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ALUMINUM-MAGNESIUM CASTING ALLOYS

Charles B. Willmore, Newark, Ohio, assignor to William F. Jobbins, Incorporated, Aurora, Ill., a corporation of Illinois

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This invention relates to aluminum alloys in which magnesium is a major alloying element and it relates more particularly to new and improved aluminum-magnesium alloys for use in casting.

Form a commercial standpoint, aluminum-magnesium casting alloys may be catalogued into two distinct groups. Casting alloys having a magnesium content ranging from 9 to 12 percent by weight are responsive to heat treatment for the development of improved physical properties. By heat treatment, the aluminum-magnesium intermetallic compounds are put into solid solution from which they are reprecipitated under room conditions in finely divided form as compared to the coarse crystals in which form they existed in the original casting. The major portion of the reprecipitation occurs within the first few days of aging so that improvement in physical properties are rather quickly developed.

In the group containing 1 to 9 percent magnesium, heat treatment has very little effect on the physical properties of the casting. Alloys within this lower range of magnesium content form the subject matter of this invention. The physical properties which are developed by the alloy from casting are generally referred to as the "as cast" properties. In the past, it has been possible further to subdivide this group containing lower magnesium content with respect to the method of casting; that is, the group may be divided into alloys suitable for casting in green sand, hereinafter referred to as sand casting, and it may be divided into alloys suitable for casting into permanent molds, hereinafter referred to as chill casting. The latter casting technique may relay entirely on gravitational force or positive pressures may be employed for filling the molds with the melt, as in die casting. The chief difference between sand casting and chill casting resides in the rate of heat transfer through the mold walls, it being greater in chill casting with the result that crystal formation and solidification occurs at a more rapid rate.

Chill casting usually has the effect of producing castings having smaller grain size. In aluminum-magnesium alloys, components, such as magnesium, present in quantities above their normal solid solubility limit at room temperature are retained in a metastable condition of solid solution instead of precipitating out as in the slower cooling inherent in sand casting methods. Ordinarily, these characteristics in a metal or alloy lead to improved physical properties, but the reverse effects are obtained with aluminum-magnesium alloys. No satisfactory explanation has been advanced for this opposed reaction in the behavior of aluminum-magnesium alloys whereby they fail to develop superior properties responsive to finer grain size and increased amounts of magnesium in solid solution. No one, to my knowledge, has been able to manufacture an aluminum-magnesium alloy adapted for chill casting which has physical properties that are as high or higher than those obtained by casting the same alloy in green sand.

It is an object of this invention to produce an aluminum-magnesium alloy which is not subject to the limitations and does not exhibit the undesirable expected reactions of prior art composition.

Another object is to produce an aluminum-magnesium alloy which can be used interchangeably for chill and sand casting without sacrificing any physical properties.

A further object is to produce an aluminum-magnesium casting alloy which has improved physical properties substantially equivalent to those secured by heat treatment of other types of heat treatable alloys.

A still further object is to produce an aluminum-magnesium casting alloy that has properties far superior to alloys heretofore secured by either sand casting or by heat treatment; that has excellent tensile strength and ductility without the necessity of heat treatment; that is highly resistant to corrosion and retains high luster; that has excellent machine properties; that acquires and retains a brilliant surface which can be developed by simply polishing; that develops high mechanical strength immediately upon cooling to room temperature, which strength properties are not subject to change with age as compared to the heat treated castings which ultimately become embrittled.

A still further object is to produce an aluminum alloy containing 1 to 9 percent magnesium as a major alloying element and small amounts of titanium, beryllium and manganese as minor alloying elements to provide for specific improvements in physical characteristics of the cast alloy whereby excellent combinations of tensile strength, yield strength and elongation are developed without the necessity of employing expensive heat treatment.

In accordance with this invention, a new and improved casting alloy which is capable of markedly improved physical properties in "as cast" condition is composed primarily of magnesium as the major alloying element with aluminum and titanium, beryllium and manganese as minor alloying elements.

As previously pointed out, invention herein is directed to aluminum-magnesium type alloys in which the range of magnesium is limited to between 1 to 9 percent by weight and particularly to between 3 to 9 percent by weight. Optimum results are secured when the magnesium content in the alloy is within the range of 6.0 to 8.5 percent by weight. In the past, the best aluminum base alloys having 6.0 to 8.5 per cent by weight magnesium were characterized by a tensile strength of about 32,000 pounds per square inch and elongation of about 10 per cent per inch.

In the practice of this invention, I have been able to produce an alloy which averages a tensile strength in excess of 42,000 pounds per square inch and more than 16 per cent elongation. The properties secured by this practice is the more important because it provides alloys having physical properties in the "as cast" condition which are comparable to heat treatable alloys having 9 to 12 per cent magnesium.

Titanium in amounts ranging from 0.01 to 0.40 percent by weight may be used, but it is best to maintain the titanium content to within the range of 0.10 to 0.25 percent by weight. When more than 0.25 percent by weight titanium is employed, complete solution is difficult to maintain and precipitation of titanium occurs as the alloy passes through its freezing range. The metallic and the intermetallic compounds that are formed have a tendency to make the melt more sluggish and excesses of titanium are found to be undesirable when the alloy is used for some types of casting. However, as much as 0.40 percent titanium may be used.

The beryllium content varies in accordance with the type of casting. For sand casting, it is best to hold the beryllium content within the range of 0.0005 to 0.03 per-

cent by weight and for chill casting the beryllium content is best if maintained within the range of 0.0005 to 0.20 per cent by weight. The additional benefit secured by the use of beryllium in amounts in excess of 0.07 percent does not warrant the additional cost. For chill casting, best results are secured when the amount of beryllium is above 0.001 per cent by weight.

I have found that metallurgical data with respect to the effects of metal additions to aluminum alloys for the purpose of improving strength and hardness does not usually hold true for aluminum-magnesium alloys and particularly for aluminum-magnesium alloys in which titanium and beryllium constitute alloying elements. For example, it has been suggested that copper, iron, silicon, zinc or zirconium have the properties of increasing hardness and strength of aluminum metal and its alloys, yet I have found that these same metals, when used in quantities which might be expected to improve yield strength, are highly detrimental when the alloy is composed of aluminum, magnesium, beryllium, and titanium.

Of the metals alloyed with aluminum, magnesium, beryllium, and titanium I have found that manganese has a very desirable effect in increasing yield strength without reducing tensile strength or elongation which is the usual reaction in most alloys.

In the practice of this invention, the desirable results are secured when manganese is present in the alloy in amounts ranging from 0.001 to 1.2 percent by weight. For sand casting best results are secured when manganese is present within the range of 0.05 to 0.30 percent by weight while for chill casting the most suitable range is within 0.20 to 0.60 percent by weight.

The following is an example of a sand cast alloy formulated of components without manganese as compared to the physical properties of an alloy embodying the same elements prepared under substantially the same conditions with the addition of manganese in accordance with the practice of this invention:

Magnesium	6.5 percent	6.5.
Beryllium	0.01 percent	0.01.
Titanium	0.20 percent	0.20.
Manganese	0.00 percent	0.20.
Aluminum	Balance	Balance.

Properties

Ultimate strength in lbs./sq. in	39,000	38,700
Yield strength in lbs./sq. in	17,400	19,300

By comparison, it will be evident that the addition of manganese as a minor alloying element in combination with titanium and beryllium and the major alloying element of magnesium with aluminum provides for a vast improvement in yield strength. It will be evident that a new high in strength properties is secured in an aluminum-magnesium casting alloy, properties which greatly exceed values considered possible for such alloys in "as cast" condition. As a result, many new and very important uses have been found for such material.

One of the most important advancements made by this alloy resides in the development of a new group of aluminum-magnesium casting alloys which can be used interchangeably with substantially equal success for both green sand casting and for chill and die casting. This is unusual in aluminum-magnesium alloys because of the vast differences that exist in their rate of crystallization and freezing whereby finer grain size and retention of greater proportions of metals in solid solutions are characteristic of chill casting. Before, it was necessary to formulate separately for each type of casting with the result that it was difficult for one industry to engage in various casting techniques.

The following is an example showing improvement in all physical properties in a chill cast alloy embodying features of this invention:

Magnesium	6.5	6.5	6.5
Beryllium	0.10	0.10	0.10
Titanium	0.00	0.00	0.20
Manganese	0.00	0.20	0.20
Aluminum (plus impurities)	Rest	Rest	Rest
Ultimate strength, Lbs./sq. in	28,600	38,400	40,100
Yield Strength, Lbs./sq. in	17,600	18,800	19,500
Elongation, percent	5.2	11.8	11.8

Boron may be included to advantage as a minor alloying element in the preparation of alloys embodying features of this invention. When present, the amount of boron should not exceed 0.01 percent by weight because greater amounts seem to precipitate out as intermetallic compounds. Although greater proportions of boron may be used, the properties of the alloy are sometimes harmfully affected.

Alloys used in chill casting, especially when formed in molds heated to 600° to 900° F., have been found better in many respects than those secured by the most favorable alloys in sand casting. In production, the alloy may be compounded by the addition of metallic components to molten aluminum maintained at least 100° above melting temperature. To the molten aluminum, the other elements may be added in desired amounts in a form which is relatively free of harmful impurities. With some of the elements it is best to alloy with pure metals or master alloys of aluminum, while with other, additions may best be made through the addition of reducible inorganic salts such as halides from which the metal is made available and from which gases are released for sweeping impurities out of the molten alloy. For example, beryllium can be incorporated to best advantage as a master alloy with aluminum while titanium is added to greatest advantage as the inorganic salts. When added in this manner greater amounts of titanium can be incorporated since titanium so produced remains in solution.

For best results the total impurities which includes metals of the type copper, iron and silicon should be held below 0.45 percent by weight with 0.25 percent by weight being the maximum for any one of the aforementioned metals. Since alkali metals, especially sodium, are highly deleterious to the physical properties of the alloy, inclusion of more than 0.001 percent by weight thereof should be avoided.

It will be understood that numerous changes may be made in the amounts of materials, their methods of incorporation in the alloy and its fabrication into a cast product without departing from the spirit of the invention especially as defined in the following claims.

I claim:

1. An aluminum base casting alloy consisting of 3 to 9 percent by weight magnesium, 0.0005 to 0.07 percent by weight beryllium, 0.1 to 0.25 percent by weight titanium and 0.05 to 0.60 percent by weight manganese, the balance being aluminum, said alloy containing not over 0.45 percent by weight impurities including a maximum of 0.25 percent by weight of an element selected from the group consisting of copper, silicon and iron and not over 0.001 percent by weight of an alkali metal.

2. An aluminum base alloy for sand casting consisting of 3 to 9 percent by weight magnesium, 0.0005 to 0.03 per cent by weight beryllium, 0.10 to 0.25 percent by weight titanium, 0.05 to 0.30 percent by weight manganese, the balance being aluminum said alloy containing a maximum of 0.45 percent by weight impurities including a maximum of 0.25 percent by weight of an element selected from the group consisting of copper, silicon and iron.

(References on following page)

References Cited in the file of this patent

UNITED STATES PATENTS

2,079,786	Beck	May 11, 1937
2,336,512	Stroup	Dec. 14, 1943
2,564,044	Willmore	Aug. 14, 1951
2,583,473	Cooper	Jan. 22, 1952

FOREIGN PATENTS

154,875	Switzerland	Aug. 1, 1932

636,414	Great Britain	Apr. 26, 1950

OTHER REFERENCES

"Foundry Trade Journal," Nov. 17, 1938, pages 373 and 374.

"Material and Methods," June 1950, pages 61 and 62.