Non- Ferrous Fasteners

by Laurence Claus

Image courtesy of Ko Ying Hardware Industry Co., Ltd.

Fasteners are a very unique product because they are truly integral to the success of the product or application they are used in. As such, even though most fasteners are made of steel, an exceptionally versatile material because of its ability to be transformed to different strength levels and properties, some applications need additional consideration. In cases where the application demands properties that cannot be best met by steel, designers must turn to other, non-ferrous types of material.

Common non-ferrous materials for fasteners include aluminum, copper, copper alloys, titanium, and nickel alloys. Fasteners may be made from any of these materials depending on the specific needs of the product or application. Common special requirements are things like strength, weight, oxidation resistance, performance at low or high temperature, magnetic permeability, and electrical conductivity. This article will take a brief look at each of these general families of non-ferrous materials.

Aluminum:

Although Aluminum has many favorable attributes, by far, the most common reason for employing it is its lightweight properties. Aluminum is about one third the weight of steel. This makes it attractive for applications that are weight dependent, such as automobiles and aircraft. Other properties for which aluminum is often considered include its resistance to corrosion and its electrical conductivity properties.

Aluminum is broken into two classes, wrought aluminum and cast aluminum. Wrought aluminum includes bar and wire product from which most fasteners are produced. Therefore, fasteners are classified by the wrought aluminum classification system. Wrought aluminum is classified by a four digit number with the first digit ranging from a one (1) to an eight (8). All the aluminums that start with a one are considered pure aluminum. The last two numbers represent the percent purity above ninety-nine that the material is. Therefore, 1050 aluminum is 99.50% pure. The materials that fall under the families that start between two (2)and eight (8) represent different aluminum alloy groups.

Very often, this four digit number is accompanied by a series of letters and numbers. These accompanying designations will always start with one of five letters; H, O, T, F, and W and are most often followed with a number. These designations are known as the Temper Designations and provide additional information about the condition of the material. The ‘O’ designation represents annealed material, ‘H’ strain hardened material, ‘T’ thermally treated material, ‘F’ as fabricated material, and ‘W’ as solution hardened material. Fasteners are most commonly accompanied by either ‘O’ or ‘T’ designations.

Although there are many different versions of wrought aluminum alloys, there are remarkably few used for fasteners. The three most common grades and the ones that make up the majority of all manufactured fasteners made are 6061, 2024, and 7075. 6061 is commonly used for automotive and industrial applications. Even after thermal treatment it possesses only moderate strength. Both 2024 and 7075 are aerospace grades of aluminum and after thermal treatment possess significantly higher strength levels than 6061.

For fasteners the most common thermal treatments are T4 and T6. T4 represents a thermal process of solution hardening and natural aging. This means that the material is heat treated and left to naturally cool down in air, during which precipitates come out of solution and strengthen the material. T6 represents a similar process but employs artificial aging, which means that the cooling is done in a controlled, step down process in the furnace. In artificial aging the furnace cooling is more controlled resulting in slighter harder material structures than achieved by natural aging.

Today aluminum fasteners are used in many applications. Perhaps the most traditionally recognized application is aerospace, where aluminum is used in solid rivets, blind rivets, pin and collar, and panel fastener assemblies. These are predominantly made of 2024 and 7075 because these two aluminum alloys possess one of the best strength to weight ratios of the wrought aluminum family. Increasingly automotive is employing more aluminum fasteners for their lightweight properties including some of the traditional aerospace grades. These are generally used in nonstructural applications, although there are several European manufacturers that have developed proprietary grades for critical powertrain and engine fasteners.

Copper and Copper Alloys:

In applications where electrical conductivity is the primary concern, copper is the usual choice. Pure copper is easily formed so that it can be flattened or drawn into complex and intricate shapes. It is commonly used for terminal studs and other electrical connections. The disadvantage of copper, however, is that it has a low strength to weight ratio so that it is not a practical choice in most applications where strength is a concern.

Applications which utilize the corrosion protective properties of copper usually require greater strength than pure copper will give. In these instances the copper alloys are used. Essentially, there are two families of copper alloys. Those that are alloyed with zinc are the brasses. Common brass alloys used for fasteners include Naval Brass (examples include Alloy 462 and 464) and Yellow Brass (examples include Alloy 260, Alloy 360, and Alloy 270). Alloy 675, also known as Manganese Bronze, is called a bronze but, in fact, is really part of the brass family. These materials are used for general purpose machine parts and lighter duty industrial uses.

Copper may also have nickel added to make a copper-nickel alloy. These materials are stronger than brass but do not come close to providing the performance characteristics of the nickel-copper alloys, which are part of the nickel alloy family. These materials provide good protection against corrosion and erosion in high velocity sea water. Typical materials in this category include Alloy 710 and Alloy 715.

All other materials alloyed with copper are considered bronzes. The most common are Aluminum Bronze, Phosphor Bronze, Manganese Bronze, and Silicon Bronze. Bronzes are generally stronger than brasses. Typical application of bronzes for fasteners include marine applications, especially in turbulent water conditions, pumps, and certain industrial equipment.

Titanium:

Titanium has the highest strength to weight ratio of all the materials used for fasteners. For this reason titanium fasteners are especially popular in aerospace and many defense applications. Titanium also generally has excellent oxidation resistance so that it is popular in harsh industrial environments and the oil and gas industry.

Although titanium has many appealing attributes, fasteners made of titanium alloys are quite expensive. This is partially due to the amount of processing required to consolidate titanium sands into workable raw material stock, but also because of the difficulty in processing. Titanium must be formed warm. The temperature control is important because if the temperature is too cool the material is hard or impossible to form and if it is too hot can result in the formation of undesirable Alpha Case.

Titanium exists in several different phases; Alpha, Beta and Alpha-Beta phases. At room temperature titanium would normally take the Alpha phase and possess a certain set of characteristics. However, by adding certain stabilizing elements titanium alloys can be transformed into Beta and Alpha-Beta alloys at room temperature. These possess different properties from Alpha phase materials. By far, the most commonly used titanium alloy for fasteners is Ti-6Al-4V or "6-4" titanium for short. This is an Alpha-Beta titanium which means that it possesses a good balance of strength and ductility. It also is heat treatable so that it can be transformed to provide more favorable properties.

Nickel Alloys:

The final type of non-ferrous alloys are those containing high amounts of nickel. These materials are capable of providing some exceptional performance. These are the materials that are considered super alloys because they provide exceptional strength at room, elevated, and subzero temperatures, they provide exceptional oxidation resistance, and they resist fatigue and stress rupture better than other materials.

These materials are used around engines, turbines, and in harsh environments such as those found in heat treating furnaces, food processing, and oil and gas. These materials are used in applications like aerospace engines, turbines, and on space vehicles.

A couple of common nickel alloys include A286, a nickel-iron alloy. This material is capable of high strength at temperatures up to about 1200° F. It is commonly used, therefore, in aerospace and automotive applications around high heat sources. Alloy 718, or Inconel®, is another high strength at elevated temperature alloy. Once again, Inconel® is used in demanding aerospace and automotive applications where strength is required in high heat environments. Other nickel alloys include Hastelloy®, Hastelloy X®, Waspaloy®, MP35N®, MP159®, Monel®, and K-Monel®. These last two, Monel® and K-Monel®, are Nickel-Copper alloys. They have many of the copper alloy advantages, especially in marine and turbulent water applications, but are much higher strength than the copper-nickel alloys.

Summary:

There are many non-ferrous materials available for fasteners which provide a wide range of properties and specialty application advantages. Fasteners made of these materials can be very costly, so designers must be intentional when employing them. However, when steel fasteners will not suffice, it is important that we have materials like these in our toolbox to provide the performance and requirements that we need.