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HEAT TREATED ALLOY

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This invention relates to aluminum base alloys containing from about 2 to 12 per cent copper and 0.005 to 0.1 per cent tin that are heat treated and artificially aged to improve their physical properties.

It is well known that the strength of certain aluminum base alloys may be considerably increased through heat treatment and aging at ordinary or elevated temperatures. The heat treatment generally employed consists in heating the alloy to a temperature above about 500° C. and maintaining it at this elevated temperature until virtually all of the soluble constituents present in the alloy have been dissolved within the limits of their solid solubility. The alloy is then quickly cooled to a much lower temperature, usually room temperature, and finally aged by allowing it to stand at ordinary temperatures for a few days or by reheating to a temperature between about 100 and 200° C. for a number of hours, this reheating treatment being usually termed artificial aging. It has been found that the rapidity of cooling of the alloy from the high temperature has a marked effect upon the strength of the aged product; the slower the cooling the lower will be the strength and hardness. It has therefore been the general practice to cool the hot alloy to ordinary temperatures as quickly as possible by quenching in such mediums as water or oil, the highest strength values being obtained in the alloys quenched in water at room temperature or lower. The alloys thus rapidly quenched not only have better physical properties when aged than a more slowly cooled product, but the corrosion resistance is also better.

Of the factors which affect the rate of cooling two of the outstanding ones are the character and temperature of quenching medium. It is well recognized in the heat treating art that water and oil, for example, differ in their cooling qualities, the former providing the more rapid quench. It is not desirable, however, to always employ the most drastic quenching medium, but to adapt the means of cooling to the nature of the article being quenched, thus an article of uniform cross section will stand a more rapid change in temperature with less danger of cracking than an article of non-uniform cross section. Again, the temperature of the coolant has an important influence upon the rate of cooling, the higher the temperature of the medium the less drastic is the quench.

In the quenching of heat treated aluminum base alloys under commercial operating conditions, the quenching bath which initially may be at room temperature becomes heated through continued use unless cooled in some manner. Alloys quenched in hot or boiling water, for example, are less drastically cooled than those immersed in cold water with the result that most hot water quenched articles are less corrosion resistant than the more rapidly cooled products. Although this difference is not important for many applications, it is in some cases significant where severe corrosive conditions are encountered in service. The strength of the final product after aging is also lowered in many instances by the use of a hot water quench which is disadvantageous.

The use of a hot quenching medium, however, is not without merit since the slower rate of cooling reduces the tendency of the quenched article to warp. This feature is a distinct advantage where metal of thin cross section is being treated, or where there is a marked difference in thickness of cross section between different parts of the article. For this reason a hot quenching medium is employed in certain cases in spite of the lower properties that are thereby produced.

It is an object of my invention to provide a heat treatable aluminum base alloy which can be quenched in a hot medium without adversely affecting the corrosion resistance of the final product after it has been fully aged. Another object is to provide an aluminum base alloy that possesses high physical properties in combination with good corrosion resistance after it has been quenched from the solution heat treating temperature in a hot quenching medium and artificially aged. Still another object is to provide an aluminum base alloy that can be heat treated, and quenched in hot water under commercial operating conditions, and artificially aged without lowering the physical properties or corrosion resistance. A further and more particular object is to provide a more corrosion resistant heat treated and artificially aged aluminum-copper type of alloy which can be quenched in hot water.

My invention is predicated upon the discovery that the addition of from about 0.05 to 2 per cent of cadmium to magnesium-free aluminum base alloys of the composition set forth hereinbelow makes it possible to quench these alloys in a hot medium, such as boiling water, after solution heat treatment, and then artificially age them, without adversely affecting their strength and resistance to corrosion. In other words, alloys made in accordance with my invention may be quenched at a slower rate than is ordinarily permissible for most heat treated aluminum base alloys without impairment of their desirable properties. Although the effect of cadmium is manifest when

used in amounts as small as 0.05 per cent, I generally prefer to add not less than 0.1 to 0.2 per cent. I have found that the beneficial effect of cadmium upon the resistance to corrosion of alloys quenched in a hot medium is not general among heat treated and artificially aged aluminum base alloys, but is confined to the alloys of the composition herein described.

The alloys to which my invention is applicable are those containing from 2 to 12 per cent of copper, 0.1 to 1.5 per cent of silicon, 0.005 to 0.1 per cent of tin, and a total of 0.01 to 1.5 per cent of at least one of the hardening elements manganese, chromium, titanium, molybdenum, tungsten, vanadium, zirconium, nickel, cobalt, beryllium and boron within the following proportions for each of said elements: manganese, 0.05 to 1.5 per cent; chromium, 0.05 to 1 per cent; titanium, 0.03 to 0.5 per cent; molybdenum, 0.05 to 1 per cent; tungsten, 0.05 to 1 per cent; vanadium, 0.01 to 1 per cent; zirconium, 0.05 to 0.5 per cent; nickel, 0.05 to 1 per cent; cobalt, 0.05 to 1 per cent; beryllium, 0.01 to 0.5 per cent; and boron, 0.01 to 0.5 per cent. The foregoing hardening elements constitute a group of substances which for the purposes of my invention, are alike in respect to their hardening effect upon the aluminum-copper-silicon-tin-cadmium base alloy. These elements serve to enhance particular properties of the base alloy without substantially altering its fundamental characteristics.

The term magnesium-free alloys as herein employed refers to those alloys which have less than 0.01 per cent magnesium present as an impurity. In commercial practice it is desirable to keep this impurity below a maximum of 0.005 per cent.

I have also discovered that the addition of indium to the type of aluminum-copper base alloy herein described has an effect similar to that of cadmium upon the corrosion resistance of the alloy quenched in a hot medium. The proportion of indium required to achieve this result varies between about 0.01 and 2 per cent, the preferred range being about 0.05 to 1 per cent. This element may not only be used alone as a constituent to improve corrosion resistance, but it may be employed in combination with cadmium. When so employed the total amount of the two elements should not exceed about 2 per cent.

The addition of cadmium to the aforementioned alloys also has the surprising effect of altering the type of attack that these alloys suffer when corroded. The type of corrosive attack which characterizes my alloy has been denominated as intracrystalline in contrast to the familiar intercrystalline and pitting types of corrosion found in aluminum base alloys. The basis for the distinction lies in the manner in which the various aluminum base alloys react to corroding media. In the case of intercrystalline corrosion, the attack progresses along the grain boundaries ahead of the area where the grains are dissolved thereby tending to destroy the intergranular bond. The result of such an attack is a reduction in the effective cross section of the article and an embrittlement of the alloy. The pitting type of attack is said to occur where pits develop on the surface of the alloy irrespective of the grains and grain boundaries, that is, the attack is of a general nature as compared to the selective penetration along the grain boundaries described above. In contradistinction to either of these types of corrosion the term intracrystalline denotes a preferential attack within the grain and an avoidance of the substance comprising the grain boundaries, there is less reduction in effective cross section and consequently less weakening of the metallic structure. The presence of cadmium appears to change the character of the precipitate that forms within the grains when the alloy is aged and this in turn is believed to account for the improved properties. In any event the cadmium creates a condition that is unique among heat treated and artificially aged aluminum base alloys which permits use of a quenching practice that has heretofore been found to have a deleterious effect on heat treated and aged alloys.

In thus referring to a type of attack and corrosion resistance of an alloy it is to be understood that some corrosive attack is not necessarily fatal to the alloy's continuance in service under ordinary conditions. No alloy is absolutely impervious to attack from some corroding medium, hence the terms corrosion and corrosion resistance are relative in their meaning. In the present instance I refer to my improved alloys as being more corrosion resistant than the heat treated and artificially aged aluminum-copper type of alloy commonly used at the present time.

The relative stability of my alloy under severe corrosive conditions after being quenched in hot water, as compared to other alloys treated in the same manner, is well illustrated by the following test. The test consisted of alternately immersing samples of the alloys in and removing them from an aqueous solution containing approximately 5 per cent of sodium chloride and 0.3 per cent of hydrogen peroxide over a period of 48 hours. The alloys exposed to the test were a widely used aluminum base alloy composed of about 4 per cent copper, 0.5 per cent magnesium, 0.5 per cent manganese, and balance aluminum, which for convenience may be called alloy A; a second one, called B, composed of about 4.5 per cent copper, 0.5 per cent manganese, 0.05 per cent tin, balance aluminum; and a third alloy, designated C, consisting of about 4.5 per cent copper, 0.5 per cent manganese, 0.05 per cent tin, 0.5 per cent cadmium and the balance aluminum. All of the alloys were first heat treated in the customary manner at about 510° C. They were then quenched in a predetermined manner and finally aged. The first alloy, A, was quenched in boiling water and aged at room temperature for several days before testing. The specimens of alloy B were divided into two groups, group 1 being quenched in water at room temperature and aged at 160° C. for 12 hours, while group 2 was quenched in water having a temperature of about 100° C. and then aged for the same time at the same temperature as group 1. The third alloy, C, was treated in the same manner, that is, the specimens were divided into two groups, group 1 being quenched in water at room temperature, and group 2 in water at about 100° C., and finally both groups were artificially aged at 160° C. for 12 hours.

When subjected to the above described alternate immersion corrosion test, alloy A lost 20 per cent in tensile strength and 53 per cent in elongation as compared to its properties before corrosion, whereas it might normally be expected to lose about 10 per cent in strength and 40 per cent in elongation when quenched in cold water. Group 1 of alloy B, which contained no cadmium, suffered a loss of only 8 per cent in tensile strength and 25 per cent in elongation after being quenched in cold water, while group 2 that was quenched in hot water lost 26 per cent in tensile strength and 60 per cent in elongation. The un-

favorable effect of quenching in hot water is thus quite apparent. Specimens of group 1 of alloy C, that contained about 0.5 per cent cadmium and which had been quenched in cold water lost 11 per cent in tensile strength and 51 per cent in elongation while group 2 that had been quenched in hot water showed a loss of 11 per cent in tensile strength and 41 per cent in elongation. The test thus shows a very marked improvement in corrosion resistance over the same alloy without cadmium and that the hot water quenched material was no worse than that which had been quenched in cold water which is contrary to the usual behavior of hot and cold water quenched articles.

The unique character of my alloy is further revealed by a microscopic examination of the corroded specimens. The first alloy, A, in the hot water quenched condition, after being corroded, showed that attack had commenced along the grain boundaries, as well as those specimens from alloy B which had also been quenched in hot water. However, the same alloys quenched in cold water show little or no intergranular attack, and their resistance to corrosion is considered to be satisfactory. The third alloy, C, in both hot and cold water quenched conditions, showed little or no penetration along the grain boundaries, the attack, rather, being within the grains in the form of shallow pits. This intracrystalline type of attack, as already mentioned, has not heretofore been found in heat treated and aged aluminum base alloys.

It has been found that the fully aged alloys of the kind herein described are further distinguished from the commonly used heat treated and artificially aged aluminum-copper type of alloy in that the former (those containing cadmium) can be reheated to temperatures of 150 to 230° C. for periods of time up to 30 minutes without adversely affecting their physical properties and corrosion resistance. This ability to withstand reheating after artificial aging is particularly valuable where heat treated and fully aged plates or shapes are to be joined by the driving of hot rivets. Ordinarily the hot rivet would cause an undesirable change in the microstructure which diminishes the corrosion resistance. The same property of resistance to corrosion found in my improved alloy permits reheating of articles within the aforementioned temperature range to facilitate forming operations.

The addition of cadmium to alloys of the kind herein described may enhance the strength as well as the corrosion resistance. The second alloy, B, mentioned above containing about 4.5 per cent copper, 0.5 per cent manganese and 0.05 per cent tin when heat treated, quenched in hot water, and artificially aged by heating at 160° C. for 12 hours had a tensile strength of 58,800 pounds per square inch, a yield strength of 41,800 pounds per square inch and an elongation of 13 per cent in two inches. The same alloy with the addition of 0.5 per cent cadmium when heat treated, quenched and aged in the same manner, had a tensile strength of 62,500 pounds per square inch, a yield strength of 52,300 pounds per square inch, and an elongation of 10.2 per cent.

In the manufacture of wrought alloys and the production of many castings, I prefer to use from about 2.5 to 6 per cent of copper, 0.3 to 1 per cent of silicon, 0.03 to 0.07 per cent of tin, 0.3 to 1 per cent of cadmium, and a total of from 0.03 to 1 per cent of at least one of the hardening elements of the group composed of manganese, chromium, titanium, molybdenum, tungsten, vanadium, zirconium, nickel, cobalt, beryllium, and boron within the following proportions for each of said elements: manganese, 0.1 to 1 per cent; chromium, 0.1 to 0.75 per cent; titanium, 0.03 to 0.25 per cent; molybdenum, 0.1 to 0.75 per cent; tungsten, 0.1 to 0.75 per cent; vanadium, 0.1 to 0.75 per cent; zirconium, 0.1 to 0.75 per cent; nickel, 0.1 to 0.75 per cent; cobalt, 0.1 to 0.75 per cent; beryllium, 0.05 to 0.25 per cent; and boron, 0.03 to 0.25 per cent. The total amount of said hardening elements should in no case exceed 1.5 per cent, and preferably it should be less than 1 per cent.

The amount of iron which is present as an impurity in the alloy in combination with the quantity of silicon and hardening elements which have been added, will determine the amount of cadmium that should be used if the maximum benefit is to be derived from the addition of this element. When the total amount of iron and silicon is up to about 0.4 per cent, and up to 0.2 per cent of the hardening elements are present, only 0.15 to 0.25 per cent cadmium need be added to render the heat treated and artifically aged alloy resistant to corrosion. On the other hand, if the total amount of iron and silicon is about 0.75 per cent, and 0.8 per cent manganese, for example, is present, from 0.5 to 1 per cent cadmium should be used.

In addition to the specific cadmium-containing alloy referred to hereinabove, I have found that other compositions within the foregoing range possess especially desirable properties and therefore represent preferred embodiments of my invention. Alloys of the following compositions are suitable for extrusion: 3.5 per cent copper, 0.5 per cent manganese, 0.25 per cent cadmium and 0.05 per cent tin; 3.5 per cent copper, 0.25 per cent manganese, 0.25 per cent cadmium, 0.05 per cent tin and 0.25 per cent chromium; and 4 per cent copper, 0.1 per cent manganese, 0.1 per cent cadmium, 0.05 per cent tin and 0.1 per cent titanium.

The alloys herein disclosed are susceptible to the usual heat treatment employed in improving the strength of aluminum base alloys, namely, heating at a temperature above about 475° C. for a sufficient length of time to secure substantially complete solution of soluble constituents within the limits of their solid solubility. The heat treated alloy containing cadmium may be quenched in any suitable hot medium, such for example, as boiling water. For many purposes where warpage is an important consideration the highest practicable temperature should be employed, for example, between 90 and 100° C. Following the quenching, the alloy is to be artificially aged by reheating to a temperature of from about 100 to 175° C. for periods of 1 to 60 hours depending upon the degree of hardness desired.

The term aluminum as herein employed refers to the metal of commercial grade containing the usual impurities. Other elements than the impurities and those specifically named above may be present in the alloy providing the function of the disclosed elements is not substantially disturbed.

This application is a continuation-in-part of my co-pending application, Serial No. 35,132, filed August 7, 1935.

I claim:

1. A heat treated and artificially aged magnesium-free aluminum base alloy consisting of aluminum, from 2 to 12 per cent copper, 0.1 to 1.5

per cent silicon, 0.005 to 0.1 per cent tin, 0.05 to 2 per cent cadmium, and 0.05 to 1.5 per cent manganese.

2. A heat treated and artificially aged magnesium-free aluminum base alloy consisting of aluminum, from 2.5 to 6 per cent copper, 0.3 to 1 per cent silicon, 0.03 to 0.07 per cent tin, 0.3 to 1 per cent cadmium, and 0.05 to 1.5 per cent manganese.

3. A heat treated and artificially aged magnesium-free aluminum base alloy consisting of aluminum, from 2.5 to 6 per cent copper, 0.3 to 1 per cent silicon, 0.03 to 0.07 per cent tin, 0.3 to 1 per cent cadmium, and 0.1 to 1 per cent manganese.

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