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ALUMINUM-MAGNESIUM ALLOYS

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This invention relates to an improvement in the heat treatment of aluminum-magnesium alloys.

Aluminum base alloys have found wide application in the form of structural material where lightness of weight is a paramount consideration and high strength of secondary importance. There has been an increasing demand, however, for stronger alloys which are also resistant to corrosive attack. Aluminum-magnesium alloys containing from about 5 to 15 per cent magnesium have been found to meet these requirements to an exceptional degree since they have unusually high yield and fatigue strengths combined with a remarkable corrosion resistance. While these properties commend the alloys for many purposes, considerable difficulty has been experienced in producing certain types of castings and fabricating wrought products. In particular, it was discovered that the molten alloys oxidized readily and that unsatisfactory castings were frequently obtained. This condition could be remedied, it was found, by the addition of a small amount of calcium to the molten metal prior to casting. The reduction in oxidation of the liquid metal, it was observed, also served to increase its fluidity, especially in the production of intricately shaped castings in permanent molds. The difficulties encountered in producing articles of the aforementioned alloys were thus believed to have been successfully solved by this improvement.

For many purposes these alloys in the as-cast or worked condition are entirely satisfactory with respect to strength. On the other hand, certain applications demand the highest possible strength consistent with the weight of the material. It was determined that the tensile and yield strength of cast or wrought aluminum-magnesium alloys could be substantially increased by subjecting them to an elevated temperature for a period of time followed by quenching or rapidly cooling the alloy to ordinary temperatures. The improvement is generally obtained by heating the alloy to a temperature within the range of about 250 to 450° C. for a period from a few minutes up to a number of hours depending on the nature of the article treated, and then rapidly cooling to a substantially lower temperature. It was soon observed, however, that those alloys which contained calcium did not respond as readily to heat treatment as those without this element. This effect of calcium was manifest in the lower strength values of these alloys as well as lower ductility. Attempts to diminish this deleterious effect of calcium through a reduction in the amount used only tended to decrease the beneficial influence of the element on the casting properties of the alloy. A satisfactory compromise between obtaining improved casting qualities and producing the maximum mechanical properties in the heat treated article could not be effected.

One of the principal objects of our invention is to produce better mechanical properties in heat treated aluminum-magnesium alloys that contain calcium. A further object is to obtain such favorable mechanical properties without disadvantageously affecting the casting qualities of the alloy. Another purpose of our invention is to obtain the foregoing improvement without materially changing existing foundry practices with respect to making and casting the alloy.

Our invention is based on the discovery that the presence of a small amount of tin and/or lead in aluminum-magnesium alloys containing calcium successfully counteracts the injurious effect of the last named element upon the heat treating qualities of said alloys. Only a very small proportion of counteractor is required to overcome the hurtful effect of calcium, in general, from about 0.01 to1.25 per cent of lead and/or tin is adequate to oppose the effect of from about 0.01 to 2 per cent of the alkaline earth metal. Alloys containing from about 5 to 15 per cent of magnesium are most frequently treated with calcium, but this element is effective in alloys containing either more or less than this amount of magnesium. The addition of lead and/or tin does not in any way diminish the beneficial influence of calcium on the casting characteristics of the alloys, they may be cast without difficulty in sand, permanent or ingot molds without excessive oxidation of the liquid metal where it comes in contact with the mold walls or the atmosphere. For the purpose of our invention the elements lead and tin constitute a class of substances which may be substituted one for the other, or used in combination, with substantially the same result. In event that both elements are employed, the total amount should not exceed about 1.25 per cent.

According to our observations on the internal structure of aluminum-magnesium alloys some change occurs with the addition of calcium which greatly hinders the diffusion of the magnesium throughout the aluminum matrix when the alloy is subjected to solution heat treatment. It is our belief that lead and tin posseses a greater affinity for calcium than calcium has for magnesium and aluminum. In consequence of this difference in

relative affinity, the lead and tin prevent the formation of any substance that interferes with the solution and diffusion of magnesium under the influence of heat. The degree of strength attained in a heat treated aluminum-magnesium alloy is determined by the extent to which the magnesium is dissolved, and hence any hindrance offered to the solution of the latter element tends to reduce the strength of the alloy. Whether the foregoing explanation of the behavior of lead and tin in respect to calcium is correct or not, the fact nevertheless remains that the addition of tin and/or lead to the herein disclosed alloys does improve their mechanical properties in the heat treated condition.

The benefit derived from the application of our invention may be more clearly shown through comparison of heat treated alloys with and without the addition of lead and tin. The alloys represented in Table I contain about 10 per cent magnesium and were cast in a sand mold. They were subsequently heat treated for 16 hours at 432° C. and quenched in water.

Table I

Percent of added elements			Tensile strength	Yield strength	Elongation percent in 2"
Ca	Pb	Sn	Lb. per sq. in.		
0.05	-----	-----	35,080	21,530	4.7
0.05	0.3	-----	48,670	23,440	17.2
0.05	0.5	-----	46,510	23,050	15.0
0.05	-----	0.3	46,540	21,870	15.7
0.05	-----	0.5	45,030	22,970	14.8

The improvement in the heat treating quality of the alloys containing lead and tin is at once apparent in the increased tensile strength and elongation values. The increase in elongation is a particularly desirable feature since many heat treated aluminum base alloys are less ductile and therefore more susceptible to fracture under impact. The test furthermore indicates that the presence of lead and tin not only serves to improve the mechanical properties of the alloys when heat treated under the same conditions as alloys not containing the calcium counteractors, but that if desired the period of heat treatment may be shortened and still permit obtaining the properties found in the heat treated alloy which does not contain lead and tin.

The beneficial effect of lead and tin is also evident in alloys containing a larger proportion of calcium. The alloys shown in Table II contain the same amount of magnesium as those listed in Table I, and they were also produced and heat treated under the same conditions, the chief difference between the two series being the calcium content.

Table II

Percent of added elements			Tensile strength	Yield strength	Elongation Percent in 2"
Ca	Pb	Sn	Lb. per sq. in.		
0.10	-----	-----	39,540	22,950	5.7
0.10	0.6	-----	48,240	22,180	16.2
0.10	-----	0.4	46,520	23,370	13.7

It will be observed that the presence of lead or tin counteracts the influence of calcium to about the same extent although a larger amount of calcium was employed. It is also better to use more lead or tin with an increase in the calcium content of the alloy.

While our invention is effective over the entire range of magnesium and calcium mentioned hereinabove we have found that the addition of lead and/or tin is particularly effective within the range of magnesium commonly used for commercial purposes, namely, from about 6 to 11 per cent. The calcium content of such alloys should be kept between about 0.01 and 0.5 per cent. Our preferred proportions of tin and lead lie between about 0.25 to 0.75 per cent for alloys within this range of magnesium and calcium. The amount of counteractor needed in a particular alloy may be readily determined by test, but in general, the amount varies with the calcium content, a large proportion of calcium requiring a correspondingly greater quantity of lead and/or tin than in alloys having a low calcium content.

Alloys made in accordance with our invention may be compounded in the manner commonly practiced in foundries. Only the ordinary precautions of preventing overheating, of thoroughly mixing the alloy, and of casting the metal at the proper temperature need be observed.

Aluminum of ordinary commercial purity is suitable for the manufacture of the herein described alloys. We have found, however, that better properties are obtained through use of aluminum containing less than 0.3 per cent impurities.

We claim:

1. A heat treatable aluminum base alloy containing from about 5 to 15 per cent of magnesium, 0.01 to 2 per cent of calcium and 0.01 to 1.25 per cent of at least one of the class of elements lead and tin, the balance being aluminum.

2. A heat treatable aluminum base alloy containing from about 6 to 11 per cent of magnesium, 0.01 to 0.5 per cent calcium, and 0.25 to 0.75 per cent of at least one of the class of elements lead and tin, the balance being aluminum.

3. A heat treatable aluminum base alloy consisting of from about 5 to 15 per cent of magnesium, 0.01 to 2 per cent of calcium, and 0.01 to 1.25 per cent of lead, the balance being aluminum.

4. A heat treatable aluminum base alloy consisting of from about 5 to 15 per cent of magnesium, 0.01 to 2 per cent of calcium, and 0.01 to 1.25 per cent of tin, the balance being aluminum.

5. A heat treatable aluminum base alloy consisting of from about 5 to 15 per cent of magnesium, 0.01 to 2 per cent of calcium, and a total of from about 0.01 to 1.25 per cent of both lead and tin, the balance being aluminum.

6. A heat treatable aluminum base alloy consisting of from about 10 per cent magnesium, 0.05 per cent calcium, and 0.3 per cent lead, the balance being aluminum.

7. A heat treatable aluminum base alloy consisting of from about 10 per cent magnesium, 0.05 per cent calcium, and 0.3 per cent tin, the balance being aluminum.

8. A heat treatable aluminum base alloy consisting of about 10 per cent magnesium, 0.1 per cent calcium, and 0.6 per cent lead, the balance being aluminum.

9. A heat treatable aluminum base alloy consisting of about 10 per cent magnesium, 0.1 per cent calcium, and 0.4 per cent tin, the balance being aluminum.

10. An aluminum-magnesium alloy containing from about 5 to about 15 per cent of magnesium, a small amount of calcium and from about 0.01

to 1.25 per cent of at least one of the elements lead and tin, said alloys being characterized by an increased susceptibility to solution of the magnesium constituent at temperatures between 250° and 450° centigrade, such susceptibility not having been hitherto encountered in similar alloys containing the magnesium and calcium but no lead or tin.

11. An aluminum base alloy containing from about 5 to 15 per cent magnesium, 0.01 to 2 per cent calcium, and 0.01 to 1.25 per cent of at least one of the elements lead and tin, said alloys being characterized by an increased susceptibility to solution of the magnesium constituent at temperatures between 250° and 450° centigrade, such susceptibility not having been hitherto encountered in similar alloys containing the magnesium and calcium but no lead or tin.

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