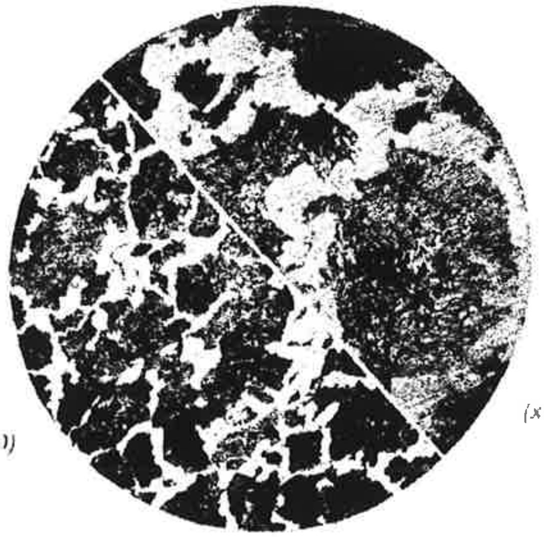
HEAT TREATMENT OF STEEL

The metallurgy of steel largely depends on the fact that when the temperature is above certain critical level iron exists in the **austenite** (γ) form (fcc) and will dissolve carbon in solid solution, while below this temperature the iron reverts to the **ferrite** (α) form (bcc) which is low in carbon therefore the excess carbon comes out of solution to produce **cementite** (Fe_3C) producing a two phase structure of ferrite and cementite known as **pearlite.** By altering the **rate** at which the temperature is lowered from above the critical level, a wide variety of different structures can be produced.

There are three principle single stage methods of heat treatment of plain carbon steels, called **ANNEALING, NORMALISING and QUENCHING** - these are just methods of cooling the steel more and more rapidly.

Full Annealing

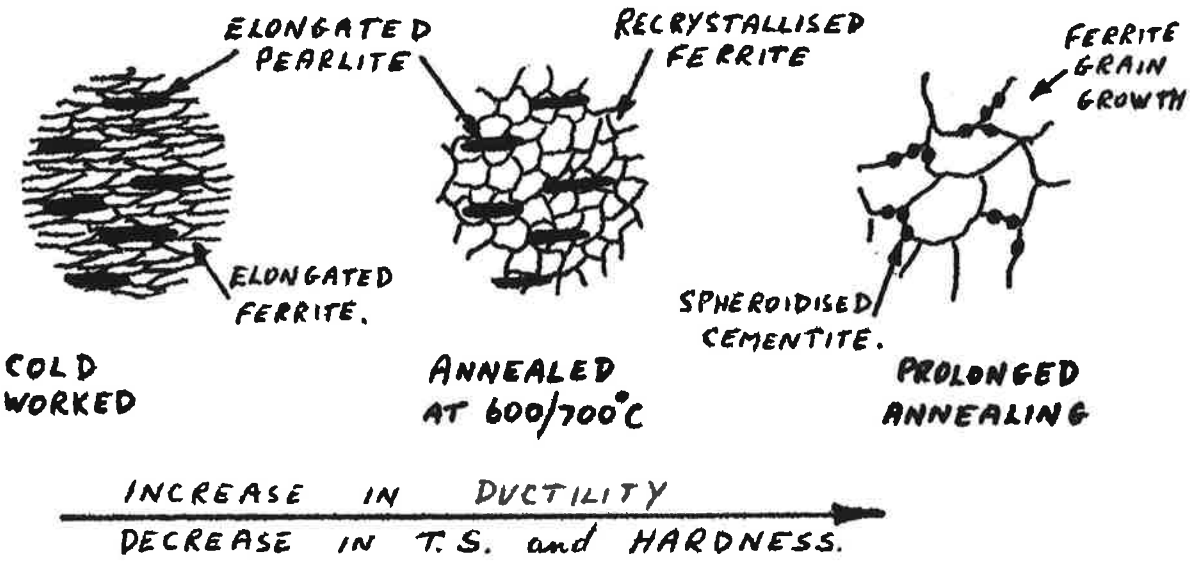
In full annealing the steel is heated to a temperature 30° above its upper critical temperature in order to dissolve all of the carbon into solid solution in the austenite form. After a suitable length of time at this temperature (1 hour per inch of section) the steel is allowed to cool **slowly** in the furnace (i.e. cooling at as near as possible to equilibrium rate).
As the temperature falls below the upper critical point ferrite is precipitated from the austenite solid solution at the grain boundaries. Meanwhile carbon diffuses into the remaining austenite, increasing its carbon content. When a temperature of 723°C is reached the carbon content of the austenite will be 0.83%. This is the **eutectoid** composition and therefore the eutectoid reaction (austenite → pearlite) takes place giving a final structure of coarse grains ferrite and pearlite. Steels annealed in this manner are in the softest possible condition.



X200 X500

Process Annealing

Process annealing or sub-critical annealing is carried out on cold worked low carbon steels in order to relieve internal stresses and soften the material. The steel is heated to 600/700°C which is just below the lower critical point



The changes taking place during process annealing are represented above. Prolonged annealing causes the cementite in the pearlite to 'ball up' or spheroidise. Ferrite grain growth can also occur if annealing temperature and time are not closely controlled.

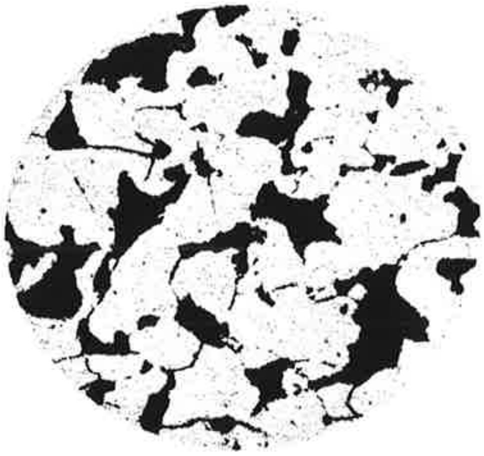
Spheroidising Annealing

High carbon steels may be softened by annealing at 650/700°C when the cementite of the pearlite balls up or speroidises. The resulting structure is one of cementite globules in a ferrite matrix. In this condition the steels can be cold drawn and posses good machinability. Spheroidisation is more readily carried out in a fine pearlite structure when fine globules of cementite are obtained. Large globules, although producing a softer structure, present difficulties in machining an generally produce a poor surface.

NORMALISING

Normalising consists of heating the steel to 30°C above the upper critical point, holding for a specified time (1 hour per inch section) to ensure complete austenite structure, followed by **cooling in still air**.
Normalising produces maximum grain refinement and consequently the steel is slightly harder and stronger than fully annealed steel.

Normalised



Annealed

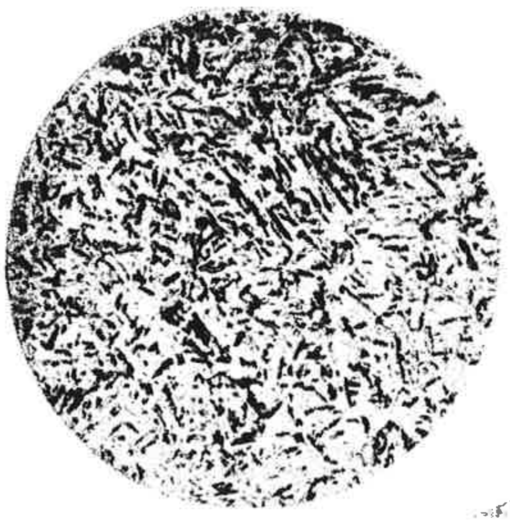
QUENCHING (HARDENING)

Hardening of steels by quenching involves heating the steel to 30°C above the upper critical point, holding the steel at that temperature for a suitable time (1 hour per inch of section) followed by quenching in brine, water or oil. In quenching the temperature falls so fast, that the carbon in the austenite fails to diffuse to form ferrite and pearlite, instead an intermediate state known as **martensite** is produced. This intermediate state is an unstable one in which the carbon atoms are held in solid solution in a distorted BCC lattice and which is intensely hard and brittle. Under the microscope the structure appears in the form of needles known as an 'acicular' structure.

"As quenched" steel is so intensely hard and brittle that it practice it is of little use. The principle value of quenching in the treatment of steel is as the first stage operation in the two-stage treatment known as **quenching and tempering**.

Quenched steel is in a very unstable condition and consequently a relatively low temperature is sufficient to "loosen" the atomic structure and allow the carbon to diffuse out to produce a more stable structure. Heating of quenched steel below the lower critical point is known as **tempering** and its effect is to make the steel less hard but very much tougher.

The main problem with quenching steels is that the volume expansion which accompanies the allotropic change from austenite to ferrite can cause cracking.



Other forms of heat treatment

Case hardening, Nitriding and carbonitriding, induction or flame hardening, and isothermal treatments such as martempering, austempering and isothermal annealing.

Assignment III

In many situations there is a requirement for components to be tough and ductile, whilst at the same time having a hard wearing surface. The production of ductility and hardness in the same component requires special surface hardening heat treatments. Describe the type of engineering component that would require surface hardening treatments and describe the treatments available to produce them.