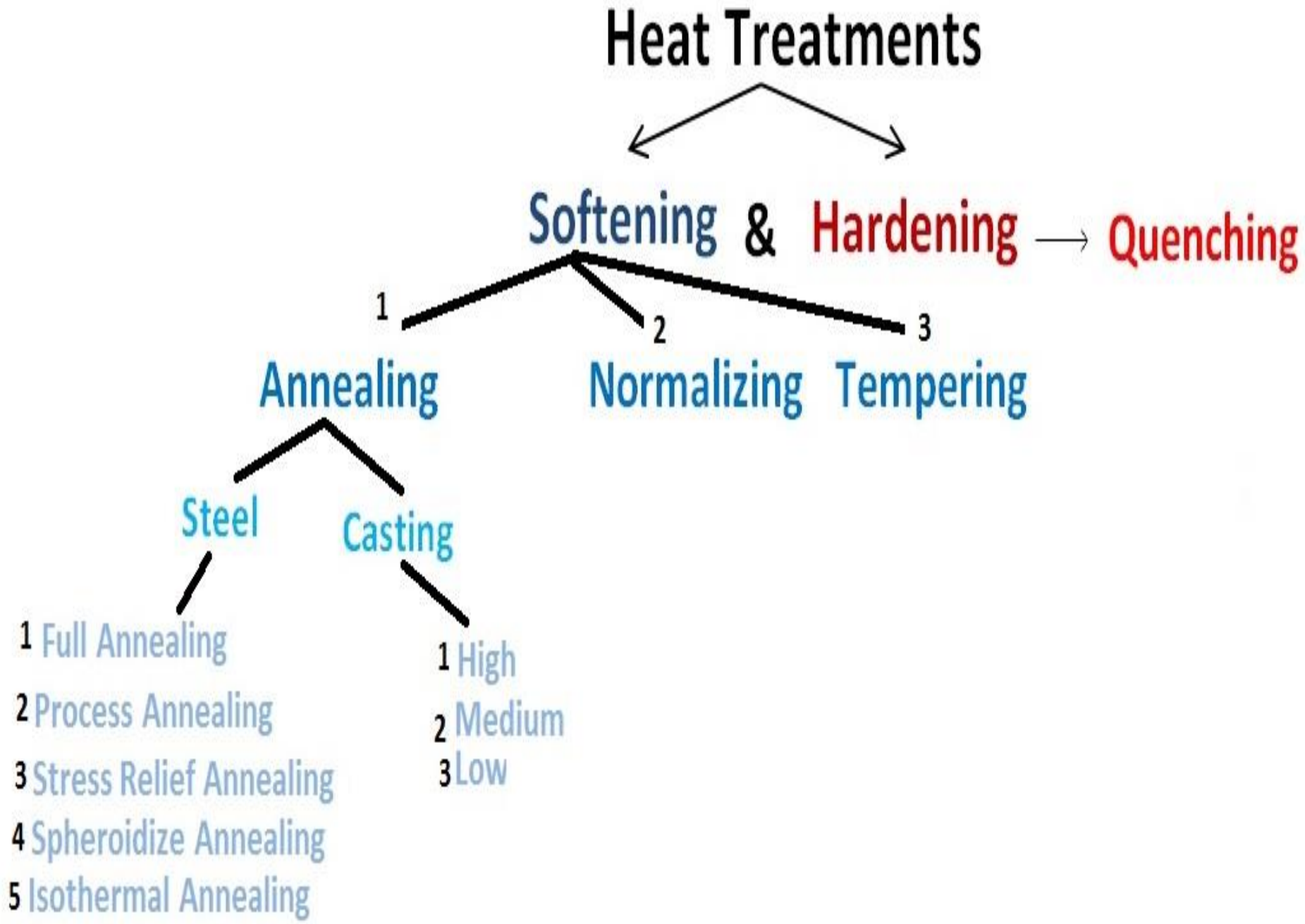
- the slower heating lead to uniform temperature distributed over the whole part. while the higher heating can lead to uneven heating in one section of a part by expanding faster than another section in the same part result in distortion or cracking.
- The heating rate depends on heat conductivity of the metal , e. g. a metal with a high-heat conductivity heats faster than one with a low conductivity.
- shape , size and cross section for the part. Parts with large cross sections require slower heating rates to remain close to the surface temperature.

Heat Treatment stages

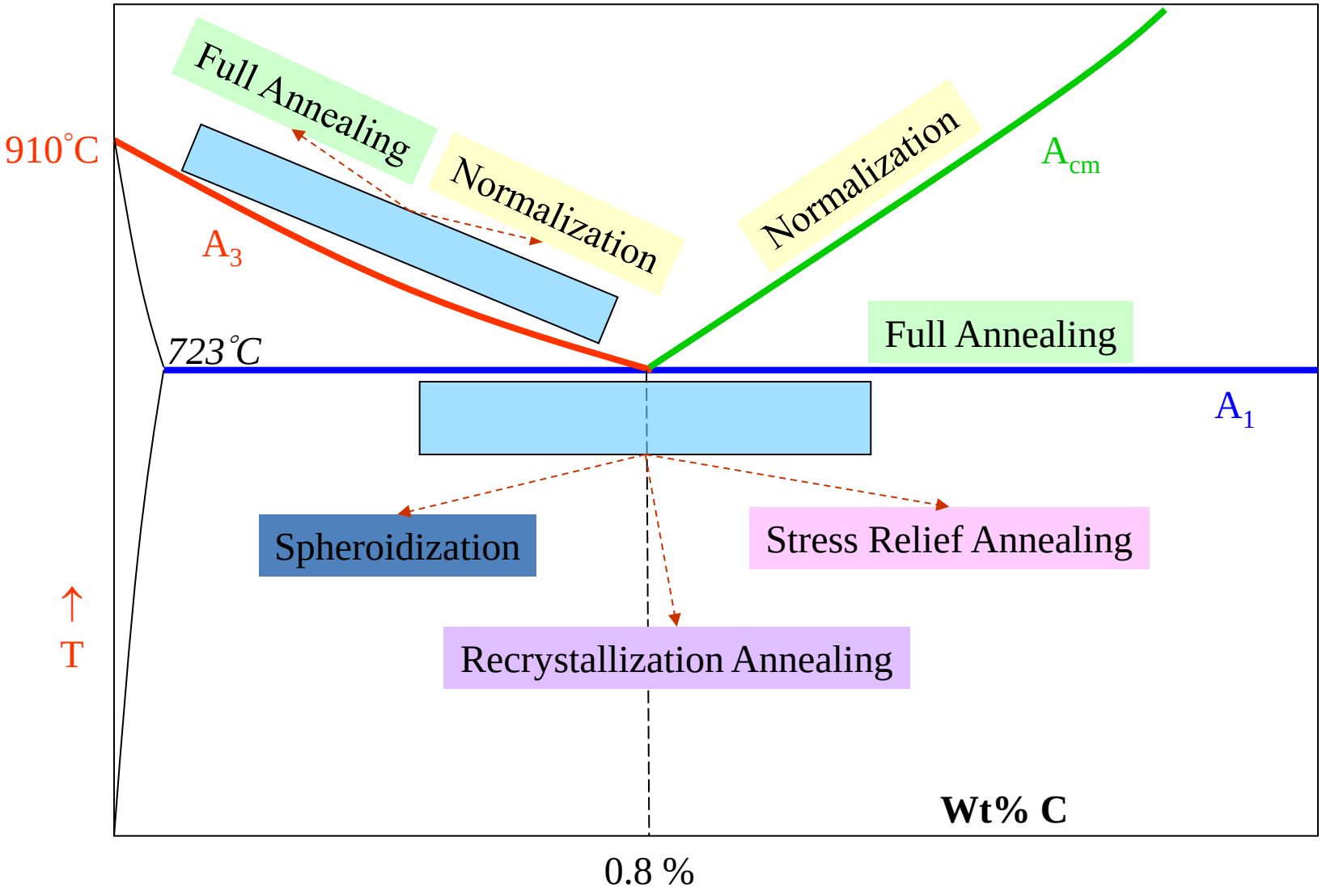
2-Soaking stage:

holding the metal at a given temperature , when the desired internal structural changes take place for a given time when the heat distributed uniformly thought the metal. Holding time depends on chemical analysis of the metal, mass of the part and cross sections' shape, e.g. the more complex cross section shape, the longer soaking time .

3- Cooling rate: There are different cooling rates depending on the medium, e.g. oil, water, brine, etc. Selection the rate at which the metal is cooled depends on the metal and the properties desired.


Heat Treatments
Softening & Hardening → Quenching
1
2
3
Annealing
Normalizing
Tempering
Steel
Casting
1 Full Annealing
2 Process Annealing
3 Stress Relief Annealing
4 Spheroidize Annealing
5 Isothermal Annealing
1 High
2 Medium
3 Low

- Ranges of temperature where Annealing, Normalizing and Spheroidization treatment are carried out for hypo- and hyper-eutectoid steels.
- Details are in the coming slides.



A- Softening Treatments (Annealing)

A- Annealing of Steel: heating the steel **above its critical temperature (recrystallization temperature)** for enough time, then cooling it to reduce hardness, remove residual stress (stress relief), improve toughness, restore ductility, or refine grain size.

Annealing Stages:

With increasing annealing temperature, the steel would be undergone three stages of phase transformations:

1- **Recovery**: It occurs at the lower temperature stage of all annealing process. The purpose to eliminate residual stresses introduced during deformation without reducing the strength of the cold worked material. **The grain size and shape do not change during this stage.**

Annealing Stages:

2- Recrystallization: It occurs at a medium temperature stage of annealing. It is designed to eliminate all of the effects of the strain produced during cold working. **New strain free grains nucleate and grow to replace those deformed by internal stresses.**

3- Grain Growth: it occurs after completion re-crystallization stage. The purpose is to reduce the amount of grain boundary area by movement of grain boundaries by diffusion. In this stage, the microstructure starts to coarsen and **may cause the steel material to lose a substantial part of its original strength**

Types of Steel's Annealing

1- Process annealing:

(intermediate annealing, subcritical annealing

1- Process annealing is a heat treatment that is often used to soften and increase the ductility of a previously strain hardened metal . Ductility is important in shaping and creating a more refined piece of work through processes such as rolling, drawing, forging, spinning and heating.

2- Heating the steel to a temperature below the lower critical temperature. Then, soaking long enough to relieve stresses, followed by furnace cooling.

3- **Purpose**: Improve ductility for cold worked steels which have low ductility and high hardness.

4- The temperature range for process annealing ranges from 260 °C to 760 °C, depending on the alloy.

Types of Steel's Annealing

2- Full Annealing

1- Annealing temperature which is 30 to 50˚C above its upper critical temperature point in the furnace.

2- Soaking it at this temperature for sufficient period of time to allow microstructure transformation in the material,

3- followed by cooling down inside the furnace to room temperature. During that, austenizing is occurred with slow cooling (several hours) producing coarse pearlite ,which is relatively soft and ductile.

4- **the purpose** of the process is to soften parts that were already hardened by plastic deformation, but need to undergo subsequent machining/forming.

5- **Example** :in full annealing of hypoeutectoid steels less than 0.77% is heated to 723 to 910 C° (above A3 line) convert to single phase austenite cooled slowly at room temperature .Resulting structure is coarse pearlite with excess of ferrite it is quite soft and more ductile

Full annealing