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.

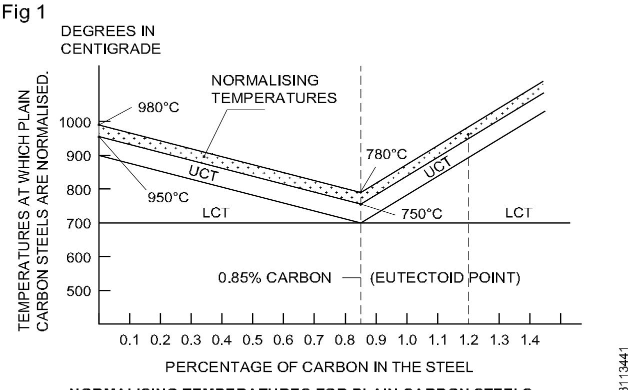
Purpose

- 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.

Normalising steel

Objectives: At the end of this lesson you shall be able to
- **state the meaning of normalising steel and its purpose**
- **state the process of normalising steel**
- **state the precaution to be taken while normalising steel.**

The process of removing the internal defects or to refine the structure of steel components is called normalising.

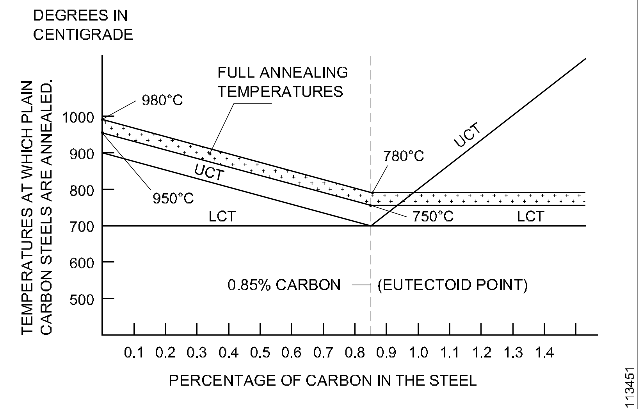
Purpose

- To produce fine grain size in the metal.
- To remove stresses and strains formed in the internal structure due to repeated heating and uneven cooling
- hammering.
- To reduce ductility.
- To prevent warping.

Process

To get the best results from normalising, the parts should be heated uniformly to a temperature of 30 to 40°C above the upper critical temperature (Fig 1), followed by cooling in still air, free from drought, to room temperature. Normalizing should be done in all forgings, castings and work-hardened pieces.

Fig 1



ANNEALING TEMPERATURES FOR PLAIN CARBON STEELS

Precautions

Avoid placing the component in a wet place or wet air, thereby restricting the natural circulation of air around the component. Avoid placing the component on a surface that will chill it.

Surface hardening of steel

Objectives : At the end of this lesson you shall be able to
- **name four different types of surface hardening process**
- **state purpose of case hardening**
- **state the purpose of carburising**
- **state the purpose of liquid carburising**
- **state the process of gas carburising.**

Most of the components must have a hard, wear-resisting supported by a tough, shock-resisting core for Slrlervlce condition and longer life. This combination ilttirent properties can be obtained in a single piece of III by surface hardening. (Fig 1)

Types of surface hardening

- Case hardening
- Nitriding
- Flame hardening
- Induction hardening

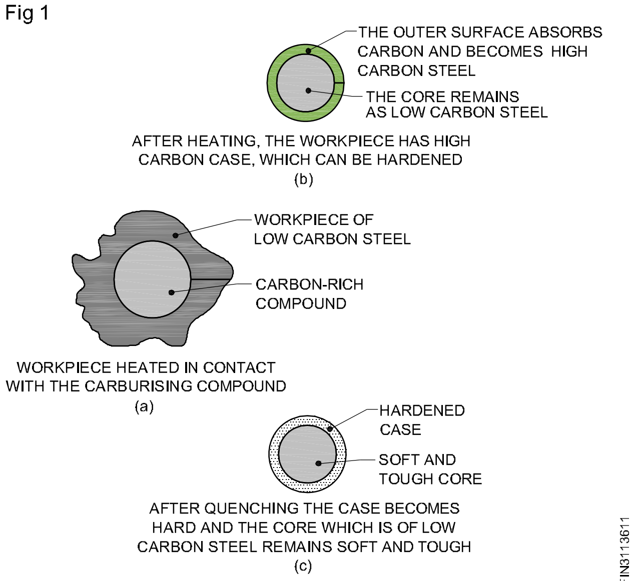
Case hardening

Parts to be hardened by this process are made from a steel with a carbon content of 0.15% so that they will not respond to direct hardening.

The steel is subjected to treatment in which the carbon content of the surface layer is increased to about 0.9%.

When the carburised steel is heated and quenched, only the surface layer will respond, and the core will remain soft and tough as required. (Fig 1)

Fig 1



The surface which must remain soft can be insulated against carburising by coating it with suitable paste or by plating it with copper.

Case hardening takes place in two stages.

1. Carburising in which the carbon content of the surface is increased.
2. Heat treatment in which the core is refined and the surface hardened.

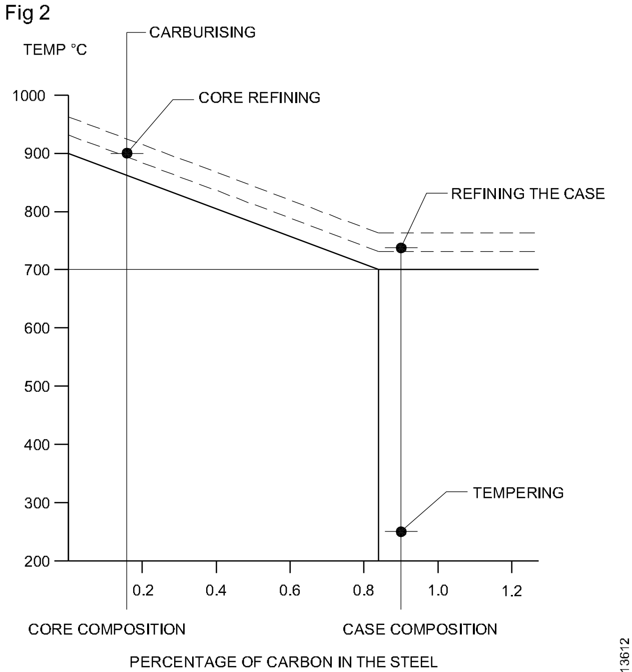
Carburising

In this operation, the steel is heated to a suitable temperature in a carbonaeous atmosphere, and kept at that temperature until the carbon has penetrated to the depth required.

The carbon can be supplied as a solid, liquid or gas.

In all cases, the carbonaeous gases coming from these materials penetrate (diffuse) into the surface of the workpiece at a temperature between 880° and 930°C. (Fig 2)

Fig 2

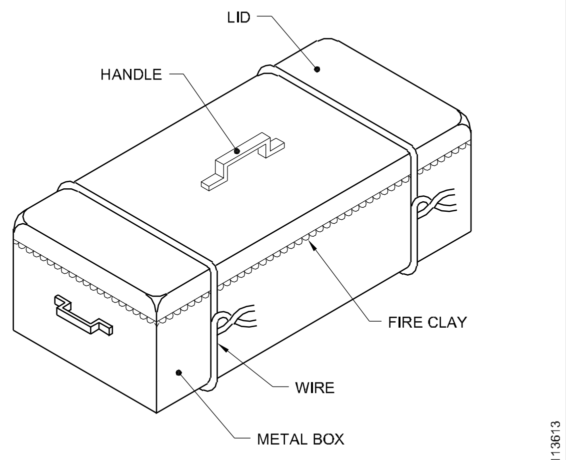


CASE HARDENING TEMPERATURES

Pack carburising (Fig 3) (solid)

The parts are packed in a suitable metal box in which they are surrounded by the carburising medium.

Fig 3

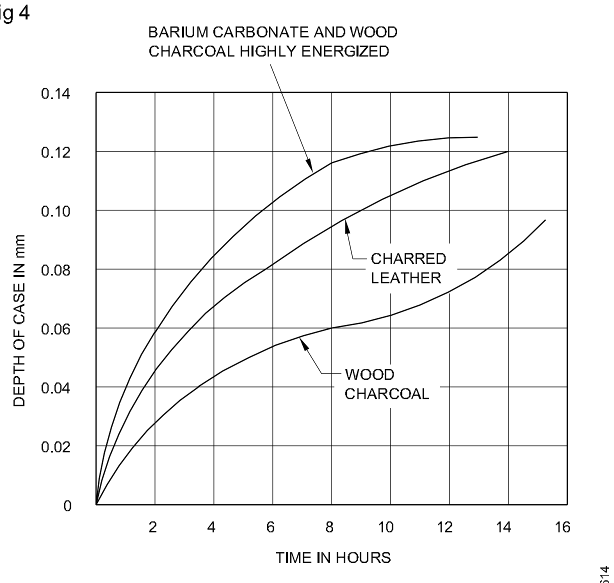


PACK CARBURISING

The lid is fitted to the box and sealed with fireclay and tied with a piece of wire so that no carbon gas can escape and no air acn enter the box to cause decarburisation.

The carburising medium can be wood, bone, leather or charcoal, but an energiser, such as barium carbonate, is added to speed up the process.(Fig 4)

Fig 4



RELATIVE RATE OF CARBURISATION WITH DIFFERENT SOLID CARBURISERS AT 698.8°C

Liquid carburising

Carburising can be done in a heated salt-bath. (Sodium carbonate, sodium cyanide and barium chloride are typical carburising salts.) For a constant time and temperature of carburisation, the depth of the case depends on the cyanide content.

Salt-bath carburising is very rapid, but is not always suitable because it produces an abrupt change in the carbon content from the surface to the core. This produces a tendency for the case to flake.

This is suitable for a thin case, about 0.25 mm deep. Its advantage is that heating is rapid and distortion is minimum.

Gas carburising

The work is placed in a gas tight container which can be heated in a suitable furnace, or the furnace itself may be the container.

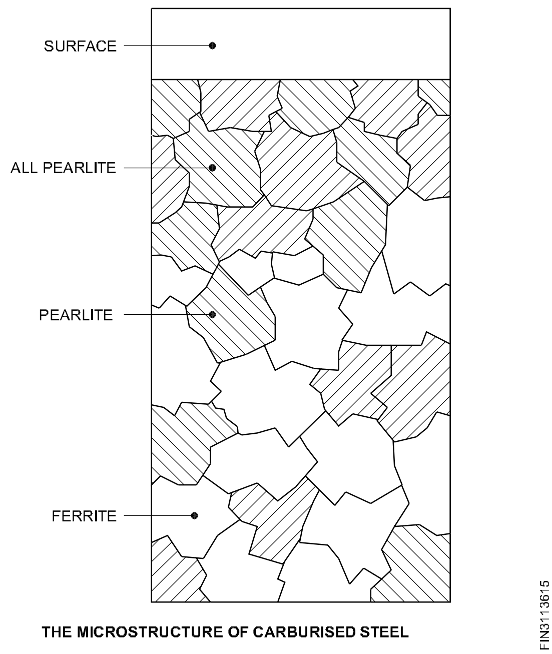
The carburising gas is admitted to the container, and the exit gas is vented.

The gas such as methane or propane may be fed directly into the container in which the work is placed.

In a continuous gas carburising furnace, the carburising, quenching and tempering processes are carried out in sequence in the same closed furnace as they progress on a conveyer from one operation to the next.

Fig 5 illustrates the appearance of the structure across its section produced by carburising.

Fig 5



THE MICROSTRUCTURE OF CARBURISED STEEL

Heat treatment

After the carburising has been done, the case will contain about 0.9% carbon, and the core will still contain about 0.15% carbon. There will be a gradual transition of the carbon content between the case and the core. (Fig 2)

Owing to the prolonged heating, the core will be coarse, and in order to produce a reasonable toughness, it must be refined.

To refine the core, the carburised steel is reheated to about 870° C and held at that temperature long enough to produce a uniform structure, and is then cooled rapidly to prevent grain growth during cooling.

The temperature of this heating is much higher than that suitable for the case, (Fig 2) and, therefore, an extremely brittle martensite will be produced.

The case and the outer layers of the core must now be refined.

The refining is done by reheating the steel to about 760°C, to suit the case, and quenching it.

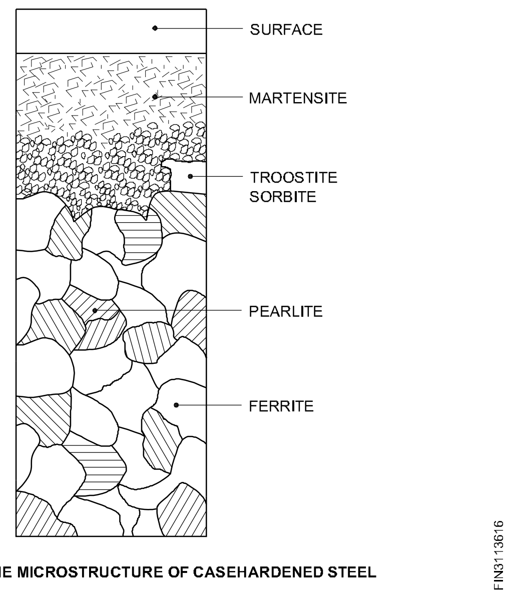
Tempering

Finally the case is tempered at about 200°C to relieve the quenching stresses.

If the part is not required to resist shock, it is unnecessary to carry out the core refining operation; in these conditions, a coarse martensite at the surface may not cause trouble, and so this part may be quenched directly after carburising.

Fig 6 illustrates the appearance of the structure across its section produced by case hardening.

Fig 6



THE MICROSTRUCTURE OF CASEHARDENED STEEL

Nitriding

Objectives : At the end of this lesson you shall be able to
- **state the process of case hardening by gas nitriding**
- **state the process of case hardening by nitriding in a salt bath.**

In the nitriding process, the surface is enriched not with carbon, but with nitrogen. There are two systems in common use, gas nitriding and salt bath nitriding.

Gas nitriding

The gas nitriding process consists of heating the parts at 500°C in a constant circulation of ammonia gas for up to 100 hours.

During the gas nitriding process, the parts are in an externally heated gas-tight box, fitted with inlet and outlet bores for the ammonia gas which supplies the nitrogen. At the completion of the 'soaking' the ammonia is still circulated until the temperature of the steel has fallen to about 150°C, when the box is opened, and the cooling completed in air. Nitriding causes a film to be produced on the surface but this can be removed by a light buffing.

Nitriding in salt bath

Special nitriding baths are used for salt-bath nitriding. This process is suitable for all alloyed and unalloyed types of steel, annealed or not-annealed, and also for cast iron.

Process

The completely stress-relieved workpieces are pre-heated (about 400°C) before being put in the salt bath (about 520-570°C). A layer 0.01 to 0.02 mm thick is formed on the surface which consists of a carbon and nitrogen compound. The duration of nitriding depends on the cross-section of the workpiece (half an hour to three hours). (It is much shorter than gas nitriding.) After being taken out of the bath, the workpieces are quenched and washed in water and dried.

Advantages

The parts can be final-machined before nitriding because no quenching is done after nitriding, and, therefore, they will not suffer from quenching distortion.

In this process, the parts are not heated above the critical temperature, and, hence warping or distortion does not occur.

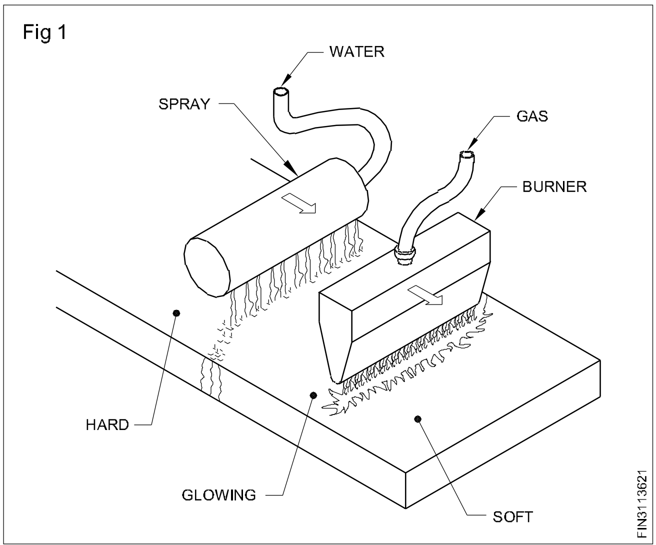
The hardness and wear-resistance are exceptional. There is a slight improvement in corrosion-resistance as well.

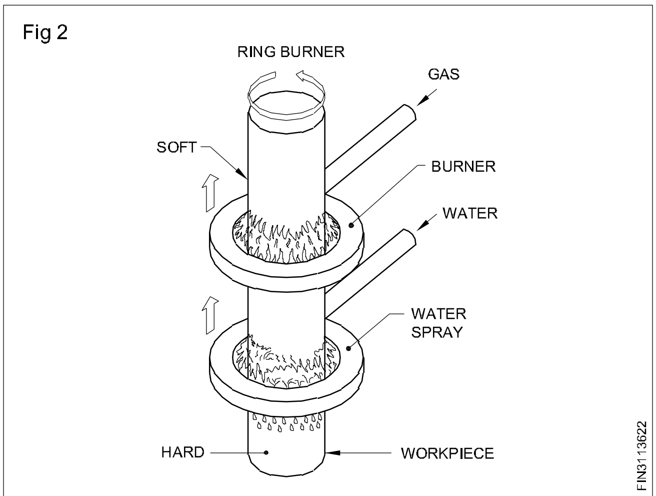
Since the alloy steels used are inherently strong when properly heat-treated, remarkable combinations of strength and wear-resistance are obtained.

Flame Hardening

Objectives : At the end of this lesson you shall be able to
- **state the process of surface hardening using a flame**
- **state the advantages and disadvantages of flame.**

In this type of hardening, the heat is applied to the surface of the workpiece by specially constructed burners. The heat is applied to the surface very rapidly and the work is quenched immediately by spraying it with water. (Figs 1 & 2) The hardening temperature is generally about 50°C higher than that for full hardening.





The workpiece is maintained at the hardening temperature for a very short period only, so that the heat is not conducted more than necessary into the workpiece.

Steels used for surface-hardening will have a carbon content of 0.35% to 0.7%.

The following are the advantages of this type of hardening.

- The hardening devices are brought to the workpiece.
- It is advantageous for large workpieces.
- Short hardening time.
- Great depth of hardening.
- Small distortion.
- Low fuel consumption.

The following are the disadvantages.

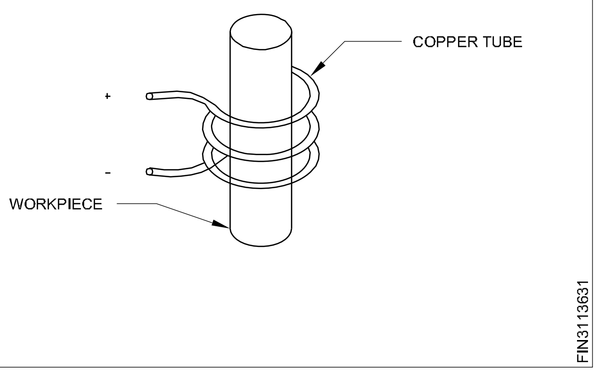
- Not suitable for small workpieces because of the danger of hardening through.
- The workpieces must be stress-relieved before hardening.

Induction hardening

Objectives : At the end of this lesson you shall be able to
- **state the process of the induction hardening method**
- **state the advantage of the induction hardening process.**

This is a production method of surface-hardening in which the part to be surface-hardened is placed within an inductor coil through which a high frequency current is passed. (Fig 1) The depth of penetration of the heating becomes less, as the frequency increases. The depth of hardening for high frequency current is 0.7 to 1.0 mm. The depth of hardening for medium freuency current is 1.5 to 2.0 mm. Special steels and unalloyed steels with a carbon content of 0.35 to 0.7% are used. After induction-hardening of the workpieces, stress-relieving is necessary.

Fig 1



The following are the advantages of this type of hardening.

- The depth of hardening, distribution in width and the temperature are easily controllable.
- The time required and distortion due to hardening are very small.
- The surface remains free from scale.
- This type of hardening can easily be incorporated in mass production.