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ALUMINUM BASE ALLOY

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ABSTRACT OF THE DISCLOSURE

The present invention relates to new and improved aluminum base alloys containing magnesium. More particularly, the present invention resides in aluminum base alloys containing from 5.5 to 10% magnesium and characterized by improved physical properties such as high strength and stress corrosion resistance.

The advantages to be derived from alloying magnesium with aluminum base alloys were recognized very early in the development of aluminum technology. Consequently, the aluminum-magnesium series of alloys is one of the oldest used commercially.

The development of inert gas shield arc methods in welding in recent years has stimulated additional interest in sheet and plate of the stronger alloys in this series. In addition, the excellent physical properties of these alloys in welded structures is well recognized, such as the high yield strength obtainable without heat treatment, good weldability and good ductility.

Attempts have frequently been made to increase the magnesium content of the aluminum base alloys in wrought form up to 10%. These attempts, however, have not resulted in commercialization of aluminum base alloys containing more than 5.5% magnesium because of inherent problems of stress corrosion susceptibility of these alloys in the cold worked condition. Therefore, at the present time there are no satisfactory commercially available aluminum base alloys containing more than 5.5% magnesium in cold worked tempers.

It is, therefore, highly desirable to develop such alloys due to the excellent physical properties which they promise, such as light weight, high strength levels equivalent to those of mild steel, excellent ductility and weldability. However, the inherent problems of stress corrosion susceptibility of these alloys in the cold worked tempers must be overcome. In other words, aluminum base alloys containing greater than 5.5% magnesium are generally not used at present commercially in strain hardened tempers because of their great susceptibility to stress corrosion cracking.

Accordingly, it is a principal object of the present invention to provide new and improved aluminum base alloys containing greater than 5.5% magnesium.

It is a further object of the present invention to provide alloys as aforesaid which are characterized by excellent physical characteristics, such as high yield strength, good weldability and good ductility.

It is a still further and particular object of the present invention to provide alloys as aforesaid which overcome the great susceptibility of this type of alloy to stress corrosion cracking.

It is a further object of the present invention to provide a convenient and expeditious process for obtaining the aforesaid alloys.

Further objects and advantages of the present invention will appear hereinafter.

It has been found in accordance with the present invention that the foregoing objects and advantages may be readily attained by providing an aluminum base alloy consisting essentially of the following composition: from 5.5 to 10% magnesium; from 0.05 to 0.3% chromium; from 0.10 to 0.80% cobalt; from 0.10 to 0.60% copper; and the balance essentially aluminum. In the preferred embodiment, the present invention employs from 6 to 8% magnesium; from 0.1 to 0.2% chromium; from 0.15 to 0.60% cobalt; from 0.15 to 0.40% copper; and the balance essentially aluminum.

It has been found surprisingly that the foregoing alloy in the foregoing critical compositional ranges overcomes the heretofore noted disadvantages of the art. Particularly surprising is the unusual stress corrosion resistance of the alloy of the present invention. For example, environmental stress corrosion tests were run in a rigorous atmosphere with the following results: an alloy of the present invention containing 7.2% magnesium, 0.15% chromium, 0.56% cobalt, and 0.26% copper, balance essentially aluminum, was subjected for a period in excess of one year with no stress corrosion failures, with the test still proceeding; whereas substantially the same alloy without the cobalt and copper exhibited stress corrosion failure in 300 days; and substantially the same alloy without the cobalt, copper and chromium exhibited stress corrosion failure after 100 days of exposure.

Furthermore, the present invention provides a process for obtaining the foregoing improved alloys which comprises: (A) providing an aluminum base alloy consisting essentially of the foregoing materials in the foregoing critical compositional ranges; (B) hot rolling said alloy at a temperature of from 450 to 950° F. to a gage of less than 2″; and (C) cold rolling said alloy. The alloy is preferably cold rolled to intermediate gage, although it may be cold rolled to final gage directly, if desired. The amount of cold rolling reduction is limited by mill capability.

Prior to the hot rolling step, it is preferred to provide a heat treatment or homogenization step at from 850 to 975° F. for from 5 to 30 hours and preferably 10 to 16 hours.

Preferably the alloy is stabilized after cold rolling by holding at a temperature of from 200 to 450° F. for at least 15 minutes and preferably 1 to 4 hours; however, the alloy may, if desired, be utilized in the cold rolled condition.

In the preferred embodiment the following additional process steps are performed after cold rolling but before stabilizing in the event that more cold rolling reduction is necessary or desired or if the material is required in the annealed temper: (D) annealing at a temperature of 500 to 1000° F., and preferably 650 to 950° F. for at least 5 minutes and preferably at least 60 minutes; and (E) cooling said alloy, preferably at a rate of 50° F. per hour or less, to room temperature. After the intermediate anneal, the alloy may again be cold rolled to the desired temper. This sequence of annealing, cooling, and cold rolling may be repeated as often as necessary. In addition, as indicated above, the alloy may be stabilized after the final cold roll by holding said alloy at a temperature of 200 to 450° F. for at least 15 minutes and preferably 1 to 4 hours.

It is further preferred that all thermal treatments, including the preliminary heat treatment or homogenization treatment, the hot rolling step, and subsequent interannealing of the hot rolled material, be followed by a slow, controlled cool down rate of 500° F. per hour or less to room temperature and preferably 50° F. per hour or less.

The process of the present invention provides an improvide alloy in the cold rolled tempers. The greatest improvements are provided when the alloy is subjected to two (2) or more cold rolls with intermediate anneals and in particular when the alloy is in the cold rolled plus stabilized condition. When the alloy is in the cold worked temper it is characterized by a minimum yield strength of 45,000 p.s.i., with yield strengths generally on the order of 48,000 to 60,000 p.s.i., a minimum tensile strength of 55,000 p.s.i. and generally from 60,000 to 75,000 p.s.i. and a minimum elongation of 6% with elongations generally on the order of 8 to 10%. After recovery, i.e., after the holding or stabilizing step, the alloy is characterized by a minimum yield strength of 35,000 p.s.i. and generally from 37,000 to 55,000 p.s.i., a minimum tensile strength of 50,000 p.s.i. and tensile strength generally from 56,000 to 70,000 p.s.i. and a minimum elongation of 12% with elongations generally from 15 to 20 percent.

It is also quite surprising that the fully annealed properties of the alloys of the present invention are quite high as compared to conventional aluminum-magnesium alloys, for example, the fully annealed properties of the alloys of the present invention are: yield strength, from 20,000 to 30,000 p.s.i., tensile strength, from 45,000 to 55,000 p.s.i., and elongation, from 20 to 30%.

The foregoing characteristics of the alloys of the present invention are particularly surprising and represent a considerable improvement over conventional alloys of this type.

In addition, the cold rolled properties, both before and after recovery, are characterized by good corrosion resistance and excellent stress corrosion resistance. These alloys, surprisingly, will not fail both in cold worked and stabilized tempers under prolonged exposure in the ambient temperature range, i.e., up to 180° F.; whereas, all other alloys of this type will catastrophically fail under these conditions. The alloys of the present invention in the cold worked and stabilized tempers have been shown to hold up for one year and longer in rigorous, natural environmental testing, with the test still proceeding without failure.

The melting and casting of the alloys is not particularly critical. The alloys may be melt and cast by any conventional method, such as, for example, the direct chill or tilt mold method.

The alloy of the present invention also exhibits good physical properties as a cast product and will show a significant strength advantage over conventional aluminum-magnesium alloys. For this use, the alloy may be cast into final shape using conventional sand and permanent molding techniques.

In addition to the foregoing critical alloying additions, the present invention contemplates small amounts of additional alloying ingredients which will not deleteriously affect the properties of the alloy and may, in fact, enchance a given physical property. For example, indium; gallium; cadmium; lithium; manganese; zinc; thorium; boron; tellurium; misch metal; germanium; and hafnium.

In addition to the foregoing alloying additions, naturally the present invention contemplates the use of the normal impurity levels common to commercial grade aluminum. However, impurity ranges should be maintained within the following limits: iron, up to 0.50%; silicon, up to 0.50%; manganese, up to 0.35%; zinc, up to 0.2%; titanium, up to 0.15%; beryllium, up to 0.02%; and others in total up to 0.2%. In fact, it may be desirable to add one or more of the foregoing materials in order to enhance a given property, for example, castability or to minimize staining during annealing. Beryllium is a preferred alloying addition in amounts from 0.0005 to 0.02%, and optimally from 0.001 to 0.005%.

The present invention will be more readily understandable from a consideration of the following illustrative examples.

EXAMPLE I

Ingots, designated alloy A, were prepared of the alloy of the present invention in a conventional manner summarized as follows: melting and alloying were carried out in an induction heating furnace. The melt was stirred after each alloying addition and just before flexing, with the melt being degassed by gaseous chlorine fluxing at a rate of 3000 cc. per minute for 15 minutes. The melt temperature was maintained at 1350 to 1360° F. The charge was then bottom poured using standard, direct chill casting techniques at an average casting speed of 3.5 to 4.0" per minute on a 3" x 6" mold section.

The alloys of the present invention were prepared in this manner and had the following composition:

	Percent
Magnesium	7.2
Iron	0.29
Silicon	0.12
Copper	0.26
Titanium	0.13
Beryllium	0.002
Chromium	0.15
Cobalt	0.56

EXAMPLE II

For comparative purposes, two alloys were prepared in the same manner as in Example I to have the following composition:

Comparative alloy B

	Percent
Magnesium	7.2
Iron	0.05
Silicon	0.05
Copper	0.03
Titanium	0.004
Beryllium	0.001
Chromium	0.004

Comparative alloy C

Magnesium	7.0
Iron	0.255
Silicon	0.11
Copper	0.082
Titanium	0.015
Beryllium	0.005
Chromium	0.10

EXAMPLE III

The alloys prepared in Examples I and II were homogenized at 950 to 975° F. for 16 hours at temperature followed by slow cooling at a rate slower than 50° F. per hour to room temperature. The ingots were then hot rolled at 675° F. to 0.172" gage, followed by slow cooling at the above rate to room temperature, followed by cold rolling to 0.086" gage. The alloys were then interannealed at 800° F. for 4 hours followed by slow cooling to room temperature at the above rate followed by cold rolling to 0.060" gage. The alloys were then cut up for testing with the following results:

TABLE I

Alloy	Yield Strength, p.s.i.	Tensile Strength, p.s.i.	Elongation, percent
A	50,000	64,400	6.7
B	41,400	54,500	11.4
C	49,900	63,500	8.6

EXAMPLE IV

The alloys treated in accordance with Example III in 0.060" gage were stabilized by heating to 300° F. and holding at that temperature for four hours. The alloys were then cut up for testing with the following results:

TABLE II

Alloy	Yield Strength, p.s.i.	Tensile Strength, p.s.i.	Elongation, percent
A	40,600	59,500	13.8
B	28,000	47,300	22.7
C	37,600	56,800	18

EXAMPLE V

This example shows the surprising stress corrosion resistance of the alloys of the present invention. In this example various samples were subjected to environmental stress corrosion tests run in a rigorous atmosphere. The test consisted of exposing a pre-stressed sample to the elements on the beach at Daytona Beach, Fla., for a period of time until the sample showed failure by stress corrosion cracking. The sample was pre-stressed by bending in the shape of a letter U. Normally the failure by stress corrosion cracking was first exhibited at the apex of the sample.

Alloys A, B and C were tested, with each sample being tested in the following conditions: (1) five samples in the cold worked condition after the treatments of Example III; (2) five samples in the stabilized condition after the treatments of Example IV; and (3) five samples in the sensitized condition, a condition designed to exaggerate stress corrosion susceptibility. The sensitization treatment consisted of heating to 300° F., holding for

24 hours and cooling to room temperature. The results are shown in the following table:

TABLE III

Alloy	Condition	Time to Failure by Stress Corrosion Cracking
A	Cold Worked	No failure after 15 months and still testing.
A	Stabilized	Do.
A	Sensitized	No failure after 10 months and still testing.
B	Cold Worked	All samples failed from 111 to 185 days.
B	Stabilized	All samples failed from 27 to 55 days.
B	Sensitized	All samples failed from 24 to 35 days.
C	Cold Worked	No failure after 12 months and still testing.
C	Stabilized	No failure after 14 months and still testing.
C	Sensitized	All samples failed from 100 to 300 days.

This invention may be embodied in other forms or carried out in other ways without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered as in all respects illustrative and not restrictive, the cope of the invention being indicated by the appended claims, and all changes which come within the meaning and range of equivalency are intended to be embraced therein.

What is claimed is:

1. An aluminum base alloy having good stress corrosion resistance consisting essentially of: from 5.5 to 10% magnesium; from 0.05 to 0.3% chromium; from 0.10 to 0.80% cobalt; from 0.10 to 0.60% copper; and the balance essentially aluminum.

2. An aluminum base alloy having good stress corrosion resistance consisting essentially of: from 6 to 8% magnesium; from 0.1 to 0.2% chromium; from 0.15 to 0.60% cobalt; from 0.15 to 0.40% copper; and the balance essentially aluminum.

3. An alloy according to claim 1 containing beryllium in an amount from 0.0005 to 0.02%.

4. An alloy according to claim 2 containing beryllium in an amount from 0.001 to 0.005%.

5. An alloy according to claim 1 containing iron in an amount up to 0.50%, silicon in an amount up to 0.50%, manganese in an amount up to 0.35%, zinc in an amount up to 0.2%, titanium in an amount up to 0.15%, beryllium in an amount up to 0.02%, and all others in total up to 0.2%.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

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It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, lines 12 and 13, "improvide" should read -- mproved --; line 68, "enchance" should read -- enhance --. olumn 4, line 52, before "0.004" insert -- less than --; line 53, efore "0.001" insert -- less than --; line 54, before "0.004" nsert -- less than --.

Signed and sealed this 9th day of December 1969.

:AL)

est:

'ard M. Fletcher, Jr.

:sting Officer

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Commissioner of Patents