Introduction
. Heat Treatment

- *Heat Treatment process is a series of operations involving the **Heating and Cooling** of metals in the solid state.*

- *Its purpose is to change a mechanical property or combination of mechanical properties so that the metal will be more useful, serviceable, and safe for definite purpose.*

- *By heat treating, a metal can be made harder, stronger, and more resistant to impact, heat treatment can also make a metal softer and more ductile.*

Three Stages of Heat Treatment

The three stages of heat treatment are listed below:

1. Heating
2. Soaking
3. Quenching

Heating

Heating of steel depends upon following factors-

1. Types of furnace
2. Types of fuel
3. Time interval
4. Temperature control in achieving the required temperature in the job
5. Heat rate
6. Structure and formation
7. Shape and the dimensions of the job

Preheating : Steel should be preheated gradually up till 600°C.

Soaking

The steel is held for some time when it has reached the required temperature. During this the entire job gets consistently heated. This is called soaking.

Soaking Time : Soaking time depends upon following factors-

1. Cross-sectional area
2. Chemical structure
3. The amount and arrangement of charge in the furnace

Under normal conditions, an alloy of carbon and steel of 10 mm thickness will need a time duration of 5 minutes, while a high steel alloy piece of 10 mm thickness will need a time duration of 10 minutes.

Quenching

Depending upon the cooling requirement, there are various quenching media available. Based on their usage, the top ones are listed below:

1. Water
2. Oil
3. Brine solution
4. Air

The salt solution cools fastest while air does it slowest. Since the boiling point of the salt solution is higher than that of the pure water the, quenching can be carried out rather soon. For plain carbon steel, water is generally used. When water is used for quenching, the rate of cooling can be increased by constantly shaking the job in the water. When oil is used for quenching, the viscosity of the used oil should be less, hence, it is utilized for specific quenching only, where there is less smoke and cooling can take place across the job with less fire expectations and ease of availability. Oil is used in quenching of alloy steel where its rate of cooling is less than that of plain carbon steel. Some typical alloy steel is best quenched by cool air.

Methods of Heat Treatment

Below listed methods are used for the purpose of heat treatment.

1. Normalizing
2. Annealing
3. Hardening
4. Tempering
5. Case hardening

Normalizing

When a material is hammered, forged or is put to heavy operations, its internal structure gets distorted and the material particles break, turning the material brittle. In this state, if the material is put to machine use, where, when the load is applied due to the internal particles the machine parts break.

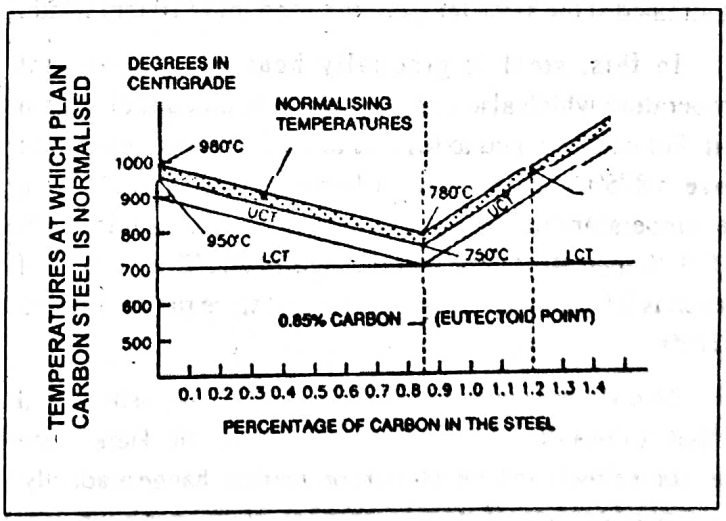

Fig. 8 : Normalizing Temperature for Plain Carbon Steel

Normalizing method is used to prevent the internal structure disorder and brittleness. In this method, the steel piece is heated to 30°C to 40°C more than the critical

temperature and is left in that state for some time. The time period depends upon the type and the quantity of the steel. It is left to cool off in the air. This improves the tensile strength and removes the stress, consequently, the grains gain strength.

5.2 Annealing

Annealing is performed in order to carry out the machining for steel metal parts, removal of internal stress, improve the structure of the internal particles, to further soften and to improve the ductility.

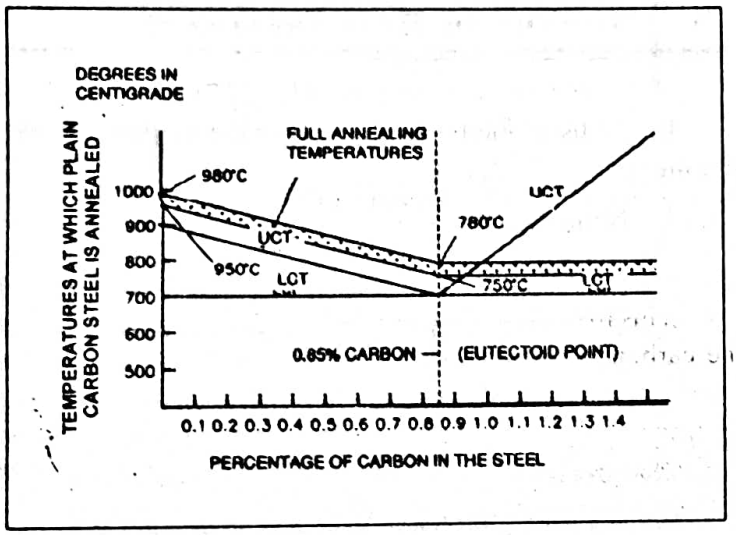

Fig. 9 : Annealing Temperature for Plain Carbon Steel

In the process of annealing, the steel is heated more than the critical temperature and is allowed to soak for sufficient time. In this soaking process the carbon steel is maintained at the same temperature for 5 min / 10 mm width.

In this, steel is gradually heated at a constant temperature which also depends upon the amount of carbon in it. For carbon equal to 0.12 % to 0.25 %, the temperature range is 875°C to 925°C, for carbon equal to 0.3 % to 0.5 %, the temperature range is 815°C to 840°C, if carbon is 0.5 % to 0.9 % then the temperature range is 780°C to 810°C, if carbon is 0.9 % to 1.3 % then the temperature range is 760°C to 780°C.

To cool, the steel is covered with dry lime, ash or sand so that it doesn't come in contact with the air. Hence, the steel cools slowly and the intrinsic properties change gradually. The rate of cooling of steel is 100°C to 150°C per hour.

5.3 Hardening

The process of hardening soft steel by heating it to a certain temperature and then cooling it is called hardening.

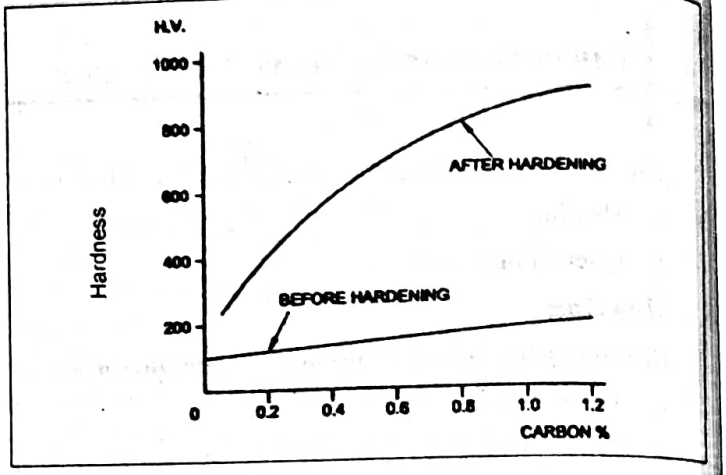

Fig. 10

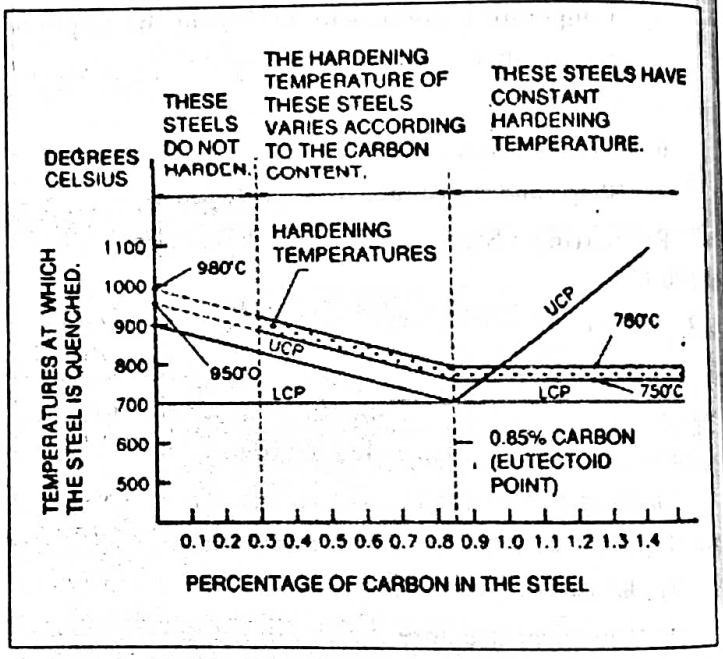

Fig. 11 : Hardening Temperature for Plain Carbon Steel

Hard steel does not outwear by friction and it gains capability to cut other metals. Depending upon the amount of carbon, it can be heated to 30°C to 40°C more than the critical temperature and is allowed to soak for some time. Generally, for a 10 mm thick steel, soaking for duration of 5 minute is sufficient and then to further cool it is submerged in oil or water. In this process, the soft steel is hardened. The steel which contains 0.15% carbon cannot be hardened.

Hardness of the steel depends upon following factors-

1. Internal structure of the steel
2. Cooling medium – air, water, oil etc.
3. Rate of cooling
4. Carbon content in the steel
5. Process of heating and cooling the steel

5.4 Tempering

When a part or equipment is hardened by the process of hardening, its edges become brittle. To reduce the effect of brittleness of the edges the method of tempering is used. In this way, the hardness of the equipment is maintained and it is not brittle either.

Table 1 : Tempering Temperature

S. No.	Equipment	Temperature (°C)	Color
1.	To toughen without unnecessary hardening	450-700	No color
2.	Screw driver, spring	340	Pigeon blue
		320	Very dark blue
		300	Dark blue
3.	Cold set for steel cutting	290	Light blue
4.	Cold chisel, press equipment	280	Dark purple
5.	Snap rivet	270	Brown purple
6.	Twist drill	260	Reddish brown
7.	Punch, reamer, tap and shearing blade	250	Brown
8.	Milling cutter, drill	240	Dark straw
9.	Turning equipment	230	Light straw

For tempering, the portion of the hardened part or equipment where tempering is required, is heated at the tempering temperature. Tempering temperature for high speed steel is 220°C to 330°C, for hardened steel is 400°C and for alloy steel is 560°C. Post heating, it is cooled either in water or oil.

In the process of cooling, the heated metal changes color, after taking heat from the surface and the air contact like brown, purple, blue etc. Based on the level of tempering required, the heated metal is submerged in water as soon as the particular color is obtained. This way the tempered part can withstand any vibrations if hit or struck.