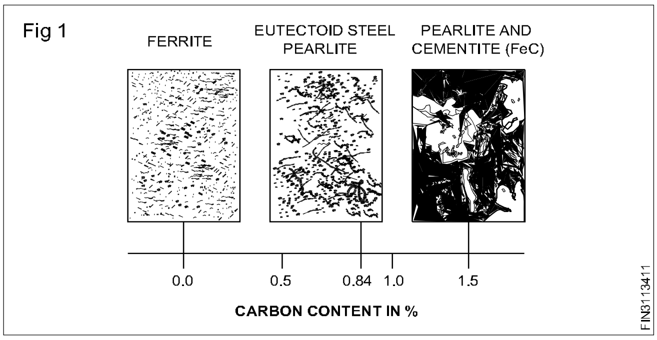
Heat treatment of plain carbon steels

Objectives: At the end of this lesson you shall be able to
- **state the purpose of heat treatment of steel**
- **state the types of structure, constituets and properties of plain carbon steels.**

Heat treatment and its purpose

The properties of steel depend upon its composition and its structure. These properties can be changed to a considerable extent, by changing either its composition or its structure. The structure of steel can be changed by heating it to a particular temperature, and then, allowing it to cool at a definite rate. The process of changing the structure and thus changing the properties of steel, by heating and cooling, is called 'heat treatment of steel'.

Types of structure of steel (Fig 1)



The structure of steel becomes visible when a piece of the metal is broken. The exact grain size and structure can be seen through a microscope. Steel is classified according to its structure.

Steel is an alloy of iron and carbon. But the carbon content in steel does not exceed 1.7%.

Ferrite

Pig iron or steel with 0% carbon is FERRITE which is relatively soft and ductile but comparatively weak.

Cementite

When carbon exists in steel as a chemical compound of iron and carbon it is called 'iron carbide' or CEMENTITE. This alloy is very hard and brittle but it is not strong.

Eutectoid/Pearlite steel

A 0.84% carbon steel or eutectoid steel is known as PEARLITE steel. This is much stronger than ferrite or cementite.

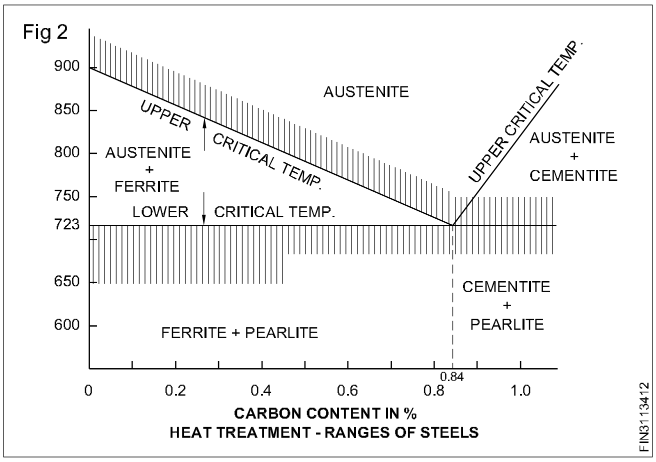
Hypereutectoid steel

More than 0.84% carbon steel or hypereutectoid steel is pearlite and cementite.

Hypoeutectoid steel

Less than 0.84% carbon steel or hypoeutectoid steel is pearlite and ferrite.

Structure of steel when heated (Fig 2)



If steel is heated, a change in its structure commences from 723°C. The new structure formed is called 'AUSTENITE'. Austenite is non-magnetic. If the hot steel is cooled slowly, the old structure is retained and it will have fine grains which makes it easily machinable.

If the hot steel is cooled rapidly the austenite changes into a new structure called 'MARTENSITE'. This structure is very fine grained, very hard and magnetic. It is extremely wear-resistant and can cut other metals.

Heat treatment processes and purpose

Because steel undergoes changes in structure on heat-ing and cooling, its properties may be greatly altered by suitable heat treatment.

The following are the various heat treatments and their purposes.

Hardening:	To add cutting ability.
	To increase wear resistance.
Tempering:	To remove extreme brittleness
	caused by hardening to an extent.

To induce toughness and shock resistance.

Annealing: To relieve strain and stress.
To eliminate strain/hardness.

To improve machinability.
To soften the steel.

Normalising: To refine the grain structure of the steel.

Heating and quenching steel for heat treatment

Objectives: At the end of this lesson you shall be able to
- **distinguish between the lower critical and the upper critical temperatures**
- **state the three stages in the heat treatment process**
- **determine the upper critical temperature for different plain carbon steels from the diagram.**

Critical temperatures

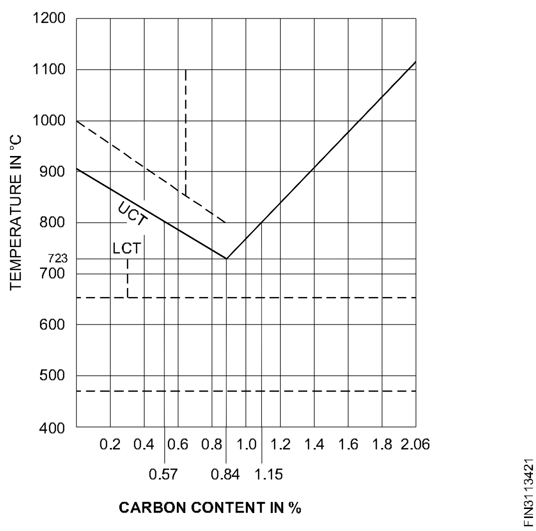
Lower critical temperature

The temperature, at which the change of structure to austenite starts - 723°C, is called the lower critical temperature for all plain carbon steels.

Upper critical temperature

The temperature at which the structure of steel completely changes to AUSTENITE is called the upper critical temperature. This varies depending on the percentage of carbon in the steel. (Fig 1)

Fig 1



Example

0.57% and 1.15% carbon steel: In these cases the lower critical temperature is 723°C and the upper critical tem-perature is 8QO°C.

For 0.84% carbon steel, both LCT and UCT are 723°C. This steel is called eutectoid steel.

Three stages of heat treatment

- Heating ,
- Soaking
- Quenching

When the steel on being heated reaches the required temperature, it is held in the same temperature for a period of time. This allows the heating to take place throughout the section uniformly. This process is called soaking.

Heating steel

This depends on the selection of the furnace, the fuel used for heating, the time interval and the regulation in bringing the part up to the required temperature. The heating rate and the heating time also depend on the composition of the steel, its structure, the shape and size of the part to be heat-treated etc.

Soaking time

This depends upon the cross-section-of the steel, its chemical composition, the volume of the charge in the furnace and the arrangement of the charge in the furnace. A good general guide for soaking time in normal condi-tions is five minutes per 10 mm of thickness for carbon and low alloy steels, and 10 minutes per 10 mm of thickness for high alloy steels.

Preheating

Steel should be preheated at low temperatures up to 600°C as slowly as possible.

Quenching

Depending on the severity of the cooling required, different quenching media are used.

The most widely used quenching media are:

- brine solution
- water
- oil
- air.

Brine solution gives a faster rate-of cooling while air cooling has the slowest rate of cooling.

Brine solution (Sodium chloride) gives severe quenching because it has a higher boiling point than pure water, and the salt content removes the scales formed on the metal surfaces due to heating. This provides a better contact with the quenching medium and the metal being heat-treated.

Water is very commonly used for plain carbon steels. While using water as a quenching medium, the work should be agitated. This can increase the rate of cooling.

The quenching oil used should be of a low viscpsity. Ordinary lubricating oils should not be used for this purpose. Special quenching oils, which can give rapid and uniform cooling with less fuming and reduced fire risks, are commercially available. Oil is widely used for alloy steels where the cooling rate is slower than plain carbon steels.

Cold air is used for hardening some special alloy steels.

Hardening of carbon steel

Objectives: At the end of this lesson you shall be able to
- **state the hardening of steel**
- **state the purpose of hardening steel**
- **state the process of hardening.**

What is hardening?

Hardening is a heat-treatment process in which steel is fitted to 30 - 50°C above the critical range. Soaking time is allowed to enable the steel to obtain a uniform temperature throughout its cross-section. Then the steel is rapidly cooled through a cooling medium.

Purpose of hardening

To develop high hardness and wear resistance properties.

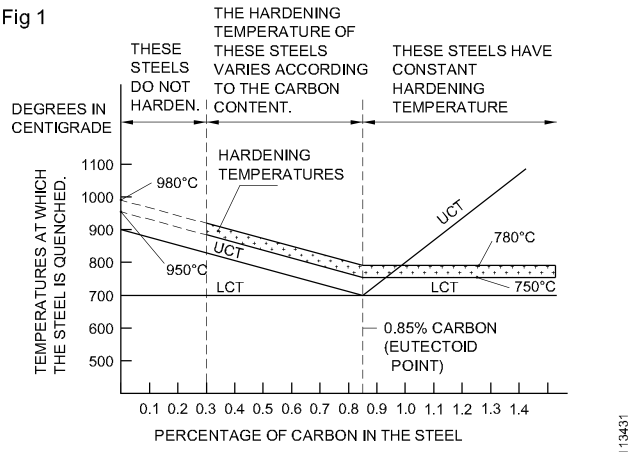
Hardening affects the mechanical properties of steel - like strength, toughness, ductility etc.

Hardening adds cutting ability.

Process of hardening

Steel with a carbon content above 0.4% is heated to 30-60°C above the upper critical temperature. (Fig 1) A soaking time of 5 mts. / 10 mm thickness of steel is allowed. (Fig 1)

Fig 1



HARDENING OF PLAIN CARBON STEELS

Then the steel is cooled rapidly in a suitable medium. Water, oil, brine or air is used as a cooling medium, depending upon the composition of the steel and the hardness required.

Tempering the hardened steel

Objectives: At the end of this lesson you shall be able to
- **state what is tempering**
- **state the purpose of tempering**
- **relate the tempering colours and temperatures with the tools to be tempered**
- **state the purpose of tempering of steels.**

What is tempering?

Tempering is a heat-treatment process consisting of reheating the hardened steel to a temperature below 400°C, followed by cooling.

Purpose of tempering the steel

Steel in its hardened condition is generally too brittle to be used for certain functions. Therefore, it is tempered.

The aims of tempering are:

- to relieve the internal stresses
- to regulate the hardness and toughness
- to decrease the brittleness
- to restore some ductility
- to induce shock resistance.

Process of tempering the steel

The tempering process consists of heating the hardened steel to the appropriate tempering temperature and soaking at this temperature, for a definite period.

The period is determined from the experience that the full effect of the tempering process can be ensured only, if the tempering period is kept sufficiently long. Table 1 shows the tempering temperature and the colour for different tools.

TABLE 1

Tools or articles	Temperature in degrees (C)	Colour
Turning tools.	230	Pale straw.
Drills and milling cutters.	240	Dark straw.
Taps and shear blades.	250	Brown.
Punches, reamers, twist drills.	260	Reddish brown
Rivets, snaps.	270	Brown purple.
Press tools, cold chisels	280	Dark purple.
Cold set for cutting steels.	290	Light blue.
Springs, screw drivers	300	Dark blue.
	320	Very dark blue.
	340	Greyish blue.
For toughening without undue hardness.	450-700	No colour.

Annealing of steel

Objectives: At the end of this lesson you shall be able to
- **state the annealing of steel**
- **state the purpose of annealing**
- **state the process of annealing.**

The annealing process is carried out by heating the steel above the critical range, soaking it for sufficient time to allow the necessary changes to occur, and cooling at a predetermined rate, usually very slowly, within the furnace.

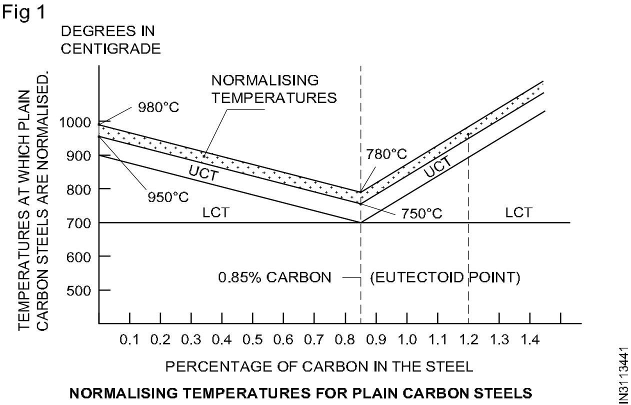
Purpose

- To soften the steel.
- To improve the machinability.
- To increase the ductility.
- To relieve the internal stresses.
- To refine the grain size and to prepare the steel for subsequent heat treatment process.

Annealing process

Annealing consists of heating of hypoeutectoid steels to 30 to 50°C above the upper critical temperature and 50°C above the lower critical temperature for hypereutectoid steels. (Fig 1)

Fig 1



NORMALISING TEMPERATURES FOR PLAIN CARBON STEELS

Soaking is holding at the heating temperature for 5 mts./ 10 mm of thickness for carbon steels.

The cooling rate for carbon steel is 100 to 150°C/hr.

Steel, heated for annealing, is either cooled in the furnace itself by switching off the furnace or it is covered with dry sand, dry lime or dry ash.