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ALUMINUM-MAGNESIUM ALLOYS

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This invention relates to aluminum-base magnesium alloys containing small amounts of manganese and to methods by which the properties of such alloys may be improved.

The light weight of the aluminum alloys has made them as a class very desirable materials for certain types of construction, especially in the aviation and automotive industries. Despite this obvious advantage of light weight, the aluminum-magnesium alloys containing more than about 5 per cent of magnesium have not been favorably regarded because of the well known difficulties encountered in attempting to cast or fabricate them. Moreover, it has been generally thought that such alloys do not possess physical properties of sufficient magnitude to justify their use as replacements for the excellent high strength aluminum alloys already in extensive commercial use. Recently, however, improvements in the alloys themselves and in methods of handling them, for example methods of casting and heat treating aluminum alloys containing between about 5 and 16 per cent and even up to about 20 per cent, of magnesium have greatly extended the field of utility of these alloys in both cast and fabricated form. With these improvements the alloys are comparable to other aluminum base alloys in physical properties, with the additional advantage of light weight.

The object of the present invention is to improve aluminum-magnesium alloys still further in the direction of the physical properties which largely affect their usefulness. Heretofore in the art it has been the belief that the addition of a third ingredient to a binary alloy may improve the alloy in one respect or another but that the addition in many cases impairs the alloy in some other respects. For example, the addition of small amounts of magnesium to binary alloys of aluminum and silicon increases the tensile strength but decreases the elongation. We have found, however, that the rule stated is not true for certain additions of manganese to aluminum-magnesium alloys, and that by the addition of small amounts of manganese an improvement can be obtained in some of the physical properties without material impairment of others.

The aluminum-magnesium alloys in which these results may be produced by the addition of manganese are those containing substantial amounts of magnesium, say between about 5 and 16 per cent, and in general it is within this range that the most useful alloys of this nature occur. Alloys containing from about 5 to 12 per cent have been found to possess the best properties under most conditions and alloys containing about 10 per cent of magnesium are particularly useful.

The amount of manganese which may be added to obtain the desired improvements varies over a comparatively narrow range. Our experience indicates that the addition of much more than 3 per cent has the effect of embrittling the alloys and making them difficult to cast. Below about 3 per cent the manganese produces a favorable increase in properties even when added in amounts as low as 0.1 per cent, but for the best results the preferred addition ranges from about 0.2 to 1.5 per cent. For example, a forging of an alloy containing 6 per cent of magnesium and 1.25 per cent of manganese, without heat-treatment, showed a tensile strength of about 56,000 pounds per square inch and a degree of ductility indicated by an elongation of about 23 per cent in two inches.

The alloys may be compounded in the molten state by well known alloying methods. For instance, the aluminum-magnesium alloy may be made by melting the aluminum and then adding the magnesium to the molten aluminum. The manganese may then be introduced by adding the proper amount of an aluminum-manganese alloy containing about 10 per cent of manganese.

Aluminum-magnesium alloys containing small amounts of manganese are amenable to fabricating processes, such as rolling, extrusion, forging and the like; and in all cases the addition of manganese definitely increases the physical properties of the alloy. Also in extruded form aluminum-magnesium alloys containing manganese possess combinations of physical properties seldom reached or excelled in other extruded aluminum alloys.

For example, the following table (No. 1) illustrates the results of the addition of manganese to aluminum base magnesium alloys when the alloy is fabricated in the form of extruded bars. In the examples given, allows A and B are in the "as extruded" state while C and D represent A and B respectively after a heat treatment of one hour at 425° C. followed by cooling to room temperature. Both alloys contained about 0.2 per cent of impurities, mostly silicon and iron.

Table No. 1

Alloy	Per cent of magnesium	Per cent of manganese	Yield point lbs. per sq. in.	Tensile strength lbs. per sq. in.	Elongation per cent in 2 inches	Brinell hardness
A	10	----------	28,260	56,900	24 to 30	98.1
B	10	0.5	30,840	65,220	31.7	101.2
C	10	----------	24,210	55,880	37.7	86.9
D	10	0.5	28,800	63,650	36	95.1

In Table No. 2 is illustrated the effect of adding increased amounts of manganese to those alloys. E, F and G represent the alloys in the as "extruded" condition, while H, I and J represent the same alloys extruded and heat treated for one hour at 425° C.

Table No. 2

Alloy	Per cent of magnesium	Per cent of manganese	Yield point lbs. per sq. in.	Tensile strength lbs. per sq. in.	Elongation per cent in 2 inches	Brinell hardness
E	10	0.5	30,840	65,220	31.7	101.2
F	10	1.0	32,825	61,300	6.7	112.2
G	10	1.5	38,100	63,325	4.5	123.7
H	10	0.5	28,800	63,650	36.0	95.1
I	10	1.0	33,305	69,450	27.2	99.4
J	10	1.5	33,715	67,810	15.5	105.2

The effects of varying amounts of magnesium and manganese are illustrated by Table No. 3 which presents alloys in the extruded condition which have been heat treated for one hour at about 425° C. and quenched.

Table No. 3

Alloy	Per cent of magnesium	Per cent of manganese	Yield point lbs. per sq. in.	Tensile strength lbs. per sq. in.	Elongation per cent in 2 inches	Brinell hardness
K	10	1.0	33,305	69,450	27.2	99.4
L	12	1.0	34,000	70,350	21.7	108.2
M	8.5	0.75	26,555	59,775	26.5	89.3

Heat-treatment of aluminum-magnesium alloys containing manganese is especially advantageous where ductility is desired, but in some cases extreme ductility is obtained at the expense of a small decrease of tensile strength and hardness. For example, in Table No. 2, alloy E as extruded has a tensile strength of 65,220 and an elongation of 31.7; whereas for the same alloy (designated H) heated for one hour at 425° C. and then quenched, the figures are 63,650 and 36.0 respectively, a loss of about 2 per cent in tensile strength and a gain of about 14 per cent in elongation. On the other hand, between alloys F and I, containing 1.0 per cent of manganese, the heat-treatment increased the tensile strength about 13 per cent and the elongation about 32 per cent.

Table No. 4 gives the physical properties found with 14 gauge sheet made from alloys containing 10 per cent of magnesium and no manganese, and 10 per cent of magnesium with 0.3 and 0.5 per cent of manganese. The values given were obtained with sheet which had been heat-treated for one-half hour at 425° C. and quenched in water.

Table No. 4

Per cent of magnesium	Per cent of manganese	Yield point, lbs. per sq. in.	Tensile strength, lbs. per sq. in.	Elongation per cent in 2 inches
10	----------	31,150	53,795	27.8
10	0.3	30,500	59,650	32.0
10	0.5	34,000	62,635	25.3

It will be seen that aluminum-magnesium alloys containing a substantial amount of magnesium and a small amount of manganese have physical properties equal to and in some cases exceeding those of any of the aluminum base alloys heretofore known and that this improvement is not confined to a single property. It is a feature of the invention that the addition of a relatively small amount of manganese does not materially lower any of the useful properties of the alloy, while in some cases all are improved. In speaking of ductility we are considering the property as indicated or measured by the conventional tests for elongation, that is to say, the percentage of elongation in two inches.

Another advantage of our alloys is found in their improved "forgeability" or capability of being shaped by forging. This improvement is well shown by decreased tendency to cracking in the flash, the cracking being in some cases entirely absent.

It is to be understood that the invention is not limited to the details specifically stated, since these may vary without departure from the invention as defined by the following claims.

We claim—

1. An aluminum-magnesium working alloy consisting of from 10 to 16 per cent magnesium, approximately, manganese from about 0.2 to 1.5 per cent, and the rest alumi-

num; the alloy having in extruded condition a tensile strength of at least about 50,000 pounds per square inch and a Brinell hardness of at least about 80.

2. An aluminum-magnesium working alloy consisting of magnesium about 10 per cent, manganese from about 0.2 to 1.5 per cent, and the rest aluminum; the alloy having in extruded condition a tensile strength of at least about 60,000 pounds per square inch and a Brinell hardness of at least about 90.

In testimony whereof we hereto affix our signatures.

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