

UNITED STATES PATENT OFFICE

2,178,573

MAGNESIUM ALLOY

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No Drawing. Application November 23, 1936,
Serial No. 112,288

3 Claims. (Cl. 75-168)

This invention relates to magnesium alloys and, particularly to those containing magnesium in excess of approximately 80 per cent.

It is well known that the addition of certain metals to magnesium results in the production of alloys possessing good strength characteristics, while the addition of other metals results in the production of alloys possessing good corrosion resistance. One of the major problems of the magnesium industry is the preparation of an alloy in which both objectives are obtained at the same time.

Accordingly, the object of the present invention is to prepare magnesium alloys which have improved physical properties and corrosion resistance. Other objects and advantages will appear as the description proceeds.

My invention is based on the discovery that highly desirable and useful alloys can be prepared by the addition of silver to magnesium and magnesium alloys, and that these alloys possess good strength characteristics, combined with good corrosion resistance.

I have discovered that the strength characteristics of magnesium may be improved to a very marked degree by the addition of suitable amounts of silver. The tensile strength of cast pure magnesium, for example, was found to be 14,000 pounds per square inch, while that of a magnesium alloy containing 2 per cent of silver was 21,100 pounds per square inch and that of a magnesium alloy containing 4 per cent of silver was 22,300 pounds per square inch. The yield strength of cast magnesium was 2,500 pounds per square inch, while the yield strengths of the magnesium alloys containing 2 per cent of silver and 4 per cent of silver were 4,100 pounds per square inch and 5,100 pounds per square inch respectively. The addition of 2 per cent and 4 per cent of silver to pure magnesium raised the percentage elongation of the cast metal from 8.0 per cent up to 10.5 per cent and 10.0 per cent respectively. The toughness of the magnesium was likewise improved by the addition of silver. The single blow impact value for pure magnesium was 9.0 foot pounds, while the corresponding values for the magnesium alloys containing 2 per cent of silver and 4 per cent of silver were 12.6 and 11.5 foot pounds respectively. The Brinell hardness values of these same two alloys were 34 and 37 respectively as compared with 33 for pure magnesium. As the percentage of silver in the alloy is increased, still greater improvements are obtained in the yield strength and hardness, with a proportional decrease in the percentage elonga-

tion and toughness. The magnesium alloy containing 8 per cent of silver, for example, had a Brinell hardness value of 45 and the magnesium alloy containing 12 per cent of silver had a Brinell hardness value of 51.

Magnesium-silver alloys, particularly those containing approximately 4 per cent or more of silver, are amenable to heat treatment. A solution heat treatment of 18 hours at 770° F. increased the tensile strength of the magnesium alloy containing 4 per cent of silver from 22,300 pounds per square inch to 24,900 pounds per square inch, and increased the percentage elongation from 10.0 per cent to 11.5 per cent without appreciably affecting other properties. A subsequent precipitation heat treatment of 48 hours at 350° F. produced a small increase in the tensile strength. Precipitation heat treatment, however, produced marked property improvements, particularly in tensile strength, yield strength, and hardness in alloys containing higher percentages of silver. A solution heat treatment of 18 hours at 770° F. followed by a precipitation heat treatment of 48 hours at 350° F., for example, increased the Brinell hardness of the magnesium alloy containing 8 per cent of silver from 45.0 to 55.5 and the Brinell hardness value of the magnesium alloy containing 12 per cent of silver from 51.0 to 65.5. Although beneficial property improvements are obtained in alloys containing approximately 0.3 to 15 per cent of silver, I normally prefer to use from 0.5 to 8 per cent of silver, except in those cases where maximum properties in the heat treated condition are required, and then I prefer to use alloys containing approximately 4 per cent to 8 per cent of silver. Alloys with low percentages of silver are better adapted for plastic deformation operations, while alloys with higher percentages of silver are better suited for the production of castings.

Furthermore, I have discovered that the addition of silver to commercial magnesium is beneficial from the standpoint of corrosion resistance. This may be illustrated by alternate immersion corrosion tests conducted in a 3 per cent salt solution. At the end of 24 hours, pure magnesium had lost weight at the rate of 65.8 mg./cm.²/day, while the magnesium alloys containing 2 per cent of silver and 4 per cent of silver lost only 51.2 and 17.3 mg./cm.²/day respectively. In another test the addition of 1 per cent of silver produced a 30 per cent decrease in the corrosion rate of magnesium.

I have also discovered that the beneficial effects of silver are retained when at least one of the

metals aluminum, manganese, zinc is added to magnesium-silver alloys, or, in other words, when silver is added to an alloy consisting of magnesium with at least one of the metals aluminum, manganese, zinc. In such alloys, the percentage of silver may vary from about 0.3 per cent to 12 per cent, the percentage of aluminum may vary from about 0.5 per cent to 12 per cent, the percentage of zinc may vary from about 0.5 per cent to 8 per cent, and the percentage of manganese may vary from about 0.1 per cent to 1 per cent (0.1 per cent to 0.5 per cent in alloys likewise containing aluminum), but the total percentage of added metals should not exceed approximately 20 per cent. The absolute percentage of each metal is dependent upon the use for which the alloy is intended and upon the percentages of the other alloying ingredients. For plastic deformation processes, I normally prefer from 0.5 per cent to 4 per cent of silver, from 0.5 per cent to 6 per cent of aluminum, from 0.2 per cent to 0.8 per cent of manganese, and from 0.5 per cent to 2.0 per cent of zinc, with a maximum of approximately 8 per cent of added metals. For castings, I normally prefer from 0.5 per cent to 8 per cent of silver, from 5 per cent to 10 per cent of aluminum, from 0.1 per cent to 0.5 per cent of manganese, and from 1 per cent to 4 per cent of zinc, the percentage of total added ingredients varying from approximately 8 per cent to 12 per cent.

The following examples serve to illustrate the beneficial effect of silver in this class of magnesium alloys as expressed by improvements in physical-mechanical properties. For example, the ternary magnesium alloy containing 2 per cent of silver and 0.2 per cent of manganese had a tensile strength of 23,000 pounds per square inch as compared with 18,000 pounds per square inch for the binary magnesium alloy containing 0.2 per cent of manganese and 21,100 pounds per square inch for the binary magnesium alloy containing 2 per cent of silver. The yield strength of this ternary magnesium-silver-manganese alloy was 4,400 pounds per square inch as compared with 3,000 pounds per square inch for the binary magnesium alloy containing 0.2 per cent of manganese and 4,100 pounds per square inch for the binary magnesium alloy containing 2 per cent of silver.

The addition of silver to magnesium-aluminum and to magnesium-aluminum-manganese alloys has been found to be particularly beneficial when the alloys are used for the production of heat treated castings. Under such conditions, comparable physical property improvements are obtained in alloys with and without manganese, but otherwise of similar composition, although the presence of manganese is desirable when the alloy is used for extrusion purposes. The addition of 2 per cent of silver, for example, increased the tensile strength of a solution heat treated magnesium alloy containing 8 per cent of aluminum and 0.2 per cent of manganese from 34,000 pounds per square inch to 36,000 pounds per square inch and the yield strength of this same alloy from 11,000 pounds per square inch to 12,000 pounds per square inch. Maximum improvement due to the presence of silver in alloys containing aluminum and manganese occurs in the aged or precipitation heat treated alloys, and here the effect is particularly pronounced in the yield strength and hardness values. For example, the addition of 2 per cent of silver to this same magnesium alloy containing 8 per cent of aluminum and 0.2 per cent of

manganese increased the yield strength from 13,000 pounds per square inch to 18,000 pounds per square inch and the Brinell hardness from 58 to 64.

The magnesium-silver-zinc and magnesium-silver-manganese-zinc alloys are satisfactory for the production of wrought shapes. While both alloys can be extruded readily, the former is better for rolling and forging operations, since the annealing temperature generally employed in such operations closely corresponds to the temperature at which precipitation of manganese occurs, and this precipitated manganese lowers the ductility and workability of the alloy. Magnesium-silver-zinc alloys, suitable for rolling, contain approximately 0.5 per cent to 3 per cent of silver and 0.5 per cent to 1 per cent of zinc, the balance being magnesium. Magnesium-silver-zinc alloys, suitable for extrusion, contain approximately 0.5 per cent to 6 per cent of silver and 0.5 per cent to 5 per cent of zinc, the balance being magnesium. Where ease of subsequent deformation is not required, as, for example, in extruded sections, I normally prefer to use magnesium-silver-manganese-zinc alloys containing 0.5 per cent to 5 per cent of silver, 0.1 per cent to 0.6 per cent of manganese, and 0.5 per cent to 6 per cent of zinc. The properties of such alloys, particularly those containing more than approximately 3 per cent of silver and 2 per cent of zinc, may be further improved by heat treatment.

Although the magnesium-silver-zinc alloys may be used for the production of castings, I generally prefer to use, for such purposes, alloys containing silver, aluminum, and zinc, or silver, aluminum, zinc, and manganese. Manganese is soluble in this type of alloy to the extent of a few tenths of a per cent, and in such amounts has no appreciable effect on physical property improvement, although it does improve the corrosion resistance of the alloy. The choice between the alloy with or without manganese, but otherwise of similar compositions, depends largely on the use for which the product is intended. A good composition, selected from the more corrosion resistant type of alloy, contains 2 per cent of silver, 8 per cent of aluminum, 0.2 per cent of manganese, and 3 per cent of zinc. This alloy, in the solution heat treated condition, has a tensile strength of 27,200 pounds per square inch, a yield strength of 13,000 pounds per square inch, 4 per cent elongation, a Brinell hardness value of 53, and a single-blow impact value of 9.7 foot pounds. In the solution-precipitation heat treated condition, this same alloy composition has the following properties,—tensile strength 31,000 pounds per square inch, yield strength 21,000 pounds per square inch, 0.5 per cent elongation, 72 Brinell hardness, and a single-blow impact value of 2.5 foot pounds.

I have likewise discovered that the corrosion resistance of the magnesium-silver alloys may be improved very materially by the addition of at least one of the metals aluminum, manganese, zinc. For example, the loss in weight in a magnesium alloy containing 2 per cent of silver when tested in 3 per cent salt solution was 51.2 mg/cm²/day, whereas the addition of 0.2 per cent of manganese reduced this corrosion rate to 4.9 mg/cm²/day. In another instance, the addition of 0.9 per cent of manganese to a binary magnesium alloy containing 1 per cent of silver reduced the corrosion rate from approximately 60 mg/cm²/day to 1.7 mg/cm²/day. In a similar fashion, the addition of 8 per cent of alu-

minum plus 0.2 per cent of manganese to a binary magnesium alloy containing 2 per cent of silver reduced the corrosion rate from 51.2 mg/cm²/day to 1.2 mg/cm²/day, while the addition of 8 per cent of aluminum plus 0.2 per cent of manganese plus 3 per cent of zinc to the binary alloy containing 2 per cent of silver reduced the corrosion rate to 0.6 mg/cm²/day.

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The above described alloys may be prepared by the well known methods of alloying metals with magnesium, such as adding the respective alloying ingredients to a bath of molten metal protected from oxidation by a cover of a fluid flux. The various alloying ingredients may be added singly or simultaneously, and are usually added as pure metals, except in those compositions containing both aluminum and manganese, in which case these two metals are preferably added in the form of a 90-10 aluminum-manganese hardener.

Other modes of applying the principle of my

invention may be employed instead of those explained, change being made as regards the ingredients and the steps herein disclosed, provided those stated by any of the following claims or their equivalent be employed.

I particularly point out and distinctly claim as my invention:

1. A magnesium-base alloy containing about 0.3 per cent to 12 per cent of silver, and from about 0.5 per cent to 12 per cent of aluminum, and from about 0.1 per cent to 0.5 per cent of manganese, the balance being magnesium.

2. A magnesium-base alloy containing 2 per cent of silver, and 8 per cent of aluminum, and 0.2 per cent of manganese, the balance being magnesium.

3. A magnesium base alloy containing about 2 to 6 per cent of silver, 0.5 to 8 per cent of aluminum, 0.1 to 0.5 per cent of manganese, the balance being magnesium.

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