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## FREE CUTTING ALLOYS

Louis W. Kempf and Walter A. Dean, Cleveland, Ohio, assignors to Aluminum Company of America, Pittsburgh, Pa., a corporation of Pennsylvania

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3 Claims. (Cl. 75—1)

This invention relates to aluminum base alloys, and it is particularly concerned with alloys of this nature containing substantial amounts of silicon together with other elements such as copper, nickel, magnesium and the like. This application is a division of our copending application Serial No. 689,882, filed September 18, 1933. Alloys disclosed but not claimed herein are claimed in our above-mentioned application Serial No. 689,882 and our co-pending applications Serial Nos. 19,618, 19,619, 19,620, 19,621, and 19,622 filed May 3, 1935.

The development of internal combustion engines of increased efficiency has rendered desirable the use of aluminum base alloys because of their lightness, strength and thermal conductivity. The relatively large thermal expansion of aluminum has, however, been a handicap where there is considerable localized variation in temperature such as in parts closely associated with the combustion chamber. For this reason alloys have been developed which have a thermal expansion closely akin to that of cast iron, the material commonly used for cylinder blocks. A type of aluminum base alloy of this character is one wherein a substantial amount of silicon is used in conjunction with smaller quantities of other elements. While such alloys are well adapted to use in internal combustion engines, they nevertheless present a difficult problem in machining because of the trouble encountered in obtaining an evenly cut, smooth surface. This condition arises in part through the occurrence of hard particles of elementary silicon distributed throughout the alloy which appear to have segregated during cooling of the alloy from the molten state. These hard particles not only cause an excessive wear on the cutting tool edge but they are also likely to be loosened from the alloy surface during the machining operation and cause a scoring or galling of the machined surface which is quite objectionable in the finished article. A means of improving the machinability is, therefore, eminently desirable especially from the standpoint of economical production of the finished article and from the behavior of the part in service.

One of the objects of our invention is to diminish the irregularity in cut caused by the hard silicon particles in an alloy of the kind described in a simple, economical manner and to thereby obtain a smooth, uniformly cut, machined finish. Another object is to accomplish the foregoing end without substantial detriment to the physical properties of the alloy.

We have now discovered that the addition of lead, bismuth, cadmium and/or thallium greatly improves the machinability and appearance of an aluminum base alloy containing silicon, nickel, copper and magnesium in spite of any hard particles that may be present. An alloy of this type adapted to the manufacture of wrought or cast pistons is one which contains from about 7 to 15 per cent silicon, 0.5 to 7 per cent nickel, 0.3 to 4 per cent copper, and 0.2 to 3 per cent magnesium. The machining quality of such an alloy may be markedly improved by the addition of at least one of the class of elements lead, bismuth, cadmium and/or thallium in amounts of from about 0.1 to 6 per cent. For the purpose of our invention the aforesaid elements are substantially equivalent in alloys of the type herein described by reason of their similar effect upon the machining quality of said alloys.

Although lead, thallium, bismuth and/or cadmium may be added to an aluminum-silicon-nickel-magnesium-copper alloy in the proportion hereinabove disclosed, we prefer to use between about 1 and 4 per cent for many applications. We have further found that better results are often obtained by adding not less than about 1.5 per cent of cadmium or bismuth to the aforementioned class of alloys. For many purposes a base alloy is very satisfactory which contains from about 10 to 15 per cent of silicon, from about 2 to 5 per cent of nickel, from about 0.5 to 2 per cent of copper and from about 0.2 to 1 per cent of magnesium. Machining tests on alloys within this range containing additions of lead, thallium, bismuth and/or cadmium have shown a marked superiority over the same alloy without the added elements.

As a particular example of the improvement in machinability obtained through the application of our invention, the case of an alloy which is employed in making wrought pistons for aircraft motors may be cited. The design of such pistons requires that considerable machining be done to finish them for service. An alloy used for this purpose has a nominal composition of 12.5 per cent silicon, 0.8 per cent nickel, 1.15 per cent magnesium, and 0.8 per cent copper, the balance being aluminum. Pistons made from this alloy frequently have score marks on the machined surface where a particle of elementary silicon may have been drawn across the metal by the tool in the course of the machining operation. The variation in hardness of the surface, probably caused by the presence of elementary silicon, also tends to produce an irregular machined surface.

It is very difficult to obtain satisfactory machined surfaces on the above alloy on a commercial scale with ordinary cutting tools without a frequent resharpening. By the addition of about 3 per cent of lead to an alloy of the composition given above, it is possible to obtain a very smooth surface with an ordinary carbon steel cutting tool. The chips flow freely from the article being machined and are shorter and more breakable than when no lead is added to the alloy. There appears to be no undesirable chatter or vibration of the cutting tool which would be induced by a marked variation in hardness. A uniformly smooth cut is made by the tool, indicating that greater cutting speeds might be used if desired with a corresponding decrease in machining cost.

The elements lead, thallium, bismuth and cadmium are not only beneficial to the machining quality of the alloy when separately used, but they may often be more effectively employed in combination. It has been found that the simultaneous presence of two or more of the indicated elements frequently produces a degree of machinability not attained by the use of an equivalent amount of a single element. For example, an aluminum base alloy containing about 12.5 per cent of silicon, 0.8 per cent of nickel, 1.15 per cent of magnesium, 0.8 per cent of copper, and about 1 per cent each of lead and bismuth, balance substantially aluminum, machined more readily under test than the same alloy containing only 2 per cent of lead and no bismuth. Likewise a combination of 2 per cent each of lead and bismuth produced a better machining quality in the alloy than 4 per cent of lead alone. The total amount of the added elements here referred to should not exceed about 6 per cent, and preferably a maximum of 4 per cent total is adhered to in order to obtain the most advantageous combination of all the properties of the alloy.

The tensile properties of the alloy are not materially affected by the additions of lead, thallium, cadmium and bismuth in total amounts of less than about 4 per cent. If a greater quantity is used, there may be a slight decline in strength but the machinability is often better, which compensates in part for the decrease in another property. For certain applications such a compromise in properties may be desirable.

The lead, thallium, bismuth and/or cadmium are most conveniently added to the molten alloy in solid metallic form, since they melt at a temperature considerably below that of the aluminum and aluminum-silicon base alloys. If more than about 1.5 per cent of these elements is to be added to the alloy, the molten bath should be heated somewhat above the ordinary melting temperatures and vigorously stirred to assure a uniform mixture. The method of adding heavy, low melting point metals to aluminum or its alloys here referred to is more fully described in copending application Serial No. 689,885 now Patent No. 1,959,029, granted May 15, 1934. When cadmium is added to the alloy, however, the temperature should not exceed about 1400° F. to avoid volatilization of the metal.

The term "aluminum" used herein and in the appended claims embraces the usual impurities found in aluminum ingot of commercial grade, or picked up in the course of the usual handling operations incident to ordinary melting practice.

The alloys herein disclosed may be subjected to the usual thermal treatments familiar to those skilled in the art for the purpose of improving or altering their physical characteristics.

We claim:

1. An aluminum base alloy containing 7 to 15 per cent of silicon, from about 0.5 to 7 per cent of nickel, from about 0.3 to 4 per cent of copper, from about 0.2 to 3 per cent of magnesium, at least 0.1 per cent of lead, at least 0.1 per cent of cadmium and at least 0.1 per cent of bismuth, the total amount of lead, cadmium and bismuth being not over 6 per cent, the balance being aluminum.

2. An aluminum base alloy containing 7 to 15 per cent of silicon, from about 0.5 to 7 per cent of nickel, from about 0.3 to 4 per cent of copper, from about 0.2 to 3 per cent of magnesium, at least 0.1 per cent of lead, at least 0.1 per cent of cadmium, and at least 0.1 per cent of bismuth, the total amount of lead, cadmium and bismuth being not over 1 to 4 per cent, the balance being aluminum.

3. An aluminum base alloy containing from about 10 to 15 per cent of silicon, from about 2 to 5 per cent of nickel, from about 0.5 to 2 per cent of copper, from about 0.2 to 1 percent of magnesium, at least 0.1 per cent of lead, at least 0.1 per cent of cadmium, and at least 0.1 per cent of bismuth, the total amount of lead, cadmium and bismuth being not over 6 per cent, the balance being aluminum.

LOUIS W. KEMPF.
WALTER A. DEAN.