Aluminum and Its Alloys

Advantages of Aluminum Alloys

Aluminum overcomes two of the disadvantages of steel. Aluminum is lighter in weight, and it is stable in environments that corrode steel. Not as well known is that aluminum can be alloyed to be heat treatable. That is, it can be soft in one state for fabrication, and then heat treated to become a stronger finished product.

The heat treatment of aluminum and some other non-ferrous metals superficially resembles that for steel, in that it involves an initial heat, followed by a quench and then a reheat. Internally, however, the structural changes are distinctly different. Heat treatments for strengthening of non-ferrous metals are called either *precipitation hardening* or *age hardening*.

The Precipitation Hardening Process

In contrast to the chemical reaction occurring in steel, aluminum and some other non-ferrous alloys can be strengthened by a process that is referred to as *precipitation hardening*, also known as *age hardening*. Within the solid state, a second phase can precipitate out of a solid solution, analogous to solid particles precipitating out of a liquid. If these second phase particles are very fine (small), then they can effectively strengthen the overall alloy. The general rule is that if precipitates are large enough to be seen with an optical microscope, then they are too big for effective strengthening.

The first heat treatment in precipitation hardening is a solution heat treatment, for exactly the same purpose as the first heat treatment in the quench hardening of steels. The requisite starting point for both is a uniform solid solution.

The desired fine microstructure of precipitates forms within a temperature range below the solution temperature. However, if the alloy is quenched directly into the precipitation temperature range, the undesired coarse particle structure forms as the metal cools down. Therefore, we quench below the precipitation temperature range and heat back up to it.

Where quenching produces the hard structure in steel, quenching of a non-ferrous alloy freezes in the soft solid solution phase. Where the tempering reheat of steel stress relieves to a slightly softer state, it is during the reheat that the precipitates form to strengthen the non-ferrous alloy. The process is slow, perhaps requiring twenty or more hours. Hence, the other descriptive name of *age hardening*.

Some alloys of aluminum have been formulated to harden at room temperatures. These *naturally aging aluminums* can be used practically as rivets. They are quenched below room temperature, deformed into fasteners, and then strengthen in service at room temperature. Like aluminum alloys, alloys of magnesium, titanium, nickel, and some steels can also be strengthened by precipitation hardening.