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3,252,841
ALUMINUM ALLOY
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This application is a continuation-in-part of patent
application Serial No. 182,649, filed March 26, 1962,
now abandoned.

This invention relates to aluminum alloys and more
particularly is concerned with a novel aluminum base
magnesium-silicon alloy containing additive metals in
predetermined quantities which provide a specific rela-
tionship between silicon and the additive metal and to
a high strength extruded product prepared thereby.

In general, the novel aluminum base alloy of the pres-
ent invention contains on a weight basis from about 0.5
to about 2 percent magnesium, from about 0.5 to about
10 percent silicon, from about 0.5 to about 20 percent
of an additive metal selected from the group consisting
of calcium, strontium, barium, rare earth, thorium and
mixtures thereof, balance aluminum, and being further
characterized in that the silicon and additive metal are
maintained within a specific predetermined ratio and the
silicon content is about equal to or in excess of that
needed for formation of magnesium silicide (Mg_2Si).

By maintaining these specific relationships between
the concentrations of alloying ingredient and silicon in
the present novel alloy, I have discovered that unexpect-
edly high tensile strengths are realized in extruded prod-
ucts prepared therefrom. The alloy is particularly suit-
ed for the preparation of pellet extrusions which exhibit
excellent and unusually high tensile strength in the ex-
truded, solution heat treated, quenched and aged con-
dition. The excellent strength characteristics of the ex-
truded products prepared from the present novel alloy
having these well-defined and requisite interrelationships
of alloying component concentrations are not predictable
nor anticipated from the known art.

To illustrate; Wood et al. (U.S. 1,932,836) alleges
an aluminum base casting alloy having high fluidity and
good general casting properties in the molten state. This
alloy contains 1 to 8 percent magnesium, 0.5 to 6 per-
cent zinc and 0.01 to 2 percent calcium, the balance being
substantially aluminum. This patent suggests that other
alloying elements such as manganese, nickel, copper,
silicon, etc. in undetermined amounts may be added in
some instances. This patented alloy which must con-
tain zinc (excluded from the present novel alloy) and
suggests the use of silicon only as an optional additive
to be used, if at all, in some undetermined amount is
not pertinent. (Silicon in a controlled, predetermined
concentration is an essential component of the present
novel alloy.)

French patent (975,591) alleges an aluminum base
alloy containing magnesium to which manganese can
be added and which also contains calcium. This alloy,
as is set forth in the patent, contains up to 1 percent
iron, up to 1 percent silicon, up to 1 percent manganese,
from 1 to 13 percent magnesium and from 0.1 to 3
percent calcium. No criticality of ratio and concentra-
tion of silicon-magnesium-additive metal is indicated in
this patent. In fact, the range covered by the French

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patent cannot meet the requisite alloy ingredient inter-
relationship needed for operability in the present novel
alloy.

Ordinarily, barium, calcium and cerium are employed
as additive metals in the present novel alloy. The actual
amount of additive to be employed in the alloy is varied
within the disclosed range in accordance with the prop-
erties and characteristics, e.g. density, etc., desired in
the extruded product. The actual silicon content em-
ployed in the alloy, within the range of from 0.5 to 10
percent as set forth hereinbefore, is established and main-
tained in accordance with the equation:

$$\text{Wt. percent Si} \geq \frac{\text{Wt. percent Mg.}}{1.73} + K \text{ (weight percent additive member)}$$

Minimum values for K to be used with the preferred
additive metals to assure the incorporation of the requi-
site amount of silicon into the alloy are barium (0.1),
calcium (1.0) and cerium, (added as misch metal) (0.1).
Preferably, for optimum alloy properties the silicon con-
tent is determined using the following K values in the
equation; barium (0.2), calcium (1.4) and cerium (0.2).

The operable concentration range and preferred con-
centration range of barium, calcium and cerium to be
employed in the alloy are shown in Table I.

TABLE I

Metal	Concentration in Alloy (weight percent)	
	Operable Range	Preferred Range
Barium.....	(1-10)	(3-6)
Calcium.....	0.75-6	2-4
Cerium ¹	1-20	5-10

¹ Added as misch metal.

If it is desired to employ thorium, strontium, or other
rare earths as additives in the alloy the absolute quan-
tities of these elements and the ratio to be used for de-
termining silicon level is the atomic percent equivalent
of the concentration levels shown hereinabove for bari-
um, calcium or cerium.

The additive members can be used alone in the alloy
or a mixture of additives can be employed. With mix-
tures of additive metals the concentration of each of
the individual members used therein is proportionally
reduced so that the total concentration of the additive
in the alloy falls within the range and in accordance with
the relationships set forth hereinbefore.

The alloy is prepared using foundry alloying and melt
techniques as practiced in the aluminum art.

This alloy is suited for use both with ingot and pellet
extrusion processes and as set forth hereinbefore is par-
ticularly suitable for fabricating high strength pellet ex-
trusions. For the two types of extrusion operations, a
melt of the alloy is solidified into ingots, or preferably
more rapidly quenched as by atomizing into pellets.
Conveniently pellets can be produced by jet atomizing
or wheel atomizing either in an inert atmosphere such as
natural gas, nitrogen, argon, etc. for example, or in air.
The billet or atomized pellets are fabricated into extru-

sions using normal billet or pellet extrusion techniques and apparatus.

For use in the pellet extrusion process, ordinarily the pellets are preheated to a temperature at least that of the extruder container and the heated pellets then are loaded into the container and extruded. However, if desired, the pellets can be used in the extrusion process without preheating. Also, the pellets can be precompacted prior to extrusion. By precompacting the pellets under reduced pressure, blistering and formation of internal voids substantially are avoided during any post extrusion heat treatment that may be employed.

The so-extruded product ordinarily is solution heat treated, quenched and aged thereby providing a final product exhibiting unexpectedly high tensile strength. In this treatment, preferably the length of time for solution heat treatment is minimized to avoid (1) agglomeration of any dispersed phase that might be present in the alloy, (2) recovery, (3) recrystallization and (4) loss of strength.

For those alloys which contain silicon in excess of the solid solubility of this element in the alloy, high strength extrusions and particularly pellet extrusions unexpectedly can be produced at relatively low extrusion temperatures, i.e. from about 750 to about 850° F. Further increase in the strength of the extrusion results by directly quenching the extruded product as it emerges from the die and aging.

The following example will serve to illustrate further the utility of the present invention but is not meant to limit it thereto.

Example.—An aluminum base-magnesium-silicon alloy containing either barium, calcium or cerium (added as misch metal) as an additive member was prepared. One portion of the alloy was atomized into pellets, about 85% of which ranged from -20 +200 mesh, U.S. Standard Sieve, balance passing through the 200 mesh sieve. A second portion of the alloy was cast into a 3 inch diameter ingot.

The two forms of the alloy were extruded as follows.

For the pellet extrusion, a batch of the pellets was preheated to about 700° F. and placed in the pellet container of a ram extruder which container also was about this same temperature.

For ingot extrusion, billets about 4 inches long were cut from the cast ingot.

The pellets and billets both were extruded at an extrusion temperature of about 800° F. and an extrusion rate of about 5 feet per minute into a strip 0.2 inch thick by 1 inch wide. The resulting strip then was solution heat treated at about 970° F. for ½ hour, quenched and aged 16 hours at 320° F.

Standard test bars were prepared and the percent elongation, tensile yield strength and tensile strength of the alloys determined at room temperature. The results of these tests are presented in Table II which follows.

TABLE II

Run No.	Alloy Composition (Values are wt. percent)	K	Test Results		
			Percent E	1,000 p.s.i.	
				TYS	TS
Ingot Extrusion:					
1-----	Al-1.2 Mg-1.55 Si-4 Ba-----	0.2	6	41	45
2-----	Al-1.2 Mg-2.3 Si-4 Ba-----	0.4	7	42	47
3-----	Al-1.2 Mg-3.5 Si-2 Ca-----	1.4	4	42	46
4-----	Al-1.2 Mg-1.7 Si-5 Ce ¹ -----	0.2	8	39	45
5-----	Al-1.2 Mg-2.7 Si-5 Ce ¹ -----	0.4	6	47	51
Pellet extrusion:					
6-----	Al-1.5 Mg-4 Si-2 Ca-----	1.6	4	50	56

¹ Added as misch metal.

In a manner similar to that shown by the foregoing examples, alloys can be prepared containing:

- Al-1Mg-0.7Si-1Ba (K=0.1)
- Al-0.5Mg-1.3Si-10Ba (K=0.1)
- Al-1.4Mg-1.4Si-3Ba (K=0.2)
- Al-1.0Mg-1.8Si-6Ba (K=0.2)
- Al-1.3Mg-1.25Si-0.5Ba (K=1.0)
- Al-1.5Mg-6.9Si-6Ca (K=1.0)
- Al-1.4Mg-9.2Si-6Ca (K=1.4)
- Al-1.0Mg-1.6Si-0.75Ca (K=1.4)
- Al-1.4Mg-9Si-1Ce (K=0.1)
- Al-1.4Mg-2.8Si-20Ce (K=0.1)
- Al-1.4Mg-1.8Si-5Ce (K=0.2)
- Al-1.4Mg-2.8Si-10Ce (K=0.2)

These alloys readily can be fabricated into ingots or pellets and subsequently extruded into fabricated form.

Various modifications can be made in the present invention without departing from the spirit or scope thereof for it is understood that I limit myself only as defined in the appended claims.

I claim:

1. A high strength aluminum alloy pellet extrusion consisting essentially of from about 0.5 to about 2 weight percent magnesium, from about 0.5 to about 10 weight percent silicon, an additive metal, and remainder aluminum, said additive metal being a member selected from the group consisting of barium, calcium and cerium, said alloy being further characterized in that the concentration of said additive metal and the actual weight percent of silicon in said alloy are predetermined in accordance with the following relationship:

- (a) wt. percent Si $\geq \frac{\text{wt. percent Mg.}}{1.73} + 0.1$ (1-10 wt. percent barium)
- (b) wt. percent Si $\geq \frac{\text{wt. percent Mg.}}{1.73} + 1.0$ (0.75-6 wt. percent calcium)
- (c) wt. percent Si $\geq \frac{\text{wt. percent Mg.}}{1.73} + 0.1$ (1-20 wt. percent cerium)

said extrusion being in the extruded, solution heat treated, quenched and aged condition and characterized by an unexpectedly high tensile strength.

2. A high strength aluminum alloy pellet extrusion consisting essentially of from about 0.5 to about 2 weight percent magnesium, from about 0.5 to about 10 weight percent silicon, an additive metal, and remainder aluminum, said additive metal being a member selected from the group consisting of barium, calcium and cerium, said alloy being further characterized in that the concentration of said additive metal and the actual weight per-

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cent of silicon in said alloy are predetermined in accordance with the following relationship:

- (a) wt. percent Si $\geq \frac{\text{wt. percent Mg.}}{1.73} + 0.2$ (3-6 wt. percent barium)
- (b) wt. percent Si $\geq \frac{\text{wt. percent Mg.}}{1.73} + 1.4$ (2-4 wt. percent calcium)
- (c) wt. percent Si $\geq \frac{\text{wt. percent Mg.}}{1.73} + 0.2$ (5-10 wt. percent cerium)

said extrusion being in the extruded, solution heat treated, quenched and aged condition and characterized by an unexpectedly high tensile strength.

3. A high strength aluminum alloy pellet extrusion consisting essentially of about 1.5 weight percent mag-

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nesium, about 2 weight percent calcium, about 4 weight percent silicon, balance aluminum, said extrusion being in the extruded, solution heat treated, and aged condition and characterized as having a minimum tensile yield strength of about 50,000 p.s.i.

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