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ALUMINUM ALLOY

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This invention relates to alloys, and more particularly to machinable aluminum base alloys having low thermal expansion and relatively high wear resistance.

Aluminum alloys having relatively low thermal expansion, together with relatively high strength and hardness, and retaining these properties after exposure to prolonged high temperatures, are especially desirable for the manufacture of castings, such as pistons or other parts, for use in internal combustion engines and the like.

Aluminum-silicon alloys containing suitable amounts of manganese and magnesium have been used in the production of such pistons; and in these alloys as the proportion of silicon is increased, the thermal expansion of the alloy is decreased, and the hardness and wear resistance of the alloy are increased. Their wear resistance, however, has not been as great as usually desired and the expansion has not been low enough. This is because it has usually been necessary to have the percentage of silicon less than about 15%, as higher amounts of silicon have decreased the machinability and fatigue resistance of the alloy to a substantial degree.

In my prior application Serial No. 366,453, filed November 20, 1940, of which this application is a continuation-in-part, is disclosed a machinable, aluminum base alloy containing silicon, magnesium, manganese, iron and copper. This alloy has greater hardness, improved wear resistance, and a relatively low thermal expansion.

In my copending application Serial No. 375,043, filed January 18, 1941, there is disclosed an alloy more desirable for some purposes and containing silicon, magnesium, copper, iron, and two or more hardening elements selected from the group consisting of manganese, nickel, chromium, cobalt, columbium, molybdenum, tungsten, vanadium, zirconium, titanium, tantalum, boron and cerium in a total amount of .5% of 5%.

While the properties of the above alloys are each very desirable for many industrial uses, including the manufacture of pistons and the like which are exposed to relatively high temperatures for long periods of time, it has been found that superior thermal conductivity and bearing properties may be obtained in a readily castable alloy containing 18% to 35% silicon, about .1% to 1% magnesium, about 1% to 5% copper, about .4% or .5% to .2% iron, about .1% to 3% tin, about 3% to 3% zinc, at least one of the hardening metals of the group consisting of manganese, nickel, chromium and cobalt in a total amount of about 3% or less, and/or at least one of the

hardening and grain refining metals selected from the group consisting of titanium, columbium, molybdenum, tungsten, vanadium, zirconium, boron, tantalum and cerium in a total amount of 2% or less, and preferably less than 1.5%. The total amount of metals selected from the above groups should preferably not exceed 4% and improved results are obtained when they are present in a total amount of more than .3%.

Silicon, which aside from aluminum is the predominant alloying ingredient, may be present in the alloy within the limits of 18% to 35%; but, silicon is preferably present in an amount from about 20% to 30% of the alloy. Silicon increases the hardness and wear resistance of the alloy and decreases its thermal expansion. Without suitable quantities of the other above mentioned constituents, however, it has a tendency to crystallize into relatively large crystals and to decrease the machinability of the alloy.

Iron tends to harden the alloy, decrease its thermal expansion, increase its machinability, and aids in maintaining the properties of the alloy at relatively high temperatures. It is preferably present within the amounts of about .7% to 1.5%, although an alloy having very desirable properties may be obtained with 2% or so, and with as little as about .4% or .5% iron. Iron, however, like silicon has the property of tending to crystallize into relatively large crystals in the absence of hardening metals of the groups set out above.

The members of the above groups each tend to harden the alloy, decrease its thermal expansion and increase its machinability. They are also beneficial in that they tend to maintain the desirable properties at relatively high temperatures, such as those encountered in internal combustion engines and the like.

Metals of the above group of hardening metals consisting of manganese, nickel, cobalt and chromium are usually most desirable in the alloy for the reason that they are more easily alloyed with the aluminum and most desirable properties are obtained when at least one of these metals is present. These four elements function in aluminum alloys as hardeners and have no appreciable function as grain refiners.

The hardening and grain refining metals of the group consisting of columbium, molybdenum, tungsten, vanadium, zirconium, cerium, titanium, tantalum and boron are generally recognized as being both hardeners and grain refiners in aluminum alloys. If grain refining is not particularly desirable, as when the whole casting is

chilled substantially simultaneously, it may not be necessary to use any of these elements. However, it is preferable to have at least one present even though one or more of the above group consisting of manganese, cobalt, chromium and nickel be also present.

The desirable proportions of the elements in the above mentioned groups which are effective to obtain my improved results are different. Thus, desirable properties may be obtained with any of the following elements: manganese in amount of about .2% to 1%; nickel in amount of about .2% to 1.5%; chromium in amount of about .1% to .5%; cobalt in amount of about .1% to .5%; columbium in amount of about .01% to .25%; molybdenum in amount of about .1% to .5%; tungsten in amount of about .1% to .5%; vanadium in amount of about .1% to .5%; zirconium in amount of about .01% to .25%; cerium in amount of about .01% to .25%; titanium in amount of about .05% to .3%; tantalum in amount of about .1% to .3%; and boron in amount of about .005% to .1%.

Since each of these hardening metals may tend to crystallize in somewhat different shapes, finer crystals and more desirable properties may be obtained in alloys having more than one of these metals present, each in relatively smaller amounts, than in alloys having the same total effective amount of a lesser number of these metals.

The members of the above mentioned groups have the desirable property of tending to inhibit the growth of the large iron and silicon crystals, especially when two or more of the members are present. Consequently, it is desirable to have two or more of these elements present, even though there be present a relatively large amount of iron. However, with a relatively large iron content, a somewhat smaller total quantity of these elements may be used to obtain substantially the same properties in the alloy as when a smaller amount of iron is present.

The total quantity of the hardening and grain refining metals in the above groups should be less than 5% and they should be present in an amount of about .8% or more, and preferably 1% or more of the alloy. In the preferred alloys having manganese, chromium, nickel, zinc and tin, with one of the grain refining and hardening group, such titanium, present, the preferred amount of manganese is about .7%; the preferred amount of nickel is around 1%; the preferred amount of chromium is around .2%; and the preferred amount of titanium is about .15% to .2%.

Magnesium, as well as improving the hardness and tensile strength of aluminum-silicon alloys, increases the elastic properties of the alloy, and also improves the machinability, and is preferably present in amounts of about .3% to about .8%, although as much as 1%, or even somewhat more, may be used, and an appreciable effect is obtained with as little as about .1%.

Copper is beneficial in the alloy in that it aids in increasing its fatigue strength and further improves its machinability. The preferred amount of copper is 1.5% to 2.5%, but the desirable properties of the alloy are obtained when copper is present from about 1% to about 5%.

Zinc when present in small amounts and up to approximately 3% has the effect of improving the mechanical properties, such as tensile strength and hardness. When added in amounts such as 2% to 3%, it tends to reduce the thermal conductivity and increase the thermal expansion. If relatively high thermal conductivity and rela-

tively low thermal expansion are desired, it is preferable to have the zinc present in an amount less than about 2%, such as .5% to 1.5%. When present in these amounts the thermal conductivity and the thermal expansion of the alloy are not materially affected.

Tin is an important addition to aluminum-silicon alloys in order to provide better thermal conductivity and bearing properties, as well as to improve machinability. Tin counteracts the undesirable decrease of thermal conductivity caused by the members of the above mentioned groups of hardening metals. Tin may be present in an amount of .1% or so to 3%, and is preferably present in an amount of from .5% to 1.5% or 2%. If present in too large an amount, tin has a tendency to segregate from the rest of the alloy and it is, therefore, not desirable to have more than 3% tin present in the alloy.

The following examples illustrate alloys desirable for the making of pistons and embodying the present invention:

Example 1

An aluminum base alloy containing about 22% silicon, about .7% manganese, about .6% magnesium, about 1.7% copper, about .9% iron, about .7% nickel, about 1% zinc, about .7% tin, and about .12% titanium was chill cast into test bars, which test bars were quenched from the mold and then heat treated for twelve hours at 350° F. The hardness of the bars thus obtained was between 120 and 140 Brinell and the tensile strength was between 24,000 and 27,000 lbs./sq. in. Pistons made from this alloy may be readily machined and have relatively great wear resistance, relatively low thermal expansion and relatively high heat conductivity, together with excellent fatigue strength.

Example 2

An aluminum base alloy containing about 21.5% silicon, about .7% manganese, about .6% magnesium, about 1.8% copper, about .7% iron, about .4% tin, and about 1% zinc was cast into test bars which were heat treated twelve hours at 355° F. The hardness of the bars thus prepared was between 130 and 140 Brinell; the tensile strength was between 27,000 and 30,000 lbs./sq. in.; and the coefficient of thermal expansion was 17.5×10^{-6} . This alloy may be readily machined with tools now available and has very desirable bearing properties. As may be seen from the above data, it has relatively low thermal expansion, is relatively hard, and has relatively great wear resistance. It also has comparatively high heat conductivity, excellent fatigue strength and elastic properties, and maintains these properties over long exposures at high temperatures, such as those encountered in internal combustion engines, motor parts and the like.

Example 3

An aluminum base alloy containing about 22% silicon, about .5% manganese, about .3% magnesium, about .8% iron, about 1.7% copper, about .8% nickel, about .4% zinc, and about .1% tin was chill cast into test bars, which test bars were quenched from the mold and tested after a suitable heat treatment. The hardness of the bars thus obtained was between 122 and 130 Brinell and the tensile strength was about 30,000 lbs./sq. in.

The alloys of the present invention are particularly desirable for the production of castings, and the castings are susceptible to the usual

heat treatments and have their tensile strength and hardness substantially improved thereby.

Furthermore, it is to be understood that various modifications of the alloys disclosed herein can be made without departing from my invention as defined in the appended claims.

What I claim is:

1. An aluminum base alloy having a relatively low thermal coefficient of expansion and relatively great wear resistance, containing about 18% to about 35% silicon, about .1% to about 1% magnesium, about 1% to 5% copper, about .4% to about 2% iron, about .2% to about 1% manganese, about .1% to 3% tin, and about 3% to 3% zinc, with the balance substantially all aluminum and minor impurities.

2. An aluminum base alloy having a relatively low thermal coefficient of expansion and relatively great wear resistance, containing about 20% to about 30% silicon, about .3% to about .8% magnesium, about 1.5% to 2.5% copper, about .7% to about 1.5% iron, about .5% to about 1% manganese, about .5% to 2% tin, and about

.5% to 2% zinc, with the balance substantially all aluminum and minor impurities.

3. An aluminum base alloy having a relatively low coefficient of thermal expansion, relatively great wear resistance and relatively high thermal conductivity, containing 18% to 35% silicon, about .1% to 1% magnesium, about 1% to 5% copper, about .4% to 2% iron, about .3% to 3% zinc, about .1% to 3% tin, and one or more hardeners and grain refiners, with the balance substantially all aluminum and minor impurities.

4. An aluminum base alloy having a relatively low coefficient of thermal expansion, relatively great wear resistance and relatively high thermal conductivity, containing 20% to 30% silicon, about .1% to 1% magnesium, about 1% to 5% copper, about .4% to 2% iron, about .3% to 3% zinc, about .1% to 3% tin, and one or more hardeners and grain refiners, with the balance substantially all aluminum and minor impurities.

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