3- Stress Relief Annealing

1- In the heat treatment of metals, quenching or rapid cooling is the cause of the greatest residual stresses, then, heating the steel to temperature range between (600 – 650)°C ,

2- soaking for few hours constantly, followed by a slow cooling down in still air.

3- **Purpose** : Reduce or remove the internal stresses produced in the metal during manufacturing processes causing distortions due to plastic deformation, non-uniform cooling, phase transformation

4- **Examples for steels need stress relief annealing** : Steel materials in the form of large steel castings, welded steel structures or cold formed parts.

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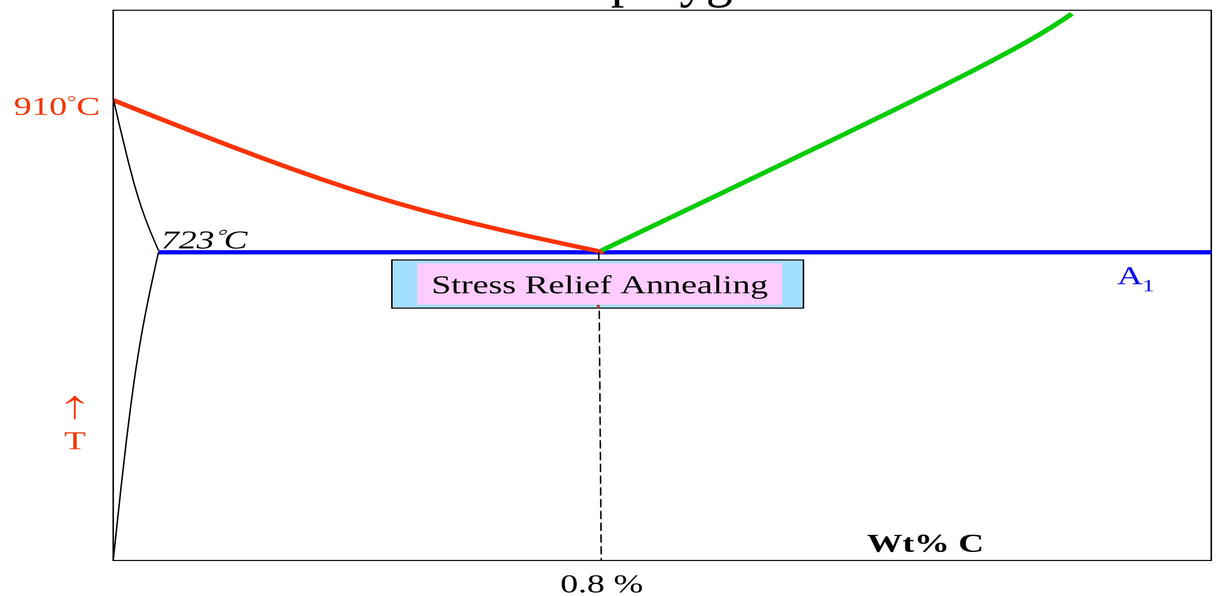
Stress Relief Annealing

- Due to various processes like quenching (differential cooling of surface and interior), machining, phase transformations (like martensitic transformation), welding, etc. the residual stresses develop in the sample. Residual stress can lead to undesirable effects like warpage of the component.
- The annealing is carried out just below A_1 , wherein 'recovery*' processes are active.

Residual stresses → Heat below A_1 → Recovery

*Annihilation of dislocations, polygonization

- Differential cooling
- Machining and cold working
- Martensite formation
- Welding



Causes of Residual Stresses

1. Thermal factors (e.g., thermal stresses caused by temperature gradients within the work piece during heating or cooling)

2. Mechanical factors (e.g., cold-working)

3. Metallurgical factors (e.g., transformation of the microstructure)

And To activate plastic deformations, the local residual stresses must be above the yield strength of the material. Soaking time also has an influence on the effect of stress-relief annealing

How to Remove Residual Stresses?

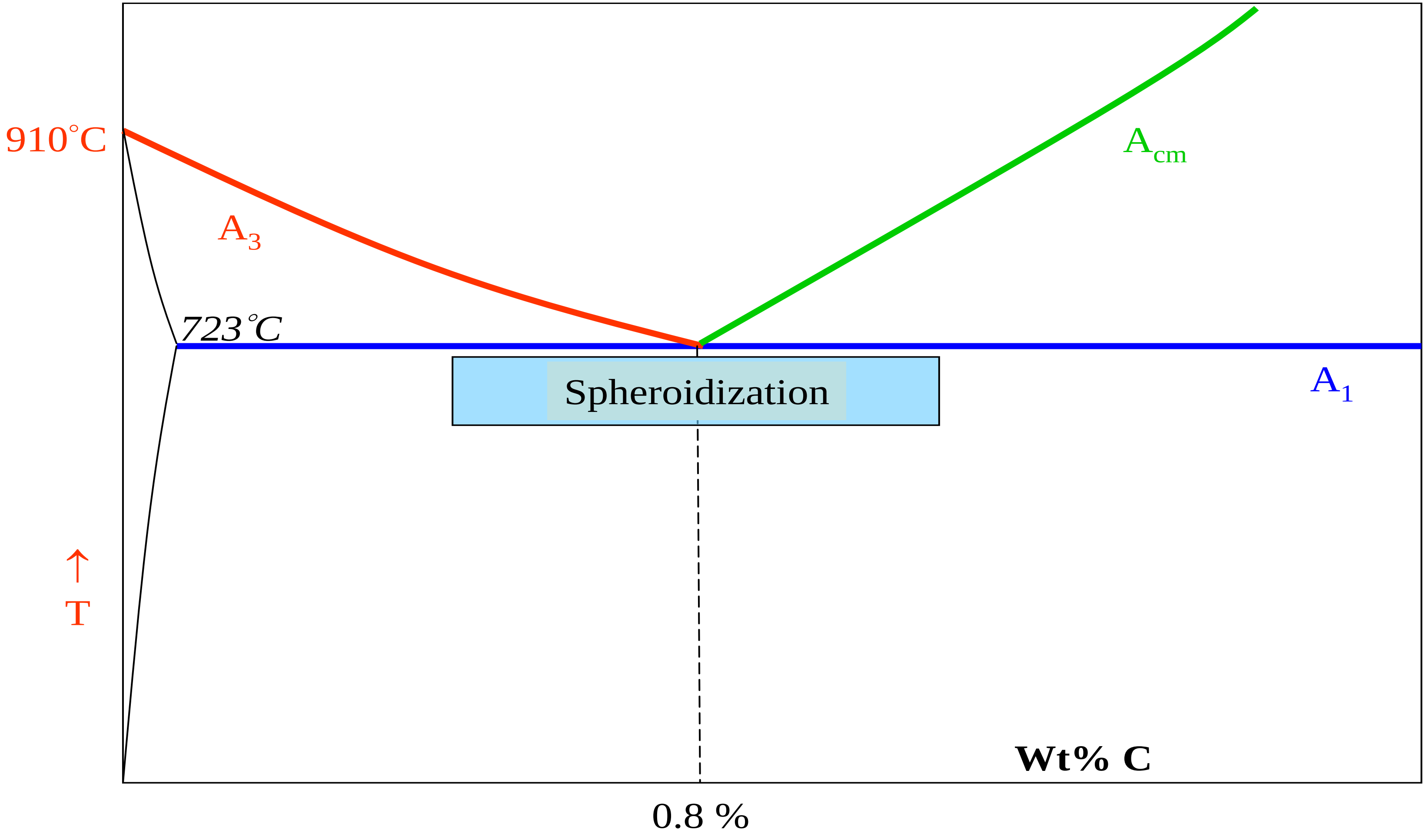
- R.S. can be reduced only by a plastic deformation in the **microstructure**.
- This requires that the **yield strength** of the material be lowered below the value of the residual stresses.
- The more the yield strength is lowered, the greater the plastic deformation and correspondingly the greater the possibility or reducing the residual stresses
- The yield strength and the ultimate tensile strength of the steel both decrease with increasing temperature

4- Spheroidise annealing

- The process is limited to steels in excess of 0.5% C and consists of heating to temperature about A1 (727°C). At this temperature any cold worked ferrite will recrystallise and the iron carbide present in pearlite will form as spheroids or “ball up”. As a result of change of carbides shape the strength and hardness are reduced.
- Pearlite is heated to just below the eutectoid temperature, and left for an extended time, the pearlite layers break down, and spherical clumps of cementite are found.
- To remove coarse pearlite and making machining process easy .
- It forms spherodite structure of maximum soft and ductility easy to machining and deforming. The main purpose of the treatment is to increase the ductility and improve their machinability of the sample.

Spheroidization Annealing

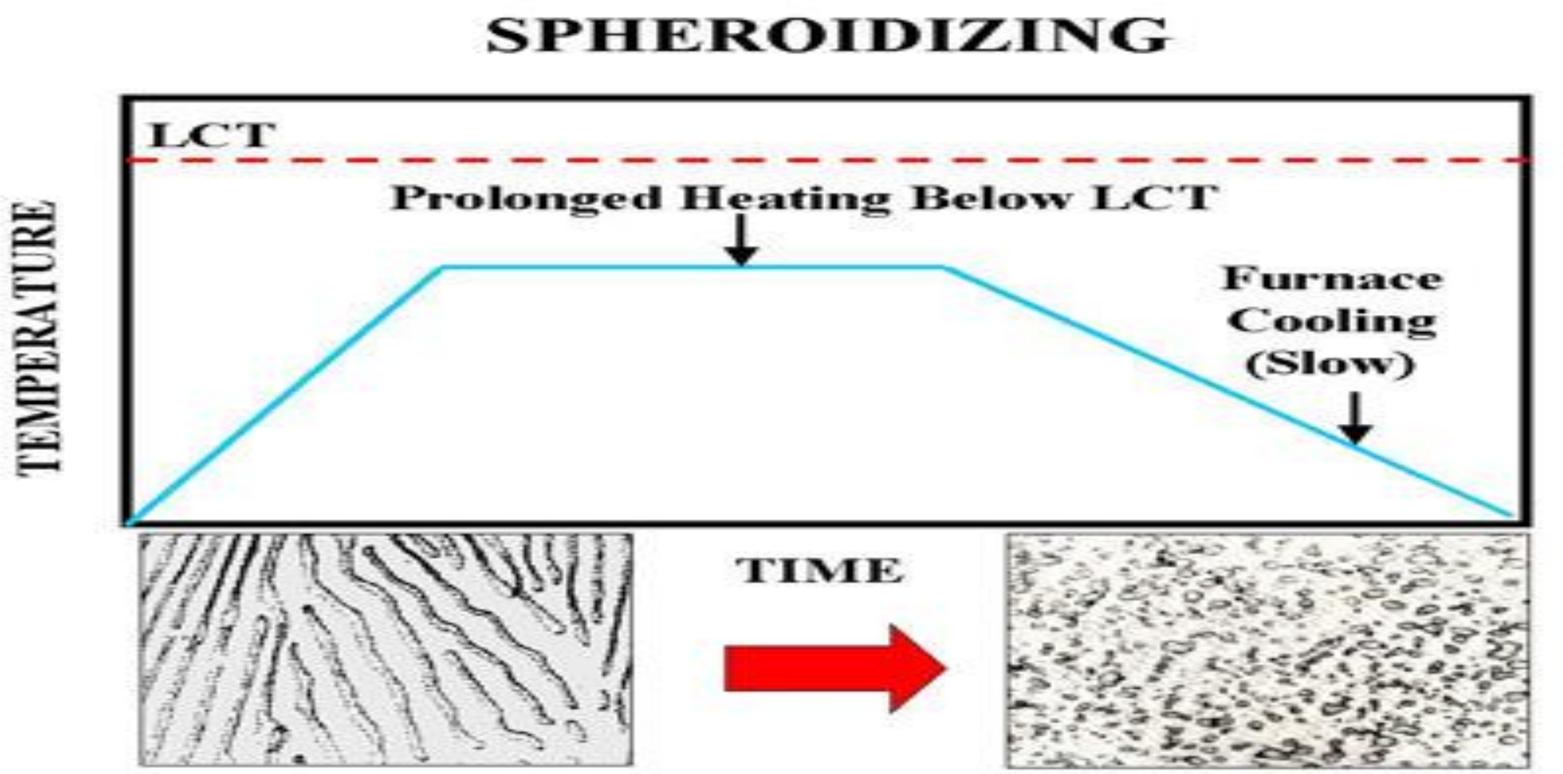
- Like stress relief annealing the treatment is done just below A_1.
- Long time heating leads cementite plates to form cementite spheroids. The driving force for this (microstructural) transformation is the reduction in interfacial energy.

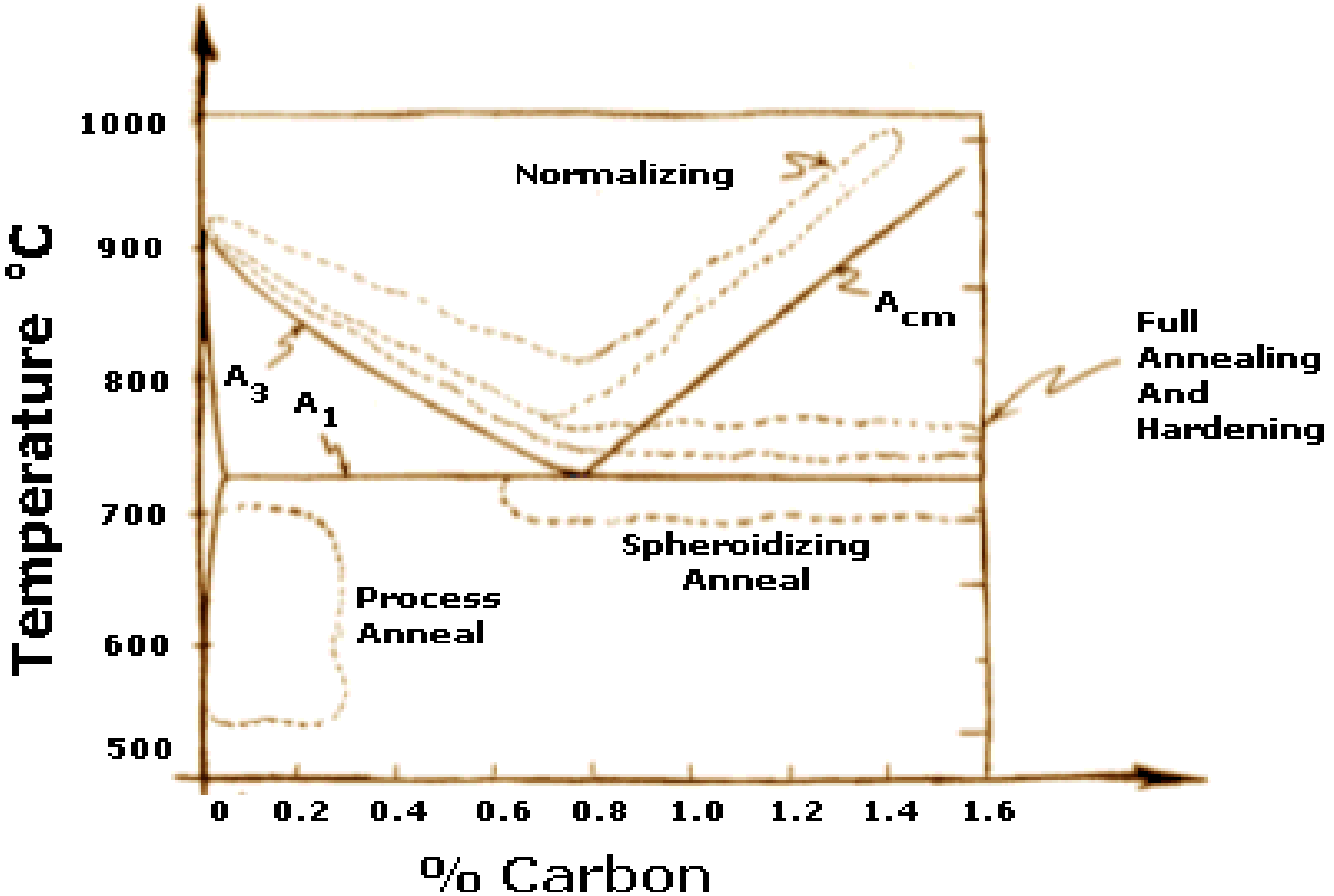


Spheroidizing

Advantage

- To soften steels
- To increase ductility and toughness
- To improve machinablity and formability
- To reduce hardness ,strength , and wear resistance





HEAT TREATMENT PROCESS

5) Isothermal Annealing

It involves four steps:

a) Heating the steel material above the upper critical temperature. This converts the structure rapidly into austenite (Ɣ) structure.

b) Cooling to a temperature below the lower critical temperature of around 600 to 700 C. This cooling is done by means of forced cooling.

c) Keeping the temperature constant for sufficient period of time (soaking) for completion the transformation with homogenous structure in the steel material before cooling.

d) Cooling the homogeneous steel structure to room temperature in air.

This process is usually employed for low and high carbon and some of the alloy steels to improve their machinability.

B- Annealing of Casting

1- Heating the castings above the critical eutectoid temperature for a length of time consistent with the cross section size, then, cooling them slowly to promote a uniform microstructure composed primarily of ferrite (α) and coarse Pearlite (ɣ).

2- Annealing softens the cast iron by slow-cooling the austenitic matrix, creating a ferritic microstructure (α).

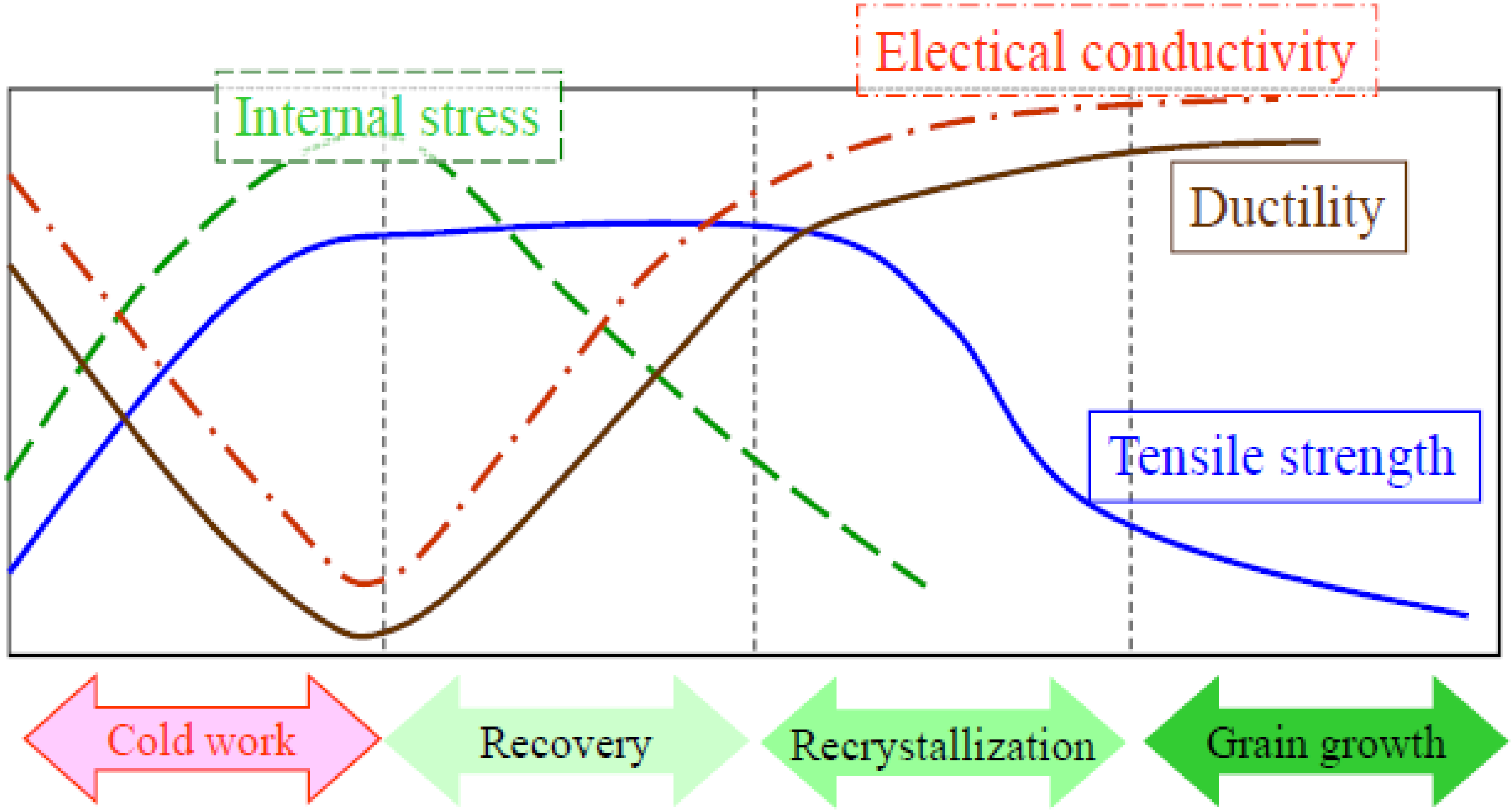
3- Purpose: to relieve residual stresses if the slow cooling is continued to a low enough temperature creating products with maximum ductility, uniform properties, and improved machinability.

B- Annealing of Casting

Objective:

Iron casting can retain residual stresses and structural variations after cooling during producing the complex shapes. The structural variation can cause distortion and non-uniform mechanical properties. To reduce this, full annealing is needed to improve machinability and also minimize the risk of distortions during any subsequent hardening or machining processes. Also, full annealing can relieve residual stresses.

Recovery Recrystallization Graingrowth



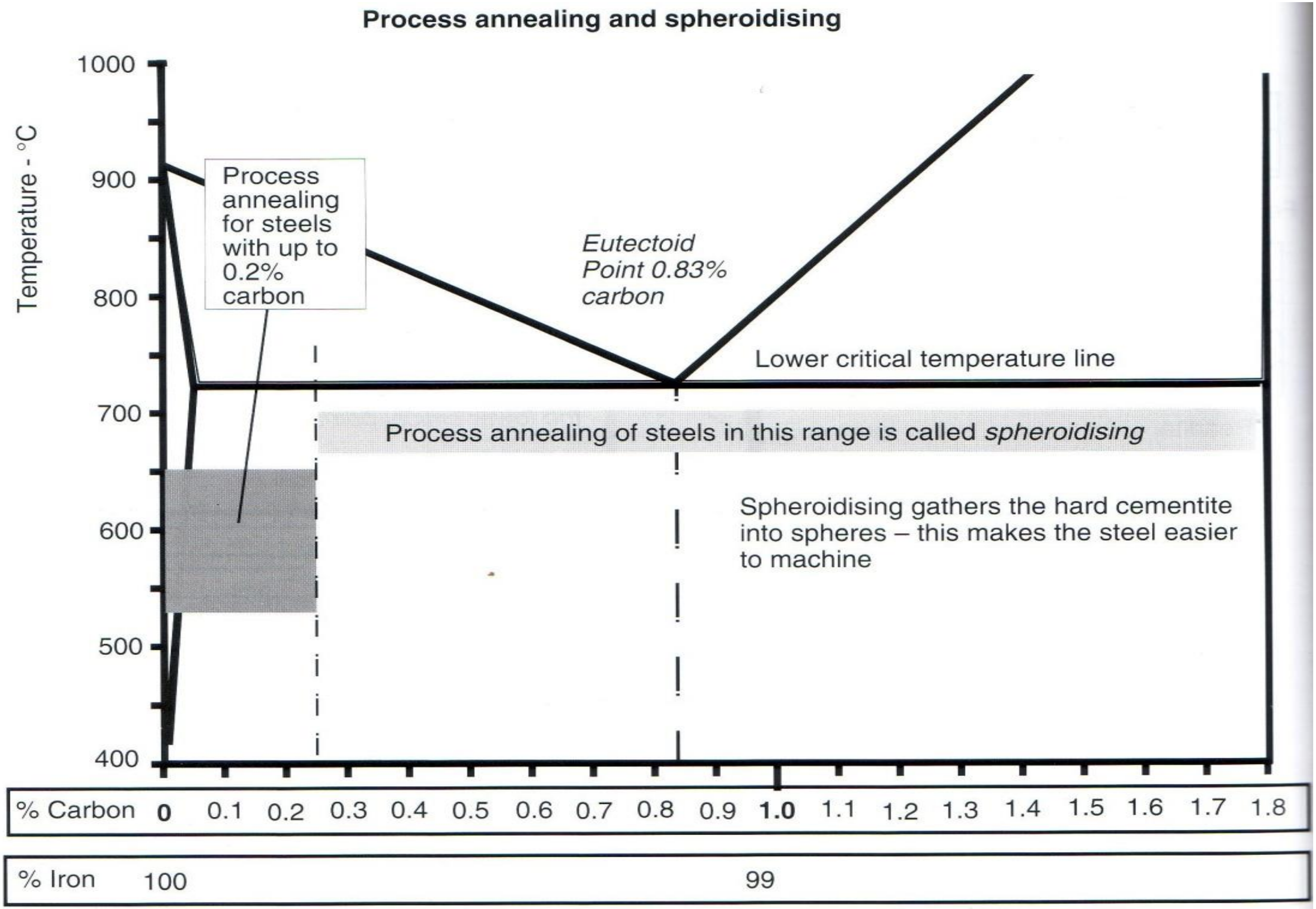
Change of properties with increased annealing temperature of a cold worked sample. Note that there are changes in properties beyond recrystallisation temperatures too due to grain growth.

There are three types of annealing (Casting): (high, medium and low)

High-temperature annealing, a casting is heated above the critical range to a temperature at which primary carbides and free cementite decompose to ferrite and graphite. If the casting is cooled slowly to below the critical range, a ferritic structure is formed and **minimum hardness is obtained.**

Medium-temperature annealing is used if massive carbides are absent. In this process, a casting is heated to just above the critical range, then slow-cooled.

Low temperature annealing, or ferritizing, heats a casting to just below the critical range, followed by slow-cooling. This is meant to convert pearlitic carbides, in the absence of free cementite, to ferrite and graphite.


Process annealing and spheroidising
Temperature - °C
1000
900
800
700
600
500
400
Process annealing for steels with up to 0.2% carbon
Eutectoid Point 0.83% carbon
Lower critical temperature line
Process annealing of steels in this range is called spheroidising
Spheroidising gathers the hard cementite into spheres – this makes the steel easier to machine
% Carbon 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8
% Iron 100 99

The Heat Treat Thermal Cycles Processes