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ALUMINUM ALLOYS

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4 Claims. (Cl. 75—146)

This invention relates to alloys, and particularly to aluminum base alloys having high strength at ordinary and elevated temperatures, and being suitable for casting and working.

It is an object of this invention to produce alloys having high elongation and relatively high tensile strength.

It is a further object of this invention to provide a relatively light alloy which may be easily cast and machined, which may be used at elevated temperatures without a rapid deterioration in the desired properties, and which may be readily treated with anodic treatment to give excellent lustre and finish.

It is a still further object of this invention to provide an alloy having a high proportional limit and high fatigue strength, and in which these properties are further enhanced by heat treatment.

It has been found that an aluminum alloy having a relatively small amount of silicon, and having zinc and magnesium present in proper proportions, will produce an alloy that may be readily cast and have improved physical properties for use, both at ordinary and elevated temperatures, and which may have these properties improved by heat treatment.

When magnesium and zinc are added to aluminum in the proper proportions a ternary compound of aluminum, magnesium and zinc is formed, which compound is soluble in solid solution in the aluminum. The presence of this compound in relatively small amounts greatly improves the characteristics of aluminum. With aluminum it produces an alloy having high strength combined with high ductility, good forging properties, good color, and excellent corrosion resistance. In calculating the amount of magnesium and zinc that should be present in the aluminum alloy to form the desired percentage of ternary compound, only magnesium which is not combined with silicon is to be calculated, as it is only such magnesium that is available to combine with zinc and aluminum to form the ternary compound. Since commercial aluminums always contain silicon, and since the amount of silicon varies considerably in such aluminums, it is necessary to determine the quantity of silicon in the aluminum used in order to provide the correct percentage of magnesium for the alloys of the present invention.

The ternary compound is said by some investigators to have a composition having substantially the formula $Al_3Mg_7Zn_6$, and other investigators have considered the formula for the ternary compound as being $Al_2Mg_3Zn_3$. For the purposes of the improved alloy it does not seem to make any substantial difference whether the magnesium and zinc are added to form a ternary compound calculated according to one formula or the other. The amounts of magnesium and zinc relative to each other are quite similar in both formulas.

An excess of zinc over and above that which cooperates with magnesium and aluminum to form a ternary compound increases the brittleness and decreases the ductility of the alloy. For this reason it is undesirable that zinc be present in quantities substantially greater than the amount sufficient to react to form such a ternary compound with magnesium and aluminum. The most desirable properties are obtained with the magnesium present in slight excess, and, when the zinc becomes excessive, the ultimate strength and proportional limit tend to decline.

Magnesium adds to the hardness and machining qualities of the alloy and should be present in an amount sufficient to combine with the available silicon, to form the ternary compound with the zinc and aluminum present, and preferably to provide an excess of magnesium less than 1%, such as .2% to .5%, and preferably about .3% or .4%, in addition to that necessary to combine with silicon and to form the ternary compound. An excess of magnesium is desirable to replenish losses that may occur when the alloy metal is remelted. In greater quantities, magnesium tends to make the alloy sluggish, decreasing castability.

Magnesium and zinc have heretofore been added to aluminum in the proportion represented by about the formula $MgZn_2$. It has been found, however, that a given percentage of ternary compound is more effective in producing desirable properties and, because the zinc content of the ternary alloys is less, they are much less dense than those heretofore produced.

Improved aluminum alloys may have the ternary compound of Al, Zn, and Mg present in an amount ranging from about 2% to 20%, the preferred range being between about 3% and 15%. At room temperature the ternary compound goes into solid solution in aluminum alloys in an amount of about 2%. The percentage in solid solution increases at high temperatures and decreases upon cooling, the excess precipitating out. Aluminum alloys containing the ternary compound may, therefore, be advantageously heat treated to improve their properties.

A small amount of silicon is usually present in

the aluminum alloys, and its presence in small quantities is not objectionable in the improved alloys. If the silicon be present in an amount of .7% or less, sufficient magnesium is added to the alloy to combine with the silicon to form Mg_2Si, which compound is more stable than the ternary compound above mentioned, and may be maintained in solid solution in aluminum alloys in an amount up to about 1.85%, which is the quantity of Mg_2Si present if the silicon is present in an amount of about .7%.

If the alloy is desired particularly for casting purposes, more silicon, such as up to about 1.5%, may be present. If, however, a somewhat larger amount of silicon is present in the alloy than is desirable for the purpose for which the alloy is intended, and such amount of silicon is not excessive, then a small amount of calcium may be added. Calcium has a stronger affinity for silicon than magnesium, and, therefore, can be used to reduce the amount of silicon for combination with magnesium. It is not desirable, however, to have a substantial amount of silicide present because in amounts of approximately 3% or so it acts as a hardener and tends to make the alloy sluggish. It is, therefore, desirable that the silicon content be below 1.5%, even when calcium is present.

While 2 or 3% of the ternary compound of aluminum, magnesium and zinc improves the properties of aluminum or aluminum alloys having low silicon content, alloys containing such low percentages of a ternary compound are relatively difficult to cast.

A casting allow that may be cast in metal molds to make average shaped castings should contain about 6% or more of the ternary compound. As the percentage of the ternary compound is increased in the alloy, the metal casts more easily and increased hardness is obtained. For alloys to be forged or shaped, the ternary compound should be present in smaller percentages, such as 2% to 8% or 10%, while, for alloys which may be readily cast into average or intricate shapes, the ternary compound should be present in an amount of from 8% to 15% or even 20%, although castings may be made in less intricate shapes with the ternary compound present in an amount of 4% or higher.

A larger proportion of the ternary compound may be present in alloys which are to be given a so-called "solution treatment" than in alloys to be given only an aging treatment or those to be quenched from the casting mold and aged at relatively low temperatures. Thus, the desirable properties of the solution heat treated alloys may be obtained when they contain the ternary compound in amounts up to 20% or so, whereas less of the ternary compound, such as 4% to 15%, is preferred in alloys which are quenched upon removal from the mold and heat treated at a low temperature.

The presence of the ternary compound of aluminum, magnesium, and zinc, is quite advantageous in producing aluminum base alloys having relatively high tensile strength, relatively high proportional limit, and relatively high fatigue, and relatively high elongation even at somewhat elevated temperatures, and which alloys may have their properties further improved by heat treatment. As hereinbefore explained, the ternary compound is particularly of advantage in aluminum base alloys having a relatively low silicon content.

Aluminum base alloys containing copper, and having relatively low silicon content, may be improved by the addition of magnesium and zinc.

The addition of magnesium and zinc to aluminum alloys containing 2% to 6% copper is desirable if the magnesium and zinc are added in an amount to form the ternary compound with a portion of the aluminum of the alloy, so that such ternary compound is present in an amount from 2% to 12%. Such alloys of aluminum and copper containing the ternary compound of aluminum, magnesium and zinc have a relatively higher tensile strength, relatively high elongation, and the properties of the alloy may be considerably improved by heat treatment.

While the alloys described herein comprise essentially aluminum, magnesium, and zinc, or these elements with copper, other elements, such as nickel, iron, manganese, and the like, may be present, but, if so, should only be present in minor quantities. These other elements may be present as impurities, as is frequently the case with alloys prepared from secondary aluminum. It is undesirable, however, that the alloys contain substantial quantities of the elements just mentioned, as they tend to impair the desirable characteristics of the aluminum, magnesium and zinc alloys set forth herein.

The following examples are illustrative of the improved alloys:

Example 1

An alloy containing 4% of the ternary, calculated on the basis of the formula $Al_3Mg_7Zn_6$, when chill cast and aged for three days at room temperature, had a tensile strength of 25,250 lbs./sq.in., an elongation of 16%, and a Brinell hardness of 49. When this alloy was annealed 7½ hours at 940° F., quenched and aged 15 hours at 350° F., its tensile strength and elongation was 27,900 lbs./sq. in. and 7.8%, respectively, and the hardness was 68.

Example 2

An aluminum alloy containing 5.5% of the ternary, when chill cast and aged at room temperature, as in the above Example 1, had a tensile strength of 31,200 lbs./sq. in., an elongation of 8%, and a Brinell hardness of 68. After the annealing treatment at 940° F., quenching in hot water, and aging at room temperature, as in the above Example 1, its tensile strength and elongation were 36,000 lbs./sq. in. and 5%, respectively, and the hardness 79.

Example 3

An aluminum alloy containing 7.8% ternary when chill cast and aged three days at room temperature, had a tensile strength of 32,400 lbs./sq. in., an elongation of 3%, and a Brinell hardness of 87. After aging for 15 hours at 350° F., the tensile strength and elongation were 38,500 lbs./sq. in. and 1.5%, respectively. After annealing for 7½ hours at 940° F., quenching, and aging for 15 hours at 350° F., the tensile strength and elongation were 44,100 lbs./sq. in. and 1.1%, respectively, and the hardness 109.

Example 4

An alloy containing about 15% of the ternary compound had a tensile strength of 28,600 lb./sq. in., an elongation of .38%, and a Brinell hardness of about 110. This alloy is relatively white, having a silvery color which is retained for a relatively long time. With slightly more ternary compound, such as about 17% or so, the tensile strength remains about the same, and the

hardness increases somewhat up to about 119 Brinell or so.

The improvement of aluminum-copper alloys by the use of the ternary compound of aluminum, magnesium and zinc is shown in the following example: A number of samples of each of the alloys A, B and C were chill cast, quenched in hot water, and aged three hours at 212° F. Tests were then made to determine the elongation, tensile strength and hardness of these samples, and the figures given below give the range of results obtained from these tests:

Example 5

	Elongation	Tensile strength	Hardness (Brinell)
	Percent		
Alloy A	4½–6	20,300–23,000	41–51
Alloy B	5½–8	26,500–28,700	55–64
Alloy C	4–6	26,500–30,700	60–70

In the above example, alloy A comprised aluminum with 5% copper; alloy B comprised aluminum with 6% of the ternary aluminum-magnesium-zinc compound disclosed herein; and alloy C comprised a mixture of 50% of each of alloys A and B, the resulting alloy therefore containing approximately 2.5% copper and about 3% of the ternary compound in addition to the aluminum.

From the above example it will be seen that the aluminum alloy containing both copper and the ternary compound has substantially the same elongation as the aluminum alloy containing 5% copper, but it has considerably greater hardness and a higher tensile strength than alloys A and B.

An increase in strength and a decrease in elongation are ordinarily obtained with increased quantities of the ternary compound. The alloys of Examples 2 and 3, in particular, with very high strength combined with high ductility, are especially suitable for the production of products requiring forging or rolling operations. The strength of the metal may be materially improved by aging or heat treating.

The percentages of zinc and magnesium in the ternary compound are almost the same, regardless of which of the above mentioned formulae are considered as the basis for the computation. Thus, in each percentage of the ternary, on the basis of $Mg_7Zn_6Al_3$, there is .264% of magnesium, and about .6% of zinc, and on the basis of the formula $Mg_3Zn_3Al_2$ there is .22% of magnesium and about .6% of zinc.

If the alloy contains uncombined silicon, about .174% of magnesium is required to combine with each .1% of uncombined silicon to form magnesium silicide, Mg_2Si, before any ternary compound will be formed. For example, if 2% of the ternary compound on the basis of $Mg_3Zn_3Al_2$ be desired in an alloy having .3% silicon, the amount of magnesium to be added to form the ternary compound will be about .45%, and the magnesium to combine with .3% silicon will be .52%, making a total of about .97%.

As stated above, it is preferable to allow a small excess of magnesium, such as 1%, and preferably .5% or even less, to insure the presence of sufficient magnesium to form a ternary when the alloy is remelted or used under conditions where magnesium may be lost. With an allowance of .5% of magnesium, the total magnesium and zinc to provide for 2% of ternary $Mg_3Zn_3Al_2$ in an alloy having .3% of free silicon would be about 1.47% magnesium and 1.2% zinc. Similarly, with such an allowance the magnesium and zinc for an alloy containing .7% free silicon and 20% of $Mg_7Zn_6Al_3$ would be 6.9% and 12%, respectively.

Therefore, the limits for magnesium set forth in the specification and claims provide for an excess of magnesium over that to combine with the silicon and that to form the ternary compound of aluminum, magnesium and zinc.

The alloys prepared according to this invention have good fatigue and tensile strengths and a relatively high proportional limit, even at relatively high temperatures; they may be heat treated to improve and modify their properties; and they have sufficient ductility and hardness so that they can be used as structural shapes, castings, machine parts, etc. These alloys have a desirable color, high corrosion resistance, and may be anodically finished or highly polished with excellent results, and are suitable for many uses, among them being the production of kitchen utensils or castings which are shaped or formed to some extent after casting. The alloys having the lower percentages of ternary compound may even be forged at room temperatures and are thus useful for many special purposes.

As previously set forth, the alloys mentioned herein may contain small amounts of other elements, and among these elements, as hereinbefore stated, is silicon, which combines with magnesium to form magnesium silicide. It is to be understood that, in considering the amount of zinc and magnesium to add to aluminum alloys to form the ternary compound of aluminum, magnesium and zinc in the alloy, such magnesium as is necessary to combine with the uncombined silicon is not to be considered as part of the magnesium necessary to form the specified amount of ternary compound.

It is to be understood that the particular compounds disclosed, and the procedure set forth, are presented for purposes of explanation and illustration, and that various equivalents can be used, and modifications of said procedure can be made, without departing from my invention as defined in the appended claims.

What I claim is:

1. An aluminum base alloy of high tensile strength and ductility containing magnesium, zinc, and the balance aluminum and minor impurities including a small amount of silicon not in excess of about 1%, the percentage of zinc in the alloy being about 1.2% to about 12%, and the percentage of magnesium in the alloy being to form magnesium silicide and to react with all that required to react with all of the free silicon of the zinc to form an aluminum-magnesium-zinc ternary compound, such percentage of magnesium being within the range of about .5% to about 7%.

2. An aluminum base alloy of high tensile strength and ductility containing magnesium, zinc, and the balance aluminum and minor impurities including a small amount of silicon not in excess of about 1%, the percentage of zinc in the alloy being about 2.4% to 7.2%, and the percentage of magnesium in the alloy being that required to react with all of the free silicon to form magnesium silicide and to react with all of the zinc to form an aluminum-magnesium-zinc ternary compound, such percentage of magnesium being within the range of about .9% to 5%.

3. An aluminum base alloy of high tensile strength and ductility containing magnesium,

zinc, and the balance aluminum and minor impurities including a small amount of silicon not in excess of about 1%, the percentage of zinc in the alloy being about 3.6% to 12%, and the percentage of magnesium in the alloy being that required to react with all of the free silicon to form magnesium silicide and to react with all of the zinc to form an aluminum-magnesium-zinc ternary compound, such percentage of magnesium being within the range of about 1.3% to about 7%.

4. An aluminum base alloy of high tensile strength and ductility containing magnesium, zinc, and the balance aluminum and minor impurities including a small amount of silicon not in excess of about 1%, the percentage of zinc in the alloy being about 3.6% to 9%, and the percentage of magnesium in the alloy being that required to react with all of the free silicon to form magnesium silicide and to react with all of the zinc to form an aluminum-magnesium-zinc ternary compound, such percentage of magnesium being within the range of about 1.3% to about 5.7%.

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CERTIFICATE OF CORRECTION.

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It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, second column, line 57, claim 1, strike out the words "that required to react with all of the free silicon" and insert the same after "being" in line 55, same claim; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 2nd day of September, A. D. 1941.

Henry Van Arsdale,
Acting Commissioner of Patents.

(Seal)