Steels

Types of Steels

Steel is defined as an alloy of iron and carbon, though other alloying elements are also found in many steels. Perhaps the most dramatic property of steel is that some alloys can be strengthened by *quench hardening*. Red hot metal is rapidly cooled by plunging it into a liquid. These alloys can thus be ductile for fabrication and much stronger as a finished product.

Steels are loosely grouped by carbon content into low carbon steels (< 0.35% carbon by weight, approximately), medium carbon steels (0.35%–0.5% carbon by weight, approximately), and high carbon steels (0.5%–1.5% carbon by weight, approximately). These numbers may seem to be small, but they reflect the fact that carbon is a small, light element, while iron is a much larger, heavier atom. When metallurgists look at the detailed structure of steels, they are concerned about the presence, and particularly the shape, of the carbide Fe_3C. This compound is 25% carbon by atom fraction, but only 6.7% carbon by weight.

There are two principal disadvantages with using steels. Among metals, steels are relatively heavy. They can also deteriorate by corrosion. However, the expectation is that, if steel will work, it will probably be the least expensive metal choice.

Low Carbon Steels

This category contains by far the largest tonnage of steel produced, as it includes the structural steels of bridges and buildings. These steels usually have only small amounts of other alloying elements. They are not quench hardened, as ductility in the final product is desired. Low carbon steels are sometimes referred to as *mild steels*.

In some cases, these steels may be surface treated to obtain the best of both worlds – a ductile, impact-resistant interior with a hard, abrasive-resistant surface. Common surface treatments for hardness include *carburizing*, *nitriding*, and *cyaniding*.

Low carbon steels may also be surface treated for corrosion resistance, using processes of *galvanizing*, *electroplating*, as well as just plain painting.

Medium Carbon Steels

Steels in this category are also medium alloy steels. Up to about 3% by weight might be comprised of varying proportions of manganese, nickel, chromium, molybdenum, or sometimes other elements. Medium alloy steels can be quench hardened, and the added alloying elements are primarily to improve *hardenability*.

Hardenability might be loosely described as the ease of obtaining hardness. To harden steel, its temperature must be changed rapidly to avoid the formation of softer equilibrium phases, and to produce the desired hard, strong phase called *martensite*. Upon quenching, the surface cools first, while the interior cools more slowly. These temperature gradients create stresses that, in the worst case, can crack the part. Also, the interior may not cool quickly enough to harden.

Steels of high hardenability are advantageous in two aspects:

- For a given quench medium, larger parts can be fully hardened.
- For a given part, a milder, less rapid quench can be used to minimize cracking.

The atoms of a metal are positioned in symmetrical geometrical arrays identified as *crystal lattices*. A particular array of an alloy is called a *phase*.

High Carbon Steels

These are also the high alloy steels, with approximately 5%–10% by weight consisting of alloying elements other than carbon. Though high carbon steels are used in the smallest amounts, these are specialty steels, often referred to as *tool steels*. They are the steels used for hammers, pick-axes, and cutting tools like knives and chisels. They are the steels used at the highest temperatures. The tool steels are generally heat treated.

The Quench Hardening Process

There are three stages to the quench hardening of steels: solution heat treat, quench, and reheat (temper).

> *The Quench Hardening Process – Solution Heat Treat*
>
> The steel is held at a high temperature to dissolve the alloying elements into a uniform, solid solution starting phase. The time required depends primarily on the size of the part.

The Quench Hardening Process – Quench

The hardening (strengthening) happens here. Rapid quenches promote hardening but risk cracking. Slower quenches prevent cracking, but may not sufficiently harden. The following media are ordered from severe quench (rapid) to mild quench (slow):

brine (salt water)	*rapid*
water	||
oil	\/
air	*slow*

The Quench Hardening Process – Reheat (Temper)

Immediately after quenching, steel is too brittle to be serviceable. Tempering is holding the part at an intermediate temperature between the initial solution temperature and the quench temperature. The purpose of tempering is to restore impact strength to the hardened part.