

UNIT-5

* Engineering Materials - I STEELS *

1. Heat Treatment:- Heat Treatment is the controlled heating and cooling of metals to alter their physical and mechanical properties without changing the product shape. Heat treatment is sometimes done inadvertently due to manufacturing processes that either heat or cool the metal such as welding or forming. Heat treatment is often associated with increasing the strength of material, but it can also be used to alter certain manufacturability objectives such as improve machining, improve formability, restore ductility after cold working operation.

Steels are particularly suitable for heat treatment, since they respond well to heat treatment and the commercial use of Steels exceeds that of any other material. Steels are heat treated for one of the following reasons:

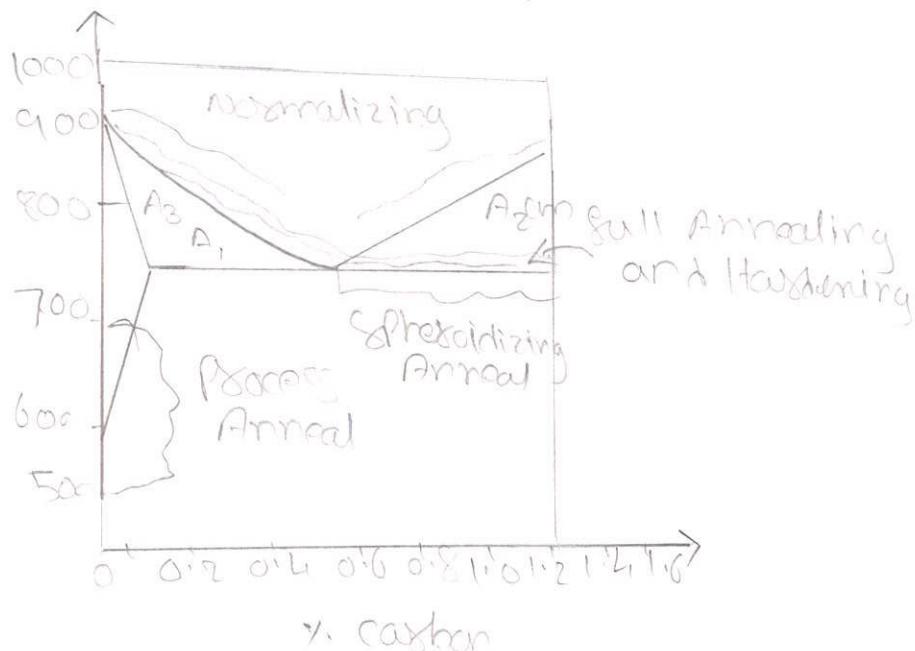
1. Softening
2. Hardening
3. Material modification.

Softening:- Softening is done to reduce strength or hardness, remove residual stresses, improve toughness, restore ductility, refine grain size or change the electromagnetic properties of the steel. Restoring ductility or removing residual stresses is a necessary operation when a large amount of cold working is to be performed, such as in a cold-drawing operation or wire drawing. Annealing - full process, spheroidizing, normalizing and tempering austempering, martempering are the principal ways by which steel is softened.

Hardening:- Hardening of steels is done to increase the strength and wear properties. One of the pre-requisites for hardening is sufficient carbon and alloy content. If there is sufficient carbon content the steel can be directly hardened. otherwise the surface of the part

has to be carbon enriched using some diffusion treatment hardening techniques.

Material modification :- Heat treatment is used to modify properties of materials in addition to hardening and softening. These processes modify the behavior of the steels in a beneficial manner to maximize the service life. e.g. stress relieving, & strength properties e.g., cryogenic treatment, & some other desirable properties.



* Heat Treatment Process *

2. Annealing :- In this process of annealing, the cold worked steel is heated to some temperature below the lower critical temperature and hence they are classified as Subcritical temperature annealing processes. They are used after cold working of annealing processes. They are used after cold working of steels to relieve the internal stresses or to reduce the hardness or to refine and modify the structure.

i) stress-relief annealing :- In this process, cold worked steel is heated to a temperature between 500 and 550°C (below its recrystallization temperature 600°C), kept at this temperature for 1-2 hours and cooled to room temperature in air. Due to this, internal stresses are partially relieved without loss of strength and hardness i.e. without change of microstructure. This is applicable to hypoeutectoid steels containing less than 0.4% C carbon.

ii) Recrystallization annealing:- This is done below A_1 temperature i.e. at temperature between 625 and 675°C. The cold worked ferrite recrystallizes and cementite tries to spheroidise during this annealing process. Not only internal stress are eliminated but also the steel becomes soft and ductile.

ii) Process annealing (intermediate annealing):- In this method, cold worked metal is heated to above its recrystallization temperature. This is also accomplished by the formation of strain free equiaxed grains. This is given to metals to soften them during mechanical processing so as to continue the cold working process without cracking of metals. It may or may not involve full recrystallization of the cold worked metal. In principle, process annealing and recrystallization annealing are same both the processes involve recrystallization and formation of new stress free equiaxed grains from strained and distorted cold worked grains.

3.

NORMALISING

Purpose:- The purpose is the same as that of annealing. For hypereutectoid steels, the process may also be used to eliminate the cementite network that may have formed due to slow cooling in the temperature range from A_{cm} to A_1 .

Process:- The process consists of heating to above the upper critical temperature (A_3) for hypoeutectoid steels and above A_{cm} for hypereutectoid steels by 30 to 50°C, holding long enough at this temperature for homogeneous austenitization and cooling to room temperature in still air.

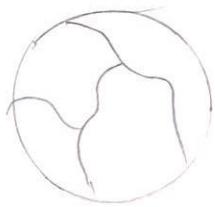
Due to air cooling which is slightly fast as compared to furnace cooling employed in full annealing, normalised components show slightly different structure and properties than annealed components, which are as below:

The properties of normalised components are not much different from those of annealed components. However, normalising takes less time and is more convenient and economical than annealing and hence is a more common heat treatment in industry. Full annealing is specifically used for complex shapes where even air cooling may cause cracking or considerable warping of the components.

Hypereutectoid steels are usually normalised from above A_{cm} temperature. This is because due to the air cooling from above A_{cm} , the proeutectoid Fe_3C separates in the form of needles in the grains of austenite which transform to Pearlite at A_1 . Thus the pearlite.

These steels can also be normalised from a low A_1 temperature. The microstructure of such steels shows fine, quite rounded particles of proeutectoid Fe_3C and needles of Fe_3C in the matrix of Pearlite. Such structures also have less brittleness.

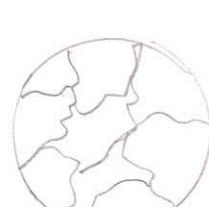
4. Hardening:- Hardness is a function of the carbon content of the steel. Hardening of a steel requires a change in structure from the body-centered cubic structure found at room temperature to the face centered cubic structure found in the austenitic region. The steel is heated to austenitic region. When suddenly quenched, the Martensite is formed. This is a very strong and brittle structure. When slowly quenched it would form Austenite and Pearlite which is a partly hard and partly soft structure. When the cooling rate is extremely slow then it would be mostly Pearlite which is extremely soft.



AUSTENITE



MARTENSITE



CEMENTITE



PEARLITE
COARSE



PEARLITE
FINE

Precipitation hardening:-

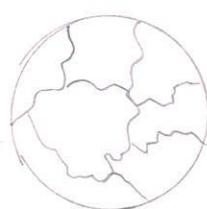
1. Solution heat treatment- where all the solute atoms are dissolved to form a single-phase solution.
2. Rapid cooling across the solvus line to exceed the solubility limit. This leads to a supersaturated solid solution that remains stable due to the low temperatures, which prevent diffusion.
3. Precipitation heat treatment where the supersaturated solution is heated to an intermediate temperature to induce precipitation and kept there for some time. If the process is continued for a very long time, eventually the hardness decreases. This is called overaging.

case hardening:- case hardening produces a hard, wear-resistant surface or case over a strong, tough core. The principal forms of casehardening are carburizing, cyaniding, and nitriding. Only ferrous metals are case-hardened. Case hardening is ideal for parts that require a wear-resistant surface and must be tough enough internally to withstand heavy loading. The steels best suited for case hardening are low-carbon and low-alloy series.

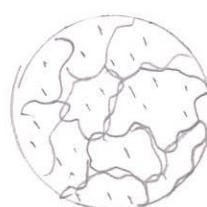
Flame Hardening:- Flame hardening is another process that is used to harden the surface of metal parts. When you use an oxyacetylene flame, a thin layer at the surface of the part is rapidly heated to its critical temperature and then immediately quenched by a combination of a water spray and the cold base metal. This process produces a thin hardened surface, and at the same time, the internal parts retain their original properties. Whether the process is manual or mechanical, a close watch must be maintained, since the flames heat the metal rapidly and the temperatures are usually determined visually.

5. Tempering:- It is a process done subsequent to quench hardening. Quench-hardened parts are often too brittle. This brittleness is caused by a predominance of martensite. This brittleness is removed by tempering. Tempering results in a desired combination of hardness, ductility, toughness, strength, and structural stability. Tempering is not to be confused with tempeks on rolled stock-these tempeks are an indication of the degree of cold work performed.

Tempering is done immediately after quench hardening. When the steel cools to about 40°C (104°F) after quenching, it is ready to be tempered. The part is reheated to a temperature of 150 to 400°C (302 to 752°F). In this region a softer and tougher structure troostite is formed. Alternatively, the steel can be heated to a temperature of 400 to 700°C that results in a softer structure known as sorbite. This has less strength than troostite but more ductility and toughness. The heating for tempering is best done by immersing the parts in oil, for tempering up to 350°C and then heating the oil with the parts to the appropriate temperature. Heating in a bath also ensures that the entire part has the same temperature and will undergo the same tempering. For temperatures above 350°C it is best to use a bath of nitrate salts. The salts baths can be heated up to 625°C . After reaching the desired temperature, the parts are held at that temperature for about 2 hours then removed from the bath and cooled in still air.



CEMENTITE

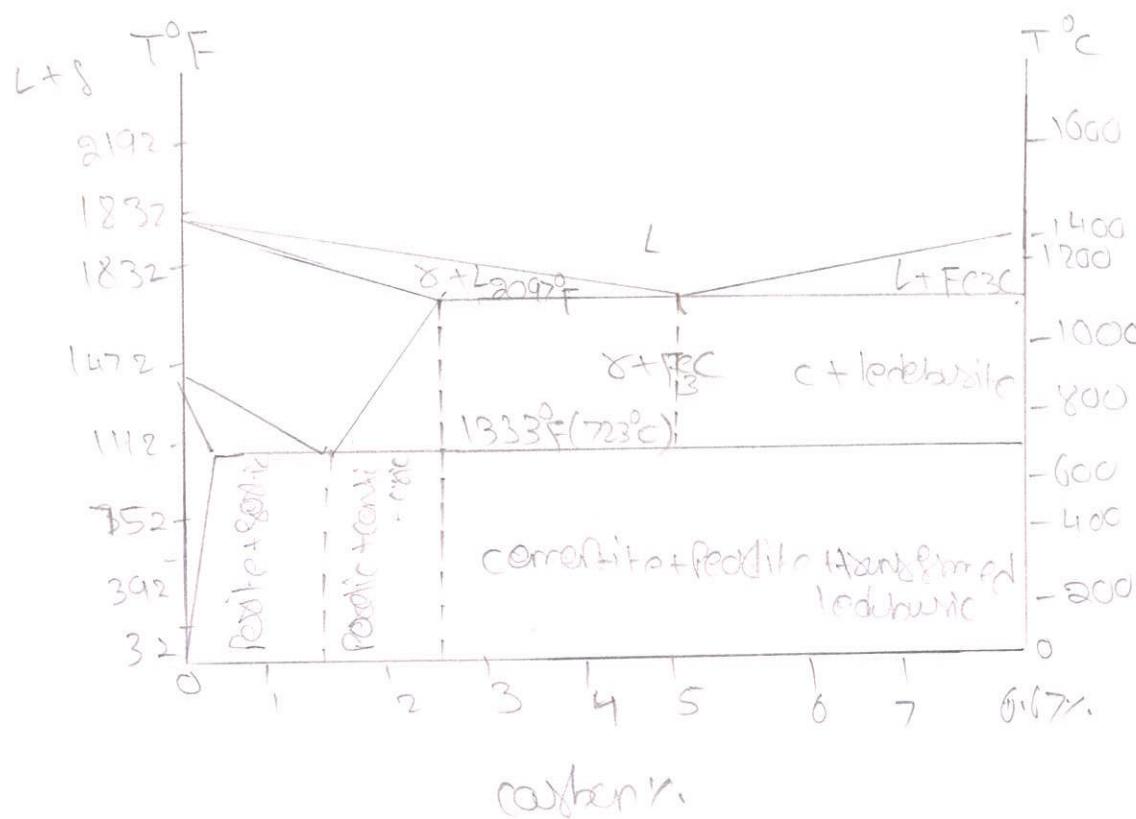


FERRITE

6. The Iron-Iron carbide ($\text{Fe}-\text{Fe}_3\text{C}$) phase diagram:-

This is one of the most important alloys for structural applications. The diagram $\text{Fe}-\text{C}$ is simplified at low carbon concentrations by assuming it is the $\text{Fe}-\text{Fe}_3\text{C}$ diagram. Concentrations are usually given in weight percent. The possible phases are.

- *. α -ferrite
- *. γ -austenite
- *. δ -ferrite
- *. liquid Fe-C solution
- *. Fe_3C or cementite



δ -ferrite:- It is solid solution of carbon in δ -iron. Maximum concentration of carbon in δ -ferrite is 0.25% at 2719°F to which is the temperature of the peritectic transformation. The crystal structure of δ -ferrite is BCC.

Austenite:- Austenite is interstitial solid solution of carbon in γ -iron. Austenite has FCC crystal structure, permitting high solubility of carbon i.e., up to 2.06% at 9097°F . Austenite does not exist below 1333°F and maximum carbon concentration at this temperature is 0.83%.

α -ferrite:- It is solid solution of carbon in iron. α -ferrite has BCC crystal structure and low solubility of carbon up to 0.025% at 1333°F . α -ferrite exists at room temperature.

Cementite:- cementite is also known as iron carbide, is an intermetallic compound of iron and carbon, having fixed composition Fe_3C . cementite is a hard and brittle substance influencing the properties of steels and cast irons.

87. Time temperature transformation (TTT) diagrams:-

It measure the rate of transformation at a constant temperature. In other words a sample is austenitised and then cooled rapidly to a lower temperature and held at that temperature whilst the rate of transformation is measured for example by dilatometry.

- * An increase in carbon content shifts the TTT curve to the right
- * An increase carbon content decreases the martensite start temperature.
- * An increase in Mo content decreases shifts the TTT curve to the right and also separates the ferrite + Pearlite region from the bainite region making the attainment of a bainitic structure more controllable.

