

1

2

3,067,028
Mg-Si-Zn EXTRUSION ALLOY
George S. Foerster, Midland, Mich., assignor to The Dow
Chemical Company, Midland, Mich., a corporation of
Delaware
No Drawing. Filed Apr. 27, 1960, Ser. No. 24,889
3 Claims. (Cl. 75-168)

The invention relates to a magnesium-base alloy and
more particularly relates to an improved magnesium-
base extrusion alloy containing silicon and zinc. These
alloys can be extruded at speeds as high as 100 feet per
minute.

Heretofore, the magnesium-aluminum-zinc alloys have
been employed as the principal extrusion alloys because
they are readily extruded at speeds up to 75 feet per
minute, they exhibit moderately high physical properties
in the extruded form and they are prepared using low
cost alloying elements.

However, the conventional alloy AZ31B containing
nominally 3 percent of aluminum, 1 percent of zinc, at
least 0.2 percent of manganese and the balance mag-
nesium, is not weldable without stress relief. Upon low-
ering the aluminum content of a magnesium-aluminum-
zinc alloy the physical strength properties of the extruded
alloy are found to be inferior to those of AZ31B. Such
is the case with the magnesium-base alloy AZ11 which
contains nominally 1 percent of aluminum, 1 percent of
zinc, the balance magnesium.

In considering other possible magnesium-base extru-
sion alloys it is well recognized that the addition of in-
creasingly larger proportions of zinc to magnesium, or
a magnesium-base alloy, tends to increase the strengths
of the resulting alloy. Typical trends are illustrated by
the strength properties listed in Table I for extrudes
formed of magnesium-zinc binary alloys. The data in
the table show the expected increase in properties with
increasingly larger proportions of zinc in the alloy and
lower properties at higher extrusion speeds.

Other alloys such as the magnesium-aluminum-zinc
alloys are known to behave similarly.

It has now been discovered that the strength properties
of a magnesium-base alloy containing silicon and zinc
are unexpectedly enhanced by providing a reduced
amount of zinc, i.e. below about 1.5 percent by weight,
in combination with a silicon content in the range of
0.2 to 2 percent by weight.

The alloy of the invention is readily prepared accord-
ing to methods well understood in the magnesium metal
art. Magnesium is melted under a conventional flux
cover and the requisite amount of silicon and zinc added
to the melt while the melt is at a temperature of about
1600° F.

Ferrosilicon is usually the source of silicon, although
other forms of silicon such as silicon metal may be used,
if desired. In the event ferrosilicon is employed, iron,
which is sparingly soluble in molten magnesium, normally
precipitates into the bottom sludge layer of the melt.
While the zinc may be added to the melt at any time,
if ferrosilicon is the source of silicon, the requisite
amount of the zinc is added to the melt as metallic zinc
after the iron settles out.

After the addition of the alloying components, the
melt is brought to casting temperatures, usually in the
range of 1250 to 1450° F., and cast into billets suitable
for extrusion stock.

The role of the alloying elements is not entirely under-
stood, but it is believed that the silicon addition pre-
cipitates in the casting as the finely divided intermetallic
compound, magnesium silicide. Magnesium silicide has
a very low solid solubility in magnesium and helps to
maintain the alloy in the fine-grained condition as well
as to increase the strength of the alloy. The silicon con-
tent of the alloy of the invention should be as high as
feasible, preferably from 0.5 to 1.5 percent.

The presence of zinc greatly improves the corrosion
resistance of the alloy and therefore at least 0.2 percent
of zinc should be employed. On the other hand at higher
zinc levels, such as above about 1.5 percent of zinc, the
tensile yield strength, compression yield strength, and
ultimate tensile strength of the alloy are decreased. To
impart ductility and to improve the surface of the ex-

TABLE I

Composition, ¹ weight percent		Extru- sion speed, ft./min.	Form of extrude	Cross-sectional dimensions, inches	Percent E	Strengths in 1,000 p.s.i.		
Zn	Zr					TYS	CYS	TS
0.9	-----	3	Rod-----	3/8 diameter-----	16	21	12	35
1.9	-----	3	Rod-----	3/8 diameter-----	18	23	13	35
1.3	0.6	12	Rod-----	3/8 diameter-----	18	38	29	45
2.4	0.6	12	Rod-----	3/8 diameter-----	18	40	33	50
1.3	0.6	12	Strip-----	1/16 x 3/4-----	5	38	29	44
2.4	0.6	12	Strip-----	1/16 x 3/4-----	6	40	38	47
1.3	0.6	20	Strip-----	1/16 x 3/4-----	6	34	19	40
2.4	0.6	20	Strip-----	1/16 x 3/4-----	8	38	29	26
1.3	0.6	40	Strip-----	1/16 x 3/4-----	11	27	15	37
2.4	0.6	40	Strip-----	1/16 x 3/4-----	12	31	20	43

¹ Balance magnesium.
NOTE.—Percent E=Percent elongation in 2 inches. TYS=Tensile yield strength. CYS=Compression
yield strength. TS=Ultimate tensile strength.

In the German Patent 519,377 there is described a
magnesium-base alloy containing from 1.8 to 5 percent by
weight of zinc and from 1 to 6 percent by weight of
silicon. The alloy of the German patent is said to be
useful when cast as pistons for internal combustion en-
gines. An example of this alloy such as one containing
4 percent by weight of zinc and 1.5 percent by weight
of silicon, the balance magnesium is not, however, suit-
able as an extrusion alloy because it tends to crack on
being welded, it cannot be extruded at speeds above about
30 feet per minute, and an extrude of the alloy does
not exhibit the level of strength properties desirable in
an extruded product.

trude without adversely affecting weldability the zinc con-
tent of the alloy should preferably be in the range of
0.5 to 1.3 percent and more desirably about 1 percent.

It has also been found that various additional alloying
elements may be added to the magnesium-silicon-zinc
alloy of the invention to advantageously modify the
properties of this alloy for special purposes.

An especially desirable additional alloying element is
manganese. The addition of small amounts of manga-
nese permits the use of a lower silicon content without
loss of mechanical strength. This is often advantageous
as silicon tends to not alloy efficiently with molten mag-
nesium, and lower silicon contents are more easily ob-

tained. Up to 1.5 percent by weight of manganese can be incorporated into the alloy to increase the mechanical strength and corrosion resistance thereof. A preferred composition is one containing by weight, about 1 percent of silicon, about 1 percent of zinc, about 0.4 percent of manganese, the balance magnesium.

Beryllium in an amount up to 0.05 percent by weight may be added to increase matrix strength and to improve resistance to oxidative attack by the atmosphere. Up to 0.5 percent of misch metal may be added to increase matrix strength and cold workability. Up to 0.5 percent of calcium may be added to increase matrix strength where some brittleness may be tolerated. Up to 0.1 percent of zirconium may be added to obtain beneficial grain refining action. And, up to 3 percent of aluminum may be added to improve the surface appearance of the resultant extrude.

Magnesium-silicon-zinc alloys prepared in accordance with the invention can be extruded at speeds as high as 100 feet per minute and at reduction ratios as great as 150 to 1. Extrusion speed does not ordinarily adversely affect the physical properties of the extruded material nor is the extrusion subject to hot shorts.

EXAMPLES

In accordance with the present invention, a series of magnesium-silicon-zinc alloys were prepared by alloying together the requisite proportions of magnesium, ferro-silicon, and zinc metal. The resulting alloys were separated from the precipitated iron and each cast as 3 inch diameter billets. The cooled solidified billets were scalped, heated to about 700° F., placed in a preheated ram-extrusion press, and extruded at a temperature of about 600° F. and at speeds in the range of 5 to 100 feet per minute. The physical properties of the resulting extrusions were measured. In Table II are listed the physical properties for 2 alloys of the invention which were each extruded at different speeds. The data show that high extrusion speed is not deleterious but even beneficial to the physical properties of the extruded product.

TABLE II
Effect of Extrusion Speed

5	Run No.	Composition, ¹ percent		Extrusion speed, feet/ minute	Physical properties of extrude			
		Si	Zn		Percent E	1,000 p.s.i.		
						TYS	CYS	TS
10								
	1-----	0.5	1	5	15	21	15	35
	2-----	0.5	1	20	14	22	16	36
	3-----	0.5	1	50	14	23	16	37
	4-----	0.5	1	100	14	23	16	37
15								
	5-----	1.2	0.5	5	8	24	17	37
	6-----	1.2	0.5	20	9	25	17	38
	7-----	1.2	0.5	50	9	26	19	38
	8-----	1.2	0.5	100	10	27	18	38

¹ Composition in weight percent, balance magnesium.

The physical properties of other alloys of the invention which were extruded at 100 feet per minute are listed in Table III. Some of the alloys listed in Table III were also tested to determine their resistance to corrosion. In these instances corrosion tests of one week duration were carried out by the alternate immersion method according to which test specimens are repeatedly immersed for 30 seconds in a 3 percent aqueous sodium chloride solution maintained at 95° F., then withdrawn from the chloride solution for 90 seconds on a two minute cycle according to ASTM standard I-B (B 192-44T).

By way of comparison extrudes formed, respectively, of a magnesium-silicon binary alloy, of a magnesium-zinc binary alloy, and of the conventional alloys AZ31B and AZ11 were tested to determine their physical properties and corrosion resistance. The results of these additional tests are also listed in Table III for comparison.

In accordance with the invention, a further series of magnesium-silicon-zinc alloys containing a fourth alloying element selected from the group consisting of manganese, misch metal, calcium, zirconium, beryllium, and

TABLE III

Run No.	Composition, ¹ percent				Extru- sion speed, feet/min.	Physical properties				
	Si	Zn	Al	Mn		Percent E	1,000 p.s.i.			Corrosion rate, M/C/C/D
							TYS	CYS	TS	
9-----	1.4	1.0	-----	-----	100	10	25	17	37	Ca. 2 1.3
10-----	1.0	1.0	-----	-----	100	12	24	17	37	
11-----	0.5	1.0	-----	-----	100	14	23	16	36	0.8 4.3
12-----	1.5	0.5	-----	-----	100	9	26	18	38	
8-----	1.2	0.5	-----	-----	100	10	27	18	38	-----
13-----	1.4	1.0	-----	-----	100	10	26	18	38	-----
14-----	1.2	1.0	-----	-----	100	12	25	17	37	-----
15-----	0.9	1.0	-----	-----	100	13	24	17	37	-----
4-----	0.5	1.0	-----	-----	100	14	23	16	37	-----
16-----	1.3	1.5	-----	-----	100	10	23	17	36	-----
Comparison-----	1.4	-----	-----	-----	100	5	22	17	37	Ca. 20 Ca. 0.4
Do-----	-----	1	3	0.4	50	15	29	14	38	
Do-----	-----	0.6	1.3	0.3	100	11	23	11	34	(?)1-6 Ca. 1
Do-----	-----	1	-----	-----	60	8	14	7	28	
Do-----	1.4	2.0	-----	-----	100	9	22	16	35	-----
Do-----	1.4	3.9	-----	-----	25	10	21	15	35	-----
Do-----	1.4	3.9	-----	-----	50	Very poor, severely cracked as extruded				

¹ Composition in weight percent, balance magnesium.

² Typical range.

NOTE.—Percent E=Percent elongation in 2 inches. TYS=Tensile yield strength in thousands of p.s.i. CYS=Compression yield strength in thousands of p.s.i. TS=Ultimate tensile strength in thousands of p.s.i. M/C/D=Milligrams corrosion loss per sq. centimeter of surface area per day.

aluminum, were prepared by alloying together the requisite proportions of magnesium, ferrosilicon, zinc and the fourth metal. The resulting alloys were separated from the precipitated iron and each cast as 3 inch diameter billets. The cooled solidified billets were scalped, and heated to about 700° F. and placed in a pre-heated ram extrusion press and extruded at a temperature of about 600° F. and at speeds in the range of 5 to 100 feet per minute. The physical properties of the resulting extrusions were determined and are listed in Table IV.

TABLE IV

Run No.	Composition, ¹ percent							Extrusion speed, feet/min.	Physical properties			
	Si	Zn	Be	Mn	Zr	Al	MM		Percent E	1,000 p.s.i.		
										TYS	CYS	TS
17...	1.5	1.0	0.01	-----	-----	-----	-----	100	10	26	18	37
18...	1.2	0.2	-----	0.3	-----	-----	-----	100	8	30	18	39
19...	1.0	0.3	-----	0.3	-----	-----	-----	100	7	30	19	41
20...	0.4	1.0	-----	0.4	-----	-----	-----	100	12	22	14	36
21...	0.9	1.0	-----	0.4	-----	-----	-----	100	12	26	13	39
22...	1.4	1.0	-----	0.2	-----	-----	-----	100	8	25	13	37
23...	1.5	1.0	-----	-----	-----	-----	0.05	100	9	24	17	36
24...	1.4	1.0	-----	-----	Tr. < .01	-----	-----	100	8	24	13	37
25...	1.7	0.9	-----	-----	-----	0.9	-----	100	6	21	15	32
26...	1.4	1.0	-----	-----	-----	3.0	-----	100	8	20	14	33

¹ Composition in weight percent, balance magnesium.

NOTE.—Percent E=Percent elongation in 2 inches. TYS=Tensile yield strength in thousands of p.s.i.

CYS=Compression yield strength in thousands of p.s.i. TS=Ultimate tensile strength in thousands of p.s.i.

MM=Misch metal, a mixture of rare earth metals; the mixture used contained about 50 percent of cerium.

Among the advantages of the alloy of the invention are the improved corrosion resistance and ductility that it exhibits compared to that of magnesium-silicon binary alloys.

This application is a continuation-in-part of a prior filed application, Serial No. 819,814, filed June 12, 1959, now abandoned.

I claim:

1. A magnesium-base alloy consisting essentially of from 0.2 to 2 percent by weight of silicon, from 0.2 to 1.5 percent by weight of zinc, the balance being essentially magnesium.

2. A magnesium-base alloy consisting essentially of from 0.5 to 1.5 percent by weight of silicon, from 0.5 to 1.3 percent by weight of zinc, the balance being essentially magnesium.

3. A magnesium-base alloy consisting essentially of

from 1 to 1.5 percent by weight of silicon, about 1 percent by weight of zinc, the balance being essentially magnesium.

References Cited in the file of this patent

FOREIGN PATENTS

40 40,937 Denmark _____ Oct. 4, 1929
409,770 Italy _____ Mar. 3, 1945