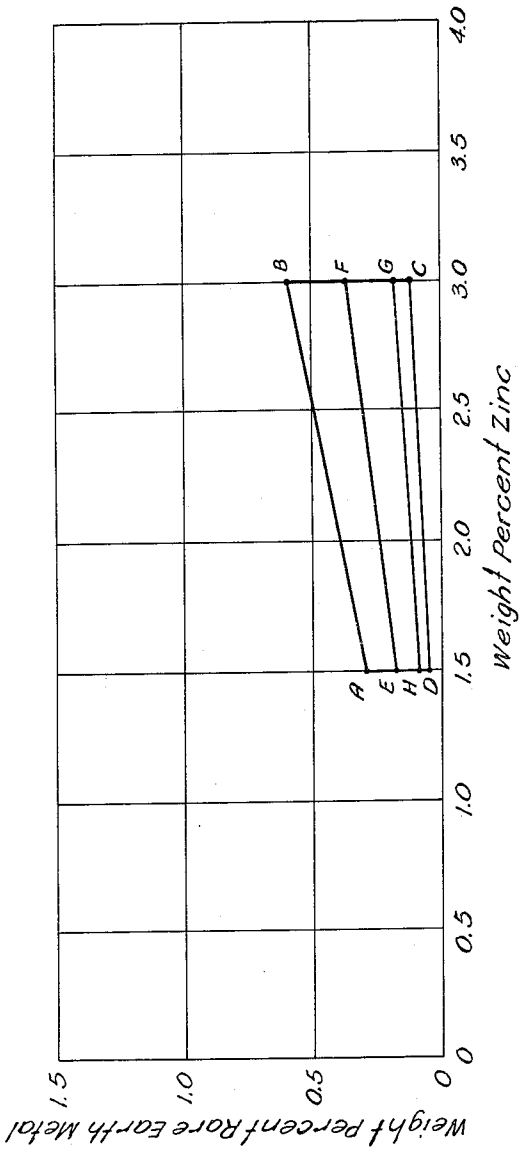
April 11, 1961 G. S. FOERSTER 2,979,398

MAGNESIUM-BASE ALLOY

Filed July 3, 1958



INVENTOR.
George S. Foerster
BY
Edward E. Schilling
AGENT

United States Patent Office 2,979,398 Patented Apr. 11, 1961

2,979,398

MAGNESIUM-BASE ALLOY

George S. Foerster, Midland, Mich., assignor to The Dow Chemical Company, Midland, Mich., a corporation of Delaware

Filed July 3, 1958, Ser. No. 746,410

4 Claims. (Cl. 75—168)

This invention relates to magnesium-base alloys. It more particularly concerns an improved magnesium-base alloy containing zinc and zirconium.

Magnesium-base alloys in rolled sheet form containing both zinc and zirconium heretofore proposed do not possess desirably high and substantially isotropic mechanical properties as well as good formability and weldability. Magnesium-base magnesium-zinc alloys have shown poor rollability when the zinc content exceeds about 3 percent due to the formation of a low melting magnesium-zinc phase. Magnesium-base magnesium-zinc alloys containing less than about 3 percent of zinc have been satisfactorily hot rolled but still exhibit poor cold workability, and as the zinc content is decreased, the alloys in rolled form possess increasingly poorer mechanical properties. The poor properties of the conventional magnesium-base magnesium-zinc alloys are believed due to heterogeneous deformation which occurs when the alloy is strain hardened as by cold rolling.

It has now been discovered that in certain limited ranges of proportions of zinc and zirconium, herein shown, the addition of misch metal to the magnesium-base alloys containing these metals greatly improves their properties. In particular, it has been found that in magnesium-base alloys containing from 1.5 to 3.0 percent of zinc (preferably 2 to 2.5 percent), and from 0.2 to 0.8 percent of zirconium (preferably 0.5 to 0.7 percent), the addition of a critical amount of rare earth metal, the amount by weight being from 0.04 to 0.2 times as much rare earth metal as zinc, the balance being magnesium, a magnesium-base alloy is obtained which in rolled form exhibits high ductility, high strength, good weldability, toughness, formability, and resistance to corrosion and the rolled products have substantially the same high tensile and compressive strengths in both the longitudinal and transverse directions of rolling. The invention then consists of the improved magnesium-base alloy herein described and particularly pointed out in the claims.

The addition of rare earth metal, which ordinarily adversely affects the extrudability and room temperature mechanical properties of magnesium-base magnesium-zinc alloys in cast form, is decidedly beneficial to the magnesium-base magnesium-zinc-zirconium alloys in rolled form. Rare earth metal additions improve hot rollability of the high zinc alloys of this kind, apparently by decreasing the concentration of the low melting magnesium-zinc phase(s), and markedly improve cold workability and resultant properties, apparently through promotion of more homogeneous deformation. However, the proportion of rare earth metal added is critical and the addition of too much rare earth metal adversely affects transverse strength, formability and mechanical properties generally.

A notable feature of the addition of rare earth metal in the critical concentration range herein disclosed is the effect on the longitudinal and transverse properties of the alloy in rolled form. The transverse properties of the magnesium-base magnesium-zinc-zirconium alloys are

quite generally higher than the longitudinal properties. Yet upon making small but increasingly larger additions, to a typical example of the said Mg—Zn—Zr alloy, of rare earth metal covering the said critical concentration range, the longitudinal properties of the resulting compositions in rolled form are found respectively to be successively larger while at the same time the transverse properties respectively are found successively to approach a maximum value and then to decrease to values smaller than that of the longitudinal properties. The compositions in the range in which the values of longitudinal and transverse properties of the alloy approach, become equal, and diverge slightly are those herein disclosed and claimed.

It has not been previously shown that upon varying the proportions of a minor component of an alloy the relative magnitudes of the transverse and longitudinal properties are reversed. Nor is it expected in the art that such a change is produced by such small changes in the proportions of a minor component.

Another important characteristic of the invention is that as the zinc content of the alloy is increased the amount of rare earth metal needed to bring about the transposition of the magnitudes of transverse and longitudinal properties of the alloy is proportionately increased. To obtain the desired combination of properties in the rolled form of the alloy suitable rare earth metal to zinc weight ratios employed are those wherein the weight percentage of rare earth metal is from 0.04 to 0.2 of the weight percentage of zinc and preferably from 0.06 to 0.12. These ratios are illustrated graphically in the appended drawing.

In the drawing in the single figure is shown a rectangular coordinate graph in which percent rare earth metal is plotted along the ordinate scale and percent zinc is plotted along the abscissa. The range of proportions of rare earth metal and zinc in the alloy herein disclosed and claimed is graphically represented by the area bounded by the lines connecting A, B, C and D, said alloy including 0.2 to 0.8 percent of zirconium which is soluble in hydrochloric acid on subjecting the alloy to the dissolving action of the acid, and the balance magnesium.

The preferred range of proportions is graphically represented in the same drawing as the area bounded by the lines connecting points E, F, G and H.

Alloys having rare earth metal to zinc ratios represented by the area above the line AB of the drawing exhibit low transverse properties while those represented by the area below the line CD exhibit low longitudinal properties and poor rollability. Below about 1 percent of zinc, the alloys exhibit low mechanical properties and above about 3.5 percent of zinc the alloys are difficult to weld or to roll without cracking.

The rare earth metals suitable for use in preparing the present alloy are: Ce, La, Pr, Nd, or misch metal. Misch metal with from 35 to 80 percent of cerium, the balance being rare earth metal and up to 5 percent of non-rare earth metal, is the preferred rare metal ingredient of the alloy. Any of the foregoing rare metals may be used alone or in any combination in compounding the alloy.

The alloy may be made in the desired proportions according to the invention by melting together the alloying ingredients in proper proportions or by using hardeners of magnesium alloys containing the alloy constituents. Protection from oxidation during alloying is effected by the use of a magnesium chloride-free saline flux as in conventional alloying. The molten alloy may be flux refined by stirring the alloy with additional flux. The so-refined alloy is allowed to settle and then is separated from the flux as by decanting into a suitable casting mold, e.g., a slab mold for rolling stock.

In rolling the cast metal, it is desirable first to scalp the cast metal so as to present a smooth clean surface to the rolls of the rolling mill. The clean rolling stock is heated to a suitable rolling temperature, e.g. about 800° to 850° F. The heated metal is then reduced in thickness by passes between the rolls of the mill, the rolling being stopped 50 to 100 Fahrenheit degrees short of the temperature at which cracking would result if the rolling were continued without reheating the metal. The temperature to which the metal may decline as it is being rolled before cracking occurs is readily determined by trial and varies with the proportions of the alloying ingredients. In general in hot rolling, the metal should be reheated when its temperature declines to about 600° or 650° F. if rolling is to be continued without cracking. Reductions in thickness of the cast metal of 20 to 30 percent may be made per pass while the metal is at a suitable rolling temperature.

By annealing the hot rolled cast metal, as for example, by heating for one hour at 700° F., the hot rolled metal may be cold rolled (warm rolls, e.g., 180° F.) as much as 40 to 50 percent by making thickness reductions of 1 to 2 percent per pass. Before proceeding with the final 40 to 50 percent cold reduction by rolling, it is generally desirable to use a preliminary total cold roll of about 15 percent, obtained in multiple passes, followed by annealing at about 700° F. for one hour to improve the subsequent cold rollability and mechanical properties.

Examples of the alloy according to the invention were cast in rolling slabs 2 inches by 4 inches by 8 inches. These rolling slabs were scalped to about 1⅞ inches thickness, heated to about 800° to 850° F. and cross-rolled to a thickness of about 1 inch, then turned 90 degrees and rolled to about ⅛ inch thickness and annealed for one hour at 700° F. The annealed strips were then cold rolled in multiple passes at 1 to 2 percent per pass to a thickness of about 0.1 inch, then annealed for one hour at 700° F. and cold rolled an additional 40 percent. The rolled strip was finally heat treated for one hour at 275° F. The properties set forth in the table were determined on the so-prepared rolled strip.

Also listed in the table for comparison is a blank consisting of a magnesium-zinc-zirconium alloy containing no added rare earth metal and prepared in rolled form in the same manner as the above examples. From a comparison of the longitudinal and transverse properties of the blank in rolled sheet form, as shown in the table, it can be seen that the magnitudes of the corresponding longitudinal and transverse properties of such a magnesium-zinc-zirconium alloy vary considerably in the absence of rare earth metal.

Table

Alloy No.	Percent Composition, Balance Mg			Properties in 1,000's p.s.i.							
				Longitudinal				Transverse			
	Zn	MM	Zr	Percent E	TYS	CYS	TS	Percent E	TYS	CYS	TS
1	1.5	0.08	0.7	8	31	28	40	16	32	32	43
2	2.0	0.20	0.7	8	36	34	45	16	34	37	46
3	2.9	0.30	0.6	8	36	35	45	18	34	36	47
Blank	3.0		0.8	6	32	28	41	17	41	34	48

E=elongation in 2 inches.
TYS=tensile yield strength at 0.2 percent deviation from the modulus line.
CYS=compressive yield strength at 0.2 percent deviation from the modulus line.
TS=ultimate tensile strength.
MM=misch metal used consisted of 48% Ce, 18% Nd, 5.5% Pr, and 28.5% La which included minor amounts of other rare earth metals.

Among the advantages of the invention are that an alloy is provided having the light weight characteristic of magnesium and possessing formability, corrosion resistance and good weldability.

I claim:

1. A magnesium-base alloy consisting of from 1.5 to 3.0 percent of zinc, rare earth metal in an amount in percent by weight which is from 0.04 to 0.2 of the zinc percentage, said rare earth metal being selected from the group consisting of cerium, lanthanium, praseodymium, neodymium, misch metal, and mixtures thereof, from 0.2 to 0.8 percent of zirconium which is soluble in hydrochloric acid on subjecting the alloy to the dissolving action of the acid, and the balance magnesium.

2. The alloy as in claim 1 in which the rare earth metal is present in an amount in percent by weight which is from 0.06 to 0.12 of the zinc percentage.

3. A magnesium-base alloy consisting of from 2 to 3 percent of zinc, rare earth metal in an amount in percent by weight which is from 0.04 to 0.2 of the zinc percentage, said rare earth metal being selected from the group consisting of cerium, lanthanium, praseodymium, neodymium, misch metal, and mixtures thereof, from 0.2 to 0.8 percent of zirconium which is soluble in hydrochloric acid on subjecting the alloy to the dissolving action of the acid, and the balance magnesium.

4. A magnesium-base alloy consisting of from 2 to 2.5 percent of zinc, rare earth metal in an amount in percent by weight which is from 0.04 to 0.2 of the zinc percentage, said rare earth metal being selected from the group consisting of cerium, lanthanium, praseodymium, neodymium, misch metal, and mixtures thereof, from 0.2 to 0.8 percent of zirconium which is soluble in hydrochloric acid on subjecting the alloy to the dissolving action, and the balance magnesium.

References Cited in the file of this patent

UNITED STATES PATENTS

2,549,955 Jessup et al. ---------- Apr. 24, 1951

FOREIGN PATENTS

540,879 Canada ---------- May 14, 1957