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3,544,394

ALUMINUM-COPPER-MAGNESIUM-ZINC POWDER METALLURGY ALLOYS

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2 Claims

ABSTRACT OF THE DISCLOSURE

Aluminum base powder metallurgy alloy article having an improved combination of high transverse yield strength and high stress corrosion cracking resistance. The alloy contains the basic precipitation hardening elements zinc, magnesium and copper plus dispersion strengthening elements iron and nickel. It may additionally contain chromium and/or manganese. The alloy is prepared by atomization of a melt of the elements, hot working, solution heat treating, quenching and artificial aging. Components of the alloy in percent by weight are, in addition to the aluminum, from at least 6.5 to 13 zinc, 1.75 to 6 magnesium, 0.25 to 2.5 copper, 0.75 to 4.25 iron and 0.75 to 6 nickel, up to 3 manganese and up to 0.75 chromium. The iron to nickel ratio is from 0.2:1 to 2.0:1.

BACKGROUND OF THE INVENTION

This invention relates to aluminum-copper-magnesium-zinc alloys prepared by powder metallurgy techniques. More particularly, it pertains to improving tensile and stress corrosion properties of articles prepared from aluminum-copper-magnesium-zinc alloys by the addition of certain dispersion strengthening elements to the melt from which the alloys are prepared by atomization. By powder metallurgy techniques we mean those processes in which the molten alloy is atomized to make fine powder, the powders are compacted, and the compact is fabricated into the desired form by hot working. The invention herein described was made in the course of or under a contract or subcontract thereunder with the Department of the Army.

One way in which to improve tensile properties, that is, in general to strengthen aluminum base alloys is by precipitation hardening. This occurs when a supersaturated solid solution precipitates its excess solute. The process is favored in alloy systems with appreciably greater solubility for the solute at elevated temperatures than at lower or ambient temperatures. The precipitate effects strengthening of the structure by setting up coherency strains in the matrix by the precipitated particles. Zinc, magnesium and copper are well known as elements which contribute substantially to precipitation hardening. It is also known that strengthening may be improved by adding to the alloy system one or more elements which form compounds having low solubilities and low diffusibilities in the solid state at elevated temperatures to impart a strengthening effect which lasts even after extensive heat treatment. This type of reaction is commonly referred to as dispersion strengthening or interference hardening.

Copper, magnesium and zinc have been disclosed to be useful precipitation hardening elements for use in aluminum base alloys. Individual dispersion strengthening ele-

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ments which have been suggested for use in improving the properties of aluminum base alloys include manganese, iron, nickel, chromium, titanium, vanadium, zirconium, cobalt, molybdenum and tungsten. Thus far it has not proved too difficult to add precipitation hardening elements because of their characteristic high liquid solubilities, high solid solubilities at high temperatures, and high solid diffusibilities at high temperatures. However, for addition of dispersion strengthening elements, standard ingot casting procedures have been of limited use when it was desired to modify the alloy composition by addition of considerable amounts of these elements. This has been due to the fact that dispersion strengthening elements are characterized by low liquid solubilities near the solidification temperatures and low solid solubilities and low solid diffusibilities at elevated temperatures. It has been proposed to combine the strengthening characteristics of both precipitation hardening and dispersion strengthening elements by using atomization of alloys from the melt to permit use of higher concentrations of elements than is possible in ingot metallurgy where the casting solidification rates are slow relative to atomizing solidification rates. Use of atomized alloy powders has helped improve the strength properties of aluminum base alloys by resulting in a structure which is several orders of magnitude finer than standard ingot metallurgy alloy structures.

While considerable improvement in strength has been possible by the aforementioned combination of dispersion strengthening and precipitation hardening, particularly with the improved results obtained by atomization of a melt of the alloy containing the dispersion strengthening elements, improvements in stress corrosion cracking resistance, one of the main features desired for light weight rocket motor and aircraft parts, have thus far been rather limited, probably partly because of the fact that, in increasing stress corrosion resistance by standard age hardening procedures, the strength properties of the alloys have been somewhat impaired, making them not entirely satisfactory for some high-stress applications.

OUTLINE OF THE INVENTION

Accordingly, it is an object of this invention to provide a novel hot worked powder metallurgy alloy article which combines a transverse yield strength which is equal to or superior to that of presently known aluminum base ingot metallurgy alloy articles containing the precipitation hardening elements copper, magnesium and zinc with a stress corrosion cracking resistance which is greater than that of such known ingot metallurgy alloy articles. Another object is to provide a method for production of novel powder metallurgy alloys which have a transverse yield strength comparable to that of known aluminum-copper-magnesium-zinc ingot metallurgy alloys plus a higher resistance to stress corrosion cracking. These and other objects of the invention will be apparent from the description and claims which follow.

In accordance with this invention a hot worked powder metallurgy alloy article is prepared in which the alloy contains in percent by weight from at least 6.5–13 zinc, 1.75–6 magnesium, 0.25–2.5 copper, 0.75–4.25 iron and 0.75–6 nickel. The alloy may additionally contain up to 3 manganese (preferably 0.25–2) and up to 0.75 chromium. It may also contain up to 1.5 percent by weight Al_2O_3 and up to a total of about 1 percent by weight of

other elements such as titanium, silicon, vanadium or the like, generally as impurities. The Fe:Ni ratio should be from 0.2:1 to 2.0:1.

One feature of the alloy article of this invention is its combination of high resistance to stress corrosion cracking with high transverse yield strength as great as or superior to that of prior art conventional ingot metallurgy aluminum-zinc-copper-magnesium alloy articles which contain less zinc and no combination of iron and nickel. By high transverse yield strength we mean at least about 60-67 k.s.i. (thousands of pounds per square inch), which is the transverse yield strength of conventional 2-inch diameter ingot metallurgy extruded rods of aluminum-zinc-copper-magnesium alloys containing less than 6.5 percent by weight zinc and not having a combination of iron and nickel. By high resistance to stress corrosion cracking we mean an absence of cracking or breaking apart of a solution heat treated and artificially aged 2-inch diameter extruded rod after at least 84 days under a stress in a transverse direction of 50 percent of its transverse yield strength in the standard stress corrosion test of alternate immersion in a 3.5 percent by weight sodium chloride solution. [ASTM STP425 (1967), pp. 8 and 188] The aforementioned conventional rods fail, that is, crack or break apart, in this test in less than 84 days.

To obtain this combination of high stress corrosion resistance and high transverse yield strength, the aging is preferably at a temperature of from about 225° to 350° F. for from about 3 to about 100 hours. According to another embodiment, a two-stage aging procedure may be used in which the first stage is at from about 225° F. to about 275° F. for from about 6 to about 96 hours and the second at from about 315° F. to about 350° F. for from about 3 to about 40 hours. The solution heat treatment is preferably at a temperature of from about 750° to 1000° F. The solution heat treatment and aging procedures described in Sprowls et al. U.S. 3,198,676 may be used according to this invention.

One method for preparation of the alloy articles of our invention is as follows:

- (1) Melting and alloying;
- (2) Atomizing, collecting and screening (for example, to 100 mesh powder with a Sharples Micromerograph mass median diameter (MMD) of 5-60 microns);
- (3) Compacting to less than 100 percent density e.g., in a tapered or split die;
- (4) Degassing by heating in a flowing nonoxidizing atmosphere;
- (5) Hot compacting to substantially 100 percent density, and then
- (6) Hot working.

The hot working may be by conventional extrusion, forging, impact extrusion or rolling.

The solution heat treatment which helps to achieve the combined high stress corrosion cracking resistance and high transverse yield strength of the alloys of this invention involves heating them as suggested for contrasting ingot metallurgy alloys containing copper, magnesium, zinc and aluminum in above-mentioned U.S. Pat. 3,198,676 to our coworkers Sprowls et al. to a temperature within the range of about 750° to 1000° F., but below the temperature of incipient fusion, and holding them within that range for a length of time sufficient to obtain substantially complete solution of the zinc, magnesium and copper components. Generally, this can be accomplished within a period of from 3 or 4 minutes up to about 10 hours depending on the thickness of the article being treated and whether the surface of the article is directly exposed to the heating medium. At the conclusion of the solution heat treatment the articles are rapidly cooled to substantially room temperature, for example, by quenching in water at temperatures below about 160° F. Cooling in this manner serves to retain a substantial portion of the dissolved components in a state of solid solution. However, by employing hot water instead of cold water it is

possible to further minimize stresses which may be induced by quenching. The above-mentioned aging treatment then follows:

The examples in the table which follows are illustrative of the improved powder metallurgy aluminum base alloy articles of the present invention. In each instance the sample survived at least 84 days without stress corrosion cracking failure when subjected to the above described standard test for measuring resistance to stress corrosion cracking. Prior art aluminum-zinc magnesium-copper ingot metallurgy alloy samples of similar composition but with less than 6.5 percent by weight zinc and no elements other than the aluminum-zinc-magnesium and copper (except for not more than a total of 1 percent of other elements present as impurities) were also tested. These failed under the same test conditions in less than 84 days. Solution heat treatment for each sample in the table was at 860° F. for 2 hours. The samples treated were prepared by atomizing a melt of the alloy to produce finely divided cast particles and screening so that most of the particles passed through a 100 mesh screen. The atomized powder of each composition was pressed to a density of 71-79 percent of the theoretical at room temperature, degassed by heating at 820° to 1000° F. in a flowing argon atmosphere and then extruded directly or first compressed and then extruded. Extrusion sizes (before scrap cuts) were about 4.5 to 4.6 feet in length by about 2 inches in diameter.

TABLE

Sample	Quench	Aging				Tr YS ⁷
		First stage		Second stage		
		Hours	° F.	Hours	° F.	
1 ⁴	CW ³	24	250	40	330	67
2 ⁵	CW	8	330	(1)		89.3
2 _a	CW	6	250	8	330	82.0
2 _b	CW	16	330			80.4
2 _c	CW	6	225	8	350	75.6
2 _d	CW	48	315			73.2
2 _e	CW	32	330			73.2
2 _f	CW	8	350	11		71.7
2 _g	BW ²	24	250			71.6
2 _h	BW ²	8	330			61.8
3 ⁶	CW	6	250	8	330	75.8
3 _a	CW	16	330			70.2
3 _b	CW	48	315			66.2

¹ No second-stage aging.

² Boiling water quench.

³ Cold water quench.

⁴ Sample 1 contained in percent by weight: 10.2 Zn, 3.9 Mg, 1.6 Cu, 1.0 Fe,

4.1 Ni, 1.6 Mn, balance Al.

⁵ Samples 2 through 2h contained in percent by weight 7.8 Zn, 2.5 Mg,

1.0 Cu, 3.5 Fe, 4.9 Ni, .09 Cr, balance Al.

⁶ Samples 3, 3a and 3b contained in percent by weight 7.6 Zn, 2.5 Mg,

1.1 Cu, 2.2 Fe, 2.3 Ni, .16 Cr, balance Al.

⁷ Transverse yield strength.

⁸ Thousands of pounds per square inch.

It is evident from the foregoing data that according to our invention we have provided an improved hot worked powder metallurgy alloy article of high corrosion resistance coupled with high transverse yield strength. One of the advantages of our invention is the opportunity to vary the aging conditions within the established ranges so as to optimize the improved properties for the particular alloy used.

Whereas particular embodiments of the invention have been described above for purposes of illustration, it will be evident to those skilled in the art that numerous variations of the details may be made without departing from the invention as defined in the appended claims.

Having thus described our invention and certain embodiments thereof, we claim:

1. A process for preparation of an aluminum base powder metallurgy alloy article of high stress corrosion cracking resistance and high transverse yield strength which comprises atomizing a melt of an aluminum base alloy consisting essentially of in percent by weight from at least 6.5 to 13 zinc, 1.75 to 6 magnesium, 0.25 to 2.5 copper, 0.75 to 4.25 iron, 0.75 to 6 nickel, up to 0.75 chromium, up to 3 manganese and balance aluminum, hot working the resulting powder, solution heat treating the resulting article, and aging said article at from about

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225° F. to about 350° F. for from about 3 to about 100 hours, thereby imparting to said article a high resistance to stress corrosion cracking and a high transverse yield strength.

2. The process of claim 1 wherein the aging is first at from about 225° F. to about 275° F. for from about 6 to about 96 hours and then at from about 315° F. to about 350° F. for from about 3 to about 40 hours.

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