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MAGNESIUM BASE ALLOY

Joseph D. Hanawalt and Charles E. Nelson, Midland, Mich., assignors to The Dow Chemical Company, Midland, Mich., a corporation of Michigan

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1 Claim. (Cl. 75—168)

This invention relates to alloys of magnesium with aluminum and manganese.

Among the most desirable commercially available alloys of magnesium from the standpoint of its general working properties and physical characteristics is the alloy of commercial magnesium with from 1 to 12 per cent of aluminum and from 0.01 to 0.5 per cent of manganese. This 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 ternary alloy cannot be utilized for many purposes for which it is otherwise well suited.

As is the case with 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 and manganese above described. The commercial alloy of magnesium, aluminum, and manganese 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 the prevailing atmospheric conditions. The comparatively poor corrosion resistance of the commercial magnesium-aluminum-manganese alloy is not due to the presence of the aluminum or of the manganese 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, and pure manganese 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 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 provide a magnesium-aluminum-manganese alloy 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 procdure 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 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 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 hereafter.

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, and containing at least one of the elements iron, nickel, copper, lead and silicon in amount not to exceed 0.002 per cent iron, not to exceed 0.001 per cent 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 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 the 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 average loss over a period of 112 days.

TABLE 1

Effect of nickel

Al	Mn	Nickel	Corrosion rate
Percent	*Percent*	*Percent*	
4.5	0.09	0.0002	0.10
6.4	0.10	0.0005	0.10
7.6	0.01	0.0005	0.11
10.6	0.11	0.001	0.10
10.7	0.17	0.001	0.08
4.9	0.22	0.001	0.16
6.7	0.05	0.001	0.10
3.5	0.18	0.0011	0.48
3.7	0.09	0.0016	0.96
8.0	0.1	0.002	3.74
12.0	0.1	0.003	4.13
4.5	0.11	0.0034	9.50

It has been found that the presence of these small amounts of the additional elements in an otherwise pure alloy of magnesium with 1 to 12 per cent of aluminum and 0.01 to 0.5 per cent of manganese 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 cast 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 ("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 0.0015 Fe	16–17
"Pure"+0.0015 to 0.002 Fe	17–19
"Pure"+0.0005 Cu	12–15
"Pure"+0.01 Cu	18.4
"Pure"+0.05 Cu	17.7
"Pure"+0.001 Pb	12–15
"Pure"+0.01 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	17.4–18.6
"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 as strong as the commercial alloy.

We claim:

A magnesium base alloy including from 1 to 12 per centum of aluminum and from 0.01 to 0.5 per centum of manganese, and containing nickel in a positive amount not exceeding 0.001 per centum, balance magnesium, said alloy having a corrosion resistance below 0.2 milligram per square centimeter per day in alternate immersion in 3 per cent aqueous sodium chloride.

JOSEPH D. HANAWALT.
CHARLES E. NELSON.