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ALLOY

Roy E. Paine, Cleveland, Ohio, assignor, by mesne assignments, to Magnesium Development Company, a corporation of Delaware

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The invention relates to magnesium-base alloys and is directed to the development of alloys of this class which have good corrosion resistance, particularly in the cast and in the cast and heat treated condition.

The art of casting magnesium presents many practical difficulties which must be surmounted before the true commercial possibilities of magnesium castings can be fully realized. An alloy which is suitable for one application may be entirely unsuited to another and, as a consequence, it is frequently necessary to sacrifice desirable characteristics of the alloy in order to more fully realize the advantages of some one or more important characteristics. Thus a compromise must quite frequently be made in order to approach in one alloy the optimum properties for a given application. For example, it may be found that corrosion resistance can be sacrificed to a certain extent to obtain higher tensile strength, yield point, hardness, or similar mechanical properties. Again, tensile strength may be sacrificed in order to obtain proper casting or working characteristics. It is an object of the present invention to develop magnesium alloys which will combine to a maximum degree the characteristics of corrosion resistance, favorable mechanical properties, workability, susceptibility to improvement by heat treatment and adaptability to sand casting.

A further object is the provision of magnesium alloys characterized by their susceptibility to be improved in mechanical properties by suitable thermal treatments. A further object is the provision of magnesium-base alloys characterized by good corrosion resistance in either the cast or in the cast and heat treated condition. A further object is the provision of magnesium alloys possessing excellent casting characteristics. A further object is the provision of magnesium-base alloys susceptible, within certain ranges, to mechanical deformation.

I have discovered that magnesium-base alloys containing from 0.5 per cent to 22 per cent of lead possess to an appreciable degree the collective characteristics of alloys which are resistant to corrosion, alloys which may be readily cast, alloys which are susceptible to alteration of properties by thermal treatments, alloys having favorable mechanical properties, and alloys which, within a restricted range, may be worked by extrusion, forging, or other means of mechanical deformation.

In accordance with my invention lead may be present in amounts as low as 0.5 per cent. The preferred casting alloys are those containing above about 5 per cent of lead since it is in these alloys that the most pronounced combination of these different properties is obtained. The alloy may be worked by extrusion over a range of from about 0.5 per cent to about 22.0 per cent of lead. As an all around casting alloy I have found a magnesium alloy containing 5 to 10 per cent of lead to be particularly adapted to general foundry purposes. Alloys falling within this preferred range of composition as well as other alloys comprised within the broader limits previously defined, have been subjected to severe tests designed to produce accelerated corrosion. Sand cast test bars poured in accordance with the best casting practice in the art were subjected to corrosion tests in the as cast and in the heat treated condition. In the example referred to the heat treatment was carried out at about 459° centigrade for about 20 hours followed by quenching in water, and both heat treated and unheat treated test bars were subjected to that corrosion test which comprises alternately immersing the metal in, and removing it from, a 3 per cent sodium chloride solution for about 80 hours, a treatment referred to hereinafter as the alternate immersion treatment.

There are certain elements which may be added to the binary magnesium-lead alloys to particular advantage. Such, for instance, are the metals calcium, cadmium and zinc. These may be added singly or in combination with each other, the zinc in amounts between about 1.0 per cent and 10.0 per cent, the calcium between about 0.1 per cent and 2.0 per cent, and the cadmium between about 1.0 per cent and 10.0 per cent. These alloying elements are substantial equivalents as indicated by their susceptibility to thermal treatment in magnesium-lead alloys. The calcium favorably affects the casting properties of the alloy without markedly decreasing its corrosion resistance. For instance, a magnesium alloy containing 21.4 per cent of lead and 0.25 per cent of calcium shows, in the as cast condition, a strength loss of only 17 per cent after alternate immersion in a 3 per cent sodium chloride solution for about 80 hours, while a heat treated magnesium alloy containing about 5 per cent of lead to which about 0.25 per cent of calcium had been added did not undergo any appreciable loss in strength under the foregoing corrosion conditions; the heat treatment in this case was a treatment at about 450° centigrade for about 20 hours. An alloy of magnesium with about 5.1 per cent of lead and 10.0 per cent of cadmium had in the sand cast condition a tensile strength of about

24,650 pounds per square inch and an elongation of about 9.8 per cent in 2 inches. After a heat treatment of about 20 hours at about 450° centigrade its tensile strength had increased to about 25,140 pounds per square inch and its elongation to 10.3 per cent in 2 inches. After an alternate immersion corrosion test for 80 hours the loss in strength was only 30 per cent. A similar result was obtained with a magnesium-base alloy containing about 5.3 per cent of lead and about 5.0 per cent of cadmium. An alloy of magnesium with about 5.0 per cent of lead and 5.0 per cent of zinc had in the sand cast condition a tensile strength of about 23,370 pounds per square inch. After a thermal treatment of about 20 hours at 450° centigrade followed by an aging treatment of about 20 hours at 150° centigrade its strength had increased to about 25,710 pounds per square inch. After an alternate immersion corrosion test of 80 hours the loss in strength was only 12 per cent. Another alloy of magnesium with about 5.2 per cent of lead and 3.2 per cent of zinc under similar conditions lost only about 10 per cent after 80 hours alternate immersion in the corrosive solution. As a preferred composition for alloys of this nature I advise (1) 5.0 per cent lead, 1.0 per cent calcium; balance magnesium; (2) 5.0 per cent lead, 5.0 per cent cadmium, balance magnesium (3) 5.0 per cent lead, 5.0 per cent zinc, balance magnesium. If more than one of the elements calcium, cadmium, or zinc be present simultaneously, I prefer not to exceed a total of 10.0 per cent for these elements.

One of the disadvantages of the alloys described herein which may affect their use in certain applications, particularly where high strength is a leading or very material consideration, is the fact that the grain structure of these alloys (with or without calcium) tends to be coarse. I have found that the metals aluminum and silicon form a class of alloying elements which may be added to magnesium-lead alloys and are substantially equivalent in this respect that they materially refine the grain structure of the alloy. Aluminum, for instance, can be added over a wide range, such as between 1.0 and 15.0 per cent; silicon may be effectively present for this purpose in amounts of about 0.1 to 2.0 per cent. When used in combination it is advisable that the total content of aluminum and silicon does not exceed 15.0 per cent. In the preferred practice of my invention I have found that the best results are usually obtained when the aluminum is present in amounts between 5 and 10 per cent.

As a prefered magnesium-lead-silicon composition I use a magnesium-base alloy containing 7.0 per cent of lead and 0.5 per cent of silicon. As a preferred magnesium-lead-aluminum alloy I use a magnesium-base alloy containing 7.0 per cent of lead and 5.0 per cent of aluminum. When the aluminum and silicon are used in conjunction I prefer to use a total of about 5.0 per cent of aluminum and silicon combined, for instance about 4.0 per cent aluminum and 1.0 per cent silicon.

Manganese alone may be added to magnesium-lead alloys in amounts between 0.1 per cent and 1.0 per cent and has a stabilizing effect upon the alloy properties in that it raises the hardness slightly, does not materially decrease the corrosion resistance, and adds to the matrix of the alloy a hardening element which expresses itself not only in an increase in tensile strength but also in surface hardness. An alloy of this nature containing about 8.0 per cent of lead and 0.85 per cent of manganese lost only 6 per cent of its original strength after 80 hours alternate immersion in a 3 per cent aqueous solution of sodium chloride and in the solution heat treated condition lost only 7 per cent of its strength in the alternate immersion treatment. A magnesium alloy containing about 10.37 per cent of lead had lost only about 10 per cent of its strength at the expiration of this period as compared with certain other commercial alloys, such as, for instance, the well known magnesium alloy containing about 7 per cent of aluminum and 0.4 per cent of manganese which, at the end of 40 hours of alternate immersion, had lost about 60 per cent of its strength.

Very favorable alloys can be compounded by using as a base an alloy magnesium, lead and aluminum and making additions thereto of at least one of the class of metals tin, manganese or zinc. The lead can be used in amounts from about 0.5 per cent to about 22.0 per cent, the aluminum from about 1.0 per cent to about 15.0 per cent, the tin from about 1.0 per cent to about 15.0 per cent, the manganese from about 0.1 per cent to about 1.0 per cent, and the zinc from about 1.0 per cent to about 10.0 per cent. A sand cast alloy within this range had, in the as cast condition, a tensile strength of 27,500 pounds per square inch and an elongation of 5.7 per cent in 2 inches. After a thermal treatment of 16 hours at 315° centigrade, the alloy had a tensile strength of 29,640 pounds per square inch and an elongation of 6.0 per cent in 2 inches. Some of the heat treated specimens were then given an alternate immersion treatment for 40 hours and after the treatment the specimens had a tensile strength of 28,413 pounds per square inch and an elongation of 5.8 per cent in 2 inches. This alloy containing 5.0 per cent of aluminum, 5.0 per cent of lead, 0.4 per cent of manganese and 2.0 per cent of zinc. The loss in strength on the corrosion treatment is observed to be less than 5 per cent as compared to about 60 per cent with the commercial magnesium-aluminum-manganese alloy disclosed hereinbefore which contains about 7 percent of aluminum and 0.4 per cent of manganese. As preferred compositions for alloys of this nature I advise (1) 7.0 per cent of lead, 7.0 per cent of aluminum, 2.0 per cent tin, balance magnesium; (2) 7.0 per cent lead, 7.0 per cent aluminum, 2.0 per cent tin, 0.5 per cent manganese, balance magnesium; (3) 7.0 per cent lead, 7.0 per cent aluminum, 2.0 per cent tin, 2.0 per cent zinc, balance magnesium.

Two alloy compositions within this range which I have used to advantage are as follows: A magnesium-base alloy containing 8.0 per cent of aluminum, 3.0 per cent of lead, 0.4 per cent of manganese, 1.0 per cent of zinc, and 3.0 per cent of tin; a magnesium-base alloy containing 8.0 per cent of aluminum, 1.0 per cent of lead, 0.4 per cent of manganese, 1.0 per cent of zinc, and 1.0 per cent of tin.

The addition of lead to the magnesium-aluminum-manganese alloys increases very considerably the corrosion resistance of these alloys, since with the addition of about 7 per cent of lead to an alloy containing 7 per cent of aluminum and 1 per cent of manganese, the loss of strength after the alternate immersion test was only about 30 per cent, as compared with about 60 per cent of the same alloy without lead.

Alloys of magnesium with lead, aluminum, and manganese have been disclosed hereinabove. I

have discovered that if to a base alloy of magnesium-lead-aluminum-manganese I add one or more of the class of metals calcium or cadmium, the resulting alloys become considerably more susceptible to variation of properties by thermal treatments and their hardness can be markedly increased by artificial aging after thermal solution treatments. In these alloys the lead content should range from about 0.5 per cent to about 22.0 per cent, the aluminum from about 1.0 per cent to about 15.0 per cent, and the manganese from about 0.1 per cent to about 1.0 per cent. To these elements as a common base I add the elements calcium, or cadmium, singly or in combination, the calcium in amounts from about 0.1 per cent to about 2.0 per cent, the cadmium from about 1.0 per cent to about 10.0 per cent. As an example of an alloy of this nature, a sand cast specimen of a magnesium-base alloy containing about 10.0 per cent of lead, about 7.0 per cent of aluminum, about 0.4 per cent of manganese, and about 5.0 per cent of cadmium, had in the cast condition a tensile strength of about 23,200 pounds per square inch. After a thermal solution treatment of 21 hours at about 430° centigrade the tensile strength of the alloy had increased to about 36,000 pounds per square inch. a gain in strength of about 55 per cent. The same alloy after the solution treatment had a Brinell hardness of about 61 and this hardness was raised to about 84 by an additional aging treatment of 20 hours at about 175° centigrade, the tensile strength increasing slightly to about 37,000 pounds per square inch.

Similarly a magnesium-base alloy containing about 5.0 per cent of lead, 7.0 per cent of aluminum, 10.0 per cent of cadmium, and 0.4 per cent of manganese had in the sand cast condition a tensile strength of about 24,000 pounds per square inch. After a thermal treatment of 21 hours at about 430° centigrade the alloy had a tensile strength of about 35,000 pounds per square inch. An additional aging treatment raised the Brinell hardness of the alloy from about 61 to about 79.

Similarly, a magnesium-base alloy containing about 5.0 per cent of lead, 10.0 per cent of cadmium, 7.0 per cent of aluminum, 1.0 per cent of manganese, and 0.25 per cent of calcium had in the sand cast condition a tensile strength of about 24,290 pounds per square inch. After a thermal treatment of 20 hours at about 430° centigrade this alloy had a tensile strength of about 33,200 pounds per square inch. After an additional thermal treatment of about 20 hours at about 150° centigrade the strength increased to about 35,600 pounds per square inch and the Brinell hardness from about 47 to about 66.

Another magnesium-base alloy containing about 10.0 per cent of lead, 7.0 per cent of aluminum, 5.0 per cent of cadmium, 0.4 per cent of manganese, and 0.1 per cent of calcium, had in the sand cast condition a tensile strength of about 23,210 pounds per square inch. After a thermal solution treatment of 21 hours at about 430° centigrade the alloy had a tensile strength of about 36,030 pounds per square inch; the Brinell hardness was about 61. After an additional aging treatment of about 20 hours at about 175° centigrade its tensile strength was about 37,010 pounds per square inch and its Brinell hardness about 84. As a desirable alloy of this nature I advise 7.0 per cent lead, 7.0 per cent aluminum and 0.4 percent manganese. If more than one of the elements calcium or cadmium are present simultaneously, the total should not exceed about 10.0 per cent for preferred purposes.

The addition of zinc in amounts from about 1.0 per cent to about 10.0 per cent to magnesium-lead alloys containing aluminum and silicon in combination decreases the linear shrinkage, thus favorably affecting the casting properties, and also increases the corrosion resistance and raises the yield point of these alloys. In alloys of this type the lead should range from 0.5 per cent to 22.0 per cent, the aluminum from 1.0 per cent to 15.0 per cent, and the silicon from 0.1 per cent to 2.0 per cent, but the total amount of aluminum and silicon should preferably not exceed 15.0 per cent.

A useful alloy of this nature is a magnesium-base alloy containing about 10.0 per cent lead, 8.0 per cent aluminum and 3.25 per cent zinc. Another useful composition is attained by substituting about 1.0 per cent silicon for part or all of the aluminum.

An alloy similarly improved in casting properties, although not to such a decided extent, is one containing from about 0.5 per cent to 22.0 per cent of lead, from about 1.0 per cent to about 10.0 per cent of zinc, and from about 0.1 per cent to about 2.0 per cent of silicon. A favorable alloy within this range is a magnesium-base alloy consisting of about 10.0 per cent of lead, about 3.25 per cent of zinc, and about 1.0 per cent of silicon, the balance being substantially magnesium.

In making up alloys of the compositions disclosed hereinabove the alloys may be compounded by any of the methods known in the art. In casting the alloys recourse may be had to the protective measures disclosed in existing patents and the published literature relating to easily oxidizable metals. The alloys, especially the magnesium-lead binary alloys, may be extruded over the entire disclosed composition range, but other types of mechanical deformation such as rolling or forging should be carried on with due regard for the fact that as the percentage of total added alloying elements increases, the necessity for precaution in working the alloy also increases.

It is my object to retain, as far as possible, the advantages of the use of magnesium base, such as low specific gravity, while securing in addition the hereinabove disclosed benefits accruing from the additions of the other alloying elements herein outlined. Accordingly, where in the appended claims the term magnesium-base alloy is used, it refers to an alloy containing more than approximately 50 per cent of magnesium.

This application is a continuation in part of my copending application Serial No. 643,052, filed November 17, 1932.

What I claim is:

1. A magnesium-base alloy containing from 0.5 to 22.0 per cent of lead and from 0.1 to 1.0 per cent of manganese, the balance being magnesium.

2. A magnesium-base alloy containing about 8.0 per cent of lead and about 0.35 per cent of manganese, the balance being magnesium.

ROY E. PAINE.