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MAGNESIUM BASE ALLOY

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1 Claim. (Cl. 75—168)

This invention relates to alloys of magnesium with aluminum, manganese and zinc. It relates in particular to an alloy containing primarily magnesium with from 1 to 12 per cent of aluminum, from 0.01 to 0.5 per cent of manganese, and from 0.1 to 1.5 per cent of zinc.

Among the most desirable commercially available alloys of magnesium from the standpoint of its general physical characteristics is the alloy of commercial magnesium with from 1 to 12 per cent of aluminum, from 0.01 to 0.5 per cent of manganese, and from 0.1 to 1.5 per cent of zinc. The alloys comprised within the above definition are ordinarily available containing from 0.5 to 1.0 per cent of zinc and in one specific embodiment the amount of zinc is most frequently about 0.7 per cent of the total weight of the alloy. The aforesaid magnesium-aluminum-manganese-zinc alloy in the form in which it has been available to industry for many years has only fair corrosion resistance (3 to 10 milligrams per square centimeter per day) compared to ultra pure magnesium which has a corrosion resistance value of not to exceed about 0.2 milligram per square centimeter per day and the commercial quaternary alloy cannot be utilized for many purposes for which it is otherwise well suited.

As is the case of many other pure metals, magnesium itself is not a desirable structural metal and industry has resorted to alloys, among the commonest of which is that of magnesium with aluminum, manganese and zinc above described. The commercial alloy of magnesium, aluminum, manganese, and from 0.1 to 1.5 per cent of zinc is comparatively easily corroded in aqueous sodium chloride solution or by brine spray and is therefore unsuited, for example, for use along the seaboard or on board ship where it might be exposed to prevailing atmospheric conditions. The comparatively poor corrosion resistance of the commercial magnesium-aluminum-manganese-zinc alloy is not due to the presence of the aluminum or of the manganese or of the zinc but it is due to the existence of additional elements in actually small but still disadvantageously high proportions. Thus, an alloy consisting of very pure magnesium, pure aluminum, pure manganese, and pure zinc and containing no other elements has a corrosion resistance at least equal to that of magnesium alone. Such a "pure" alloy, however, is not as workable in all respects as the commercial alloy and further it is improbable that it could be made generally available economically.

It is an object of the present invention to pro-

vide an alloy of magnesium with from 1 to 12 per cent of aluminum, from 0.01 to 0.5 per cent of manganese, and from 0.1 to 1.5 per cent of zinc which will have a corrosion resistance equal to that of the "pure" alloy and which, in addition to high corrosion resistance, exhibits workability at least comparable with that of the alloy heretofore commercially available.

The above-mentioned corrosion resistance values of magnesium and its alloys are determined by means of a now standard procedure known as the alternate immersion method. This method as applied to magnesium alloys comprises immersing a weighed sample of the material of measured area into a 3 per cent aqueous sodium chloride solution at room temperature for 2 minutes, withdrawing the sample and holding it in the air for 1 minute, repeating this cycle for a protracted period, and computing the loss in weight of the sample per square centimeter of surface area per day. In the standard tests herein reported, the corrosion resistance values are expressed in terms of average weight loss per day per unit area over a testing period of 112 days.

It has now been found that the foregoing and related objects may be attained and that a magnesium-aluminum-manganese-zinc alloy can be produced which will have a corrosion resistance, as measured by the alternate immersion method, at least as good as that of ultra pure magnesium and which exhibits the desired physical properties which industry requires by including in the said alloy a very small amount of at least one of the elements iron, nickel, copper, lead and silicon. It has been recognized that the presence of iron in various magnesium alloys is disadvantageous, and that the amount of iron should be kept as low as possible to minimize corrosion. This is not the whole story, however, and we have found that the mere elimination of iron or reduction of the iron content to a very low value is not sufficient to produce a non-corrosive alloy when other elements are present. Iron, even in minute traces, acts co-operatively with various other elements to lessen the corrosion resistance of a magnesium alloy. It has been found, therefore, that not only must the amount of iron be minimized, but also that the amount of numerous other elements must be controlled whether these elements are present alone or together with traces of iron. The presence of at least traces of the other elements is distinctly advantageous from some standpoints, provided the amount

thereof is below the corrosion tolerance limit, as will be more fully described hereinafter.

The invention, then, resides in an alloy characterized by a degree of corrosion resistance substantially equal to that of pure magnesium, consisting of from 1 to 12 per cent of aluminum, from 0.01 to 0.5 per cent of manganese, from 0.1 to 1.5 per cent of zinc, and containing at least one of the elements iron, nickel, copper, lead and silicon in amount not to exceed 0.002 per cent of iron, not to exceed 0.001 per cent of nickel, not to exceed 0.09 per cent of copper, not to exceed 0.7 per cent of lead, not to exceed 1.0 per cent of silicon, except that the combined weight of iron and copper, when both are present, is limited by the expression:

$$\frac{\% \text{ iron}}{0.002} + \frac{\% \text{ copper}}{0.09} \leq 1$$

the combined weight of iron and lead, when both are present, is limited by the expression:

$$\frac{\% \text{ iron}}{0.002} + \frac{\% \text{ lead}}{0.7} \leq 1$$

and when the amount of iron is greater than 0.0005 per cent, silicon is less than 0.09 per cent; the balance being magnesium. An alloy composed as above is characterized by having a corrosion rate, in the alternate immersion method in brine, of not to exceed about 0.2 milligram per square centimeter per day.

In the fractional expressions given above, the numerators represent the weight per cent of the various named constituents actually present in the alloy based on its total weight. The denominators are the individual tolerance limits for the representative element expressed in per cent by weight. Thus, the maximum amount of iron which can be present in a magnesium-aluminum-manganese-zinc alloy of the proportion hereinbefore given, while still producing a composition comparable in its corrosion resistance to pure magnesium, is 0.002 per cent. The maximum amount of nickel that can be present in such an alloy with the same limits as to corrosion resistance is 0.001 per cent. Similarly, the maximum amounts of copper, lead and silicon are 0.09 per cent, 0.7 per cent and 1.0 per cent, respectively. When iron and copper, iron and lead, or iron and silicon are both present, it has been found that they exhibit a synergetic effect on the susceptibility of the alloy to corrosion and that a limit must be imposed upon the combination of iron and copper, or of iron and lead such that the sum of quotients of the actual amount of iron divided by its tolerance limit plus the actual amount of copper or lead divided by their respective tolerance limits does not exceed unity. This limitation has been expressed mathematically in the foregoing paragraph. Whenever iron exceeds 0.0005 per cent, silicon must be less than 0.09 per cent.

The following table illustrates the critical nature of the tolerance limit for nickel given in the preceding discussion of corrosion. The elements named in the table are the only ones present in significant amounts. The amounts of these respective elements in the alloy being tested are expressed in per cent by weight of the alloy, and the corrosion rates determined by the alternate immersion method, are expressed in milligrams weight loss per square centimeter per

day based on the average loss over a period of 112 days.

TABLE
Effect of nickel

Al	Mn	Zinc	Nickel	Corrosion rate
Per cent	Per cent	Per cent	Per cent	Per cent
6.0	.2	1.07	.0005	.05
6.4	.10	.9	.0005	.10
6.7	.05	.5	.001	.10
6.0	.2	.9	.001	.13
5.8	.18	.5	.0012	3.36
6.3	.23	.55	.0055	13.3

It has been found that the presence of small amounts of additional elements, within the limits specified, in an otherwise pure alloy of magnesium with 1 to 12 per cent of aluminum, 0.01 to 0.5 per cent of manganese, and 0.1 to 1.5 per cent of zinc is advantageous. Thus, for example, the elongation values of the alloy are improved.

As evidence of this improvement, the following representative data are given on samples prepared in a uniform manner and tested according to standard procedure.

Alloy being tested	Elongation
	Per cent
Mg-3 Al-0.05 to 0.1 Mn-0.1 to 1.5 Zn ("pure" alloy)	12-15
"Pure"+0.0002 to 0.0005 Fe	13-14
"Pure"+0.0005 to 0.001 Fe	14-16
"Pure"+0.001 to 0.002 Fe	16-19
"Pure"+0.0005 Cu	12-15
"Pure"+0.01 Cu	18
"Pure"+0.001 Pb	12-15
"Pure"+0.1 Pb	18-19
"Pure"+0.0005 Si	12-15
"Pure"+0.003 Si	17-19
"Pure"+0.01 Si	17-18.5
"Pure"+combinations within tolerance limits of Fe, Ni, Cu, Pb, Si	15-18

The herein claimed improved alloy, in addition to its improved corrosion resistance and increased elongation values, is at least as hard and strong as the commercial alloy. The alloy herein claimed differs from that claimed in our co-pending application Serial No. 323,114, filed concurrently herewith, only in the presence in the present composition, of a certain stated proportion of zinc. In the quantity in which zinc occurs in the herein claimed compositions, it does not alter the corrosion tolerance limits set up in the said co-pending application which was concerned with the magnesium-aluminum-manganese alloy. The zinc does appear, however, to lessen the injurious effect of the added elements iron, nickel, copper, lead and silicon when these are present in amounts greater than the tolerance limits.

We claim:

A magnesium base alloy including from 1 to 12 per centum of aluminum, from 0.01 to 0.5 per centum of manganese, from 0.01 to 1.5 per centum of zinc, and containing nickel in a positive amount not exceeding 0.001 per centum, said alloy having a corrosion resistance below about 0.2 milligram per square centimeter per day in alternate immersion in three per centum aqueous sodium chloride.

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