Austenite

This phase is only possible in carbon steel at high temperature. It has a Face Centre Cubic (F.C.C) atomic structure which can contain up to 2% carbon in solution.

Ferrite

This phase has a Body Centre Cubic structure (B.C.C) which can hold very little carbon; typically 0.0001% at room temperature. It can exist as either: alpha or delta ferrite.

Carbon

A very small interstitial atom that tends to fit into clusters of iron atoms. It strengthens steel and gives it the ability to harden by heat treatment. It also causes major problems for welding , particularly if it exceeds 0.25% as it creates a hard microstructure that is susceptible to hydrogen cracking. Carbon forms compounds with other elements called carbides. Iron Carbide, Chrome Carbide etc.

Cementite

Unlike ferrite and austenite, cementite is a very hard intermetallic compound consisting of 6.7% carbon and the remainder iron, its chemical symbol is Fe_3C. Cementite is very hard, but when mixed with soft ferrite layers its average hardness is reduced considerably. Slow cooling gives course perlite; soft easy to machine but poor toughness. Faster cooling gives very fine layers of ferrite and cementite; harder and tougher

Pearlite

A mixture of alternate strips of ferrite and cementite in a single grain. The distance between the plates and their thickness is dependant on the cooling rate of the material; fast cooling creates thin plates that are close together and slow cooling creates a much coarser structure possessing less toughness. The name for this structure is derived from its mother of pearl appearance under a microscope. A fully pearlitic structure occurs at 0.8% Carbon. Further increases in carbon will create cementite at the grain boundaries, which will start to weaken the steel.

Cooling of a steel below 0.8% carbon

When a steel solidifies it forms austenite. When the temperature falls below the A3 point, grains of ferrite start to form. As more grains of ferrite start to form the remaining austenite becomes richer in carbon. At about 723℃ the remaining austenite, which now contains 0.8% carbon, changes to pearlite. The resulting structure is a mixture consisting of white grains of ferrite mixed with darker grains of pearlite. Heating is basically the same thing in reverse.

Martensite

If steel is cooled rapidly from austenite, the F.C.C structure rapidly changes to B.C.C leaving insufficient time for the carbon to form pearlite. This results in a distorted structure that has the appearance of fine needles. There is no partial transformation associated with martensite, it either forms or it doesn't. However, only the parts of a section that cool fast enough will form martensite; in a thick section it will only form to a certain depth, and if the shape is complex it may only form in small pockets. The hardness of martensite is solely dependant on carbon content, it is normally very high, unless the carbon content is exceptionally low.

Tempering

The carbon trapped in the martensite transformation can be released by heating the steel below the A1 transformation temperature. This release of carbon from nucleated areas allows the structure to deform plastically and relive some of its internal stresses. This reduces hardness and increases toughness, but it also tends to reduce tensile strength. The degree of tempering is dependant on temperature and time; temperature having the greatest influence.

Annealing

This term is often used to define a heat treatment process that produces some softening of the structure. True annealing involves heating the steel to austenite and holding for some time to create a stable structure. The steel is then cooled very slowly to room temperature. This produces a very soft structure, but also creates very large grains, which are seldom desirable because of poor toughness.

Normalising

Returns the structure back to normal. The steel is heated until it just starts to form austenite; it is then cooled in air. This moderately rapid transformation creates relatively fine grains with uniform pearlite.

Welding

If the temperature profile for a typical weld is plotted against the carbon equilibrium diagram, a wide variety of transformation and heat treatments will be observed. Welds. The metallurgy of a weld is very different from the parent material. Welding filler metals are designed to create strong and tough welds, they contain fine oxide particles that permit the nucleation of fine grains. When a weld solidifies, its grains grow from the course HAZ grain structure, further refinement takes place within these course grains creating the typical acicular ferrite formation shown opposite.