Nov. 24, 1970 E. J. WESTERMAN ET AL 3,542,606

HOT WORKED METAL ARTICLE OF ALUMINUM BASE ALLOY AND METHOD OF PRODUCING SAME

Filed March 15, 1968 2 Sheets-Sheet 1

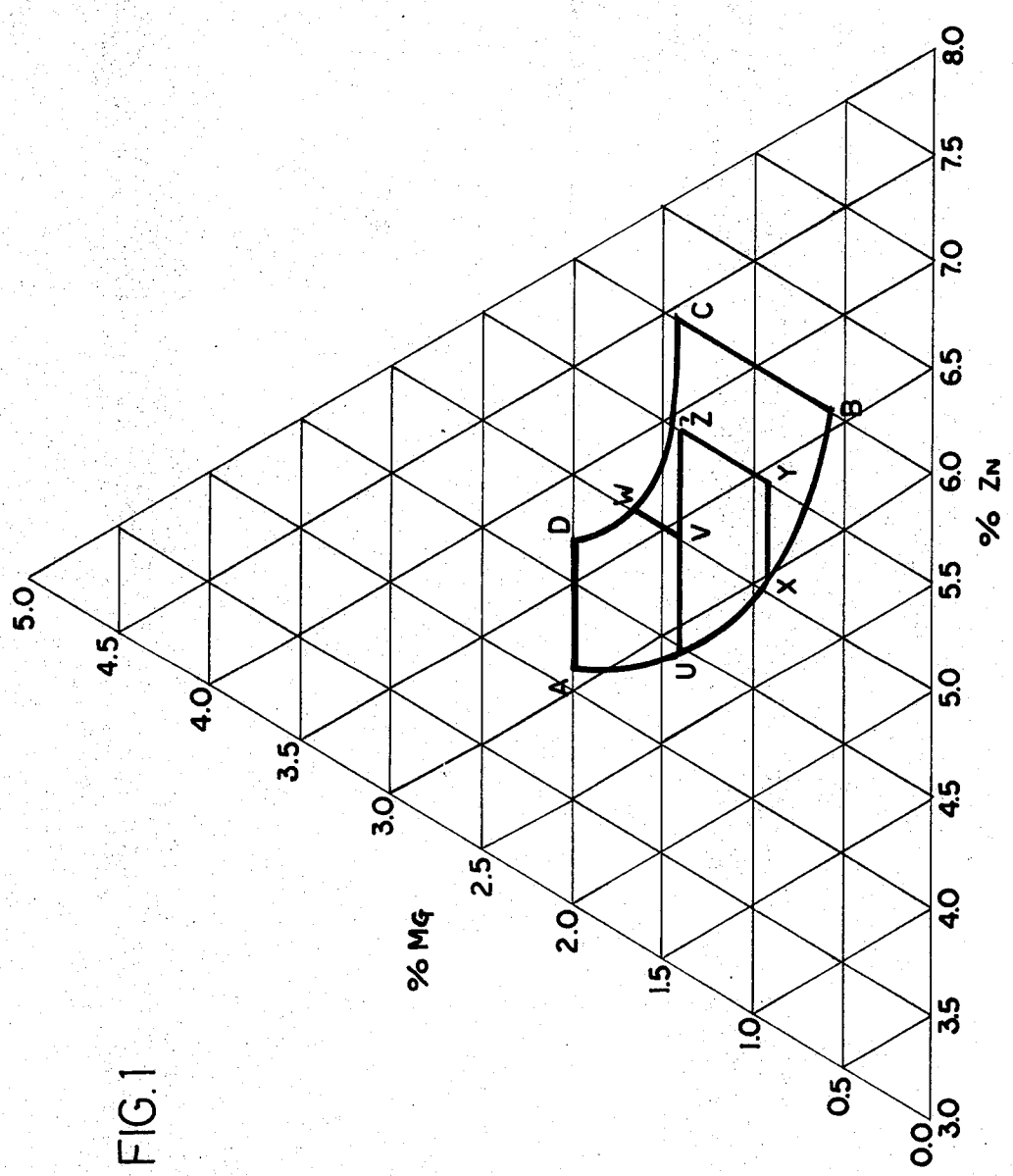


FIG. 1

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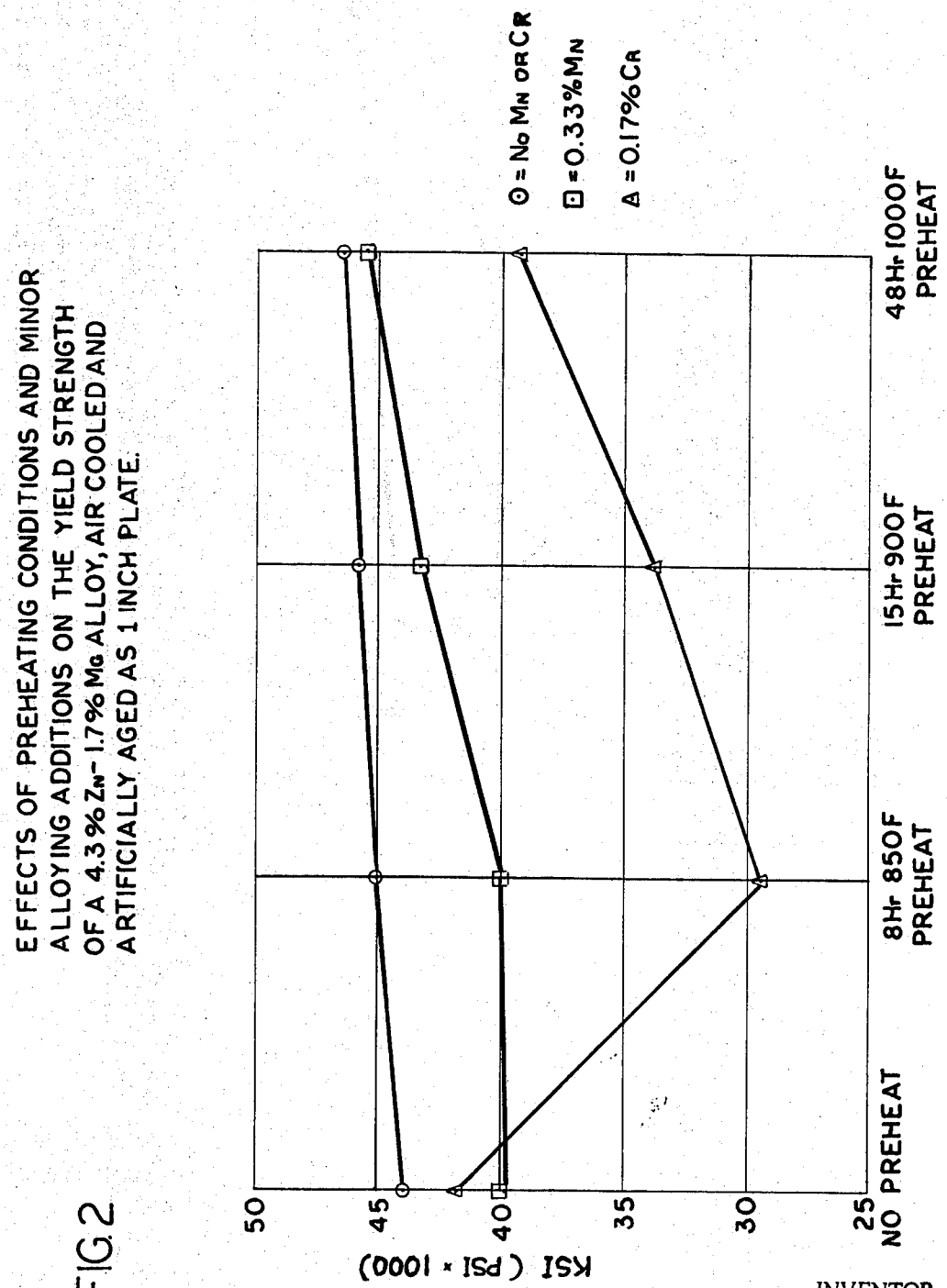


FIG 2

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HOT WORKED METAL ARTICLE OF ALUMINUM BASE ALLOY AND METHOD OF PRODUCING SAME

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U.S. Cl. 148—12.7 44 Claims

ABSTRACT OF THE DISCLOSURE

A hot worked metal article, and a method for producing the article, of certain Al-Zn-Mg-Mn alloys which are Cu-free and Cr-free and which exhibit a low quench-rate sensitivity thereby permitting the fabrication of articles to be hot worked above about the solvus temperature followed by air cooling and subsequent aging to obtain high strength and a high resistance to stress corrosion cracking.

BACKGROUND OF THE INVENTION

This invention relates to hot worked metal articles of aluminum-zinc-magnesium alloys which are strong, weldable and possess a high resistance to stress corrosion. By controlled adjustment of the zinc, magnesium and manganese in the aluminum alloy and by working the alloy above its solvus temperature, high strengths are capable of being attained by air cooling followed by aging (either natural aging or artificial aging). Further, the high strengths of the aluminum alloy articles are attained without distortion or warpage to the article. The high strengths of the aluminum alloy articles of the invention are produced without requiring a separate or subsequent solution heat treatment and quenching after working, thereby eliminating the need for expensive furnace and accessory equipment. For example, extrusions of these alloys can be air cooled from the die, plate material can be air cooled from the hot rolling operation and forgings can be air cooled from the forging press. The invention is of particular importance to facilities that do not have solution heat treat furnaces and quench tanks.

It has been long known that aluminum base alloys containing substantial amounts of zinc and magnesium develop high strength when solution heat treated and aged. Although solution heat treated and aged alloys of the Al-Zn-Mg system develop high mechanical strength, these alloys are highly susceptible to stress corrosion, that is, the alloy is susceptible to cracking when simultaneously exposed to tensile stress and corrosive conditions. The problem of improving the Al-Zn-Mg system alloys; that is, combining the high strength with improved resistance to stress corrosion cracking has been the subject of much investigation. Various alloying elements have been added to the ternary alloys in an effort to improve their resistance to stress corrosion. Also, various procedures of solution heating, quenching and aging have been investigated in an effort to reduce stress corrosion cracking.

Alloying elements exert a strong influence on the alloys of the Al-Zn-Mg system. Commonly, copper is an addition element to these alloys, increasing strength upon rapid quenching and improving stress corrosion resistance. However, copper increases the quench rate sensitivity of Al-Zn-Mg alloys; that is, it becomes necessary to quench the alloy rapidly from the solution heating temperature in order to obtain a desired high strength.

It has been known to add a small amount of chromium to the aluminum-magnesium-zinc alloy to avoid stress corrosion, however, the chromium addition in solving one problem creates another. When chromium is incorporated in the alloy, the quench-rate sensitivity is increased. Rapid quenching becomes difficult to obtain when the metal article has a large cross section or thickness, for example, forgings or extrusions of heavy section or a thick plate section.

SUMMARY OF THE INVENTION

Accordingly, it is the primary purpose of the present invention to present an aluminum-zinc-magnesium alloy article which has minimal quench-rate sensitivity and can be air quenched while advantageously maintainng high levels of strength, stress-corrosion resistance, extrudability and weldability. The invention is directed to hot worked articles of a copper-free and chromium-free aluminum base alloy consisting essentially of zinc and magnesium in the amounts, in percent by weight, of those alloys occurring in the ternary diagram of FIG. 1 within the zone bounded by lines AB, BC, CD and DA; manganese 0.2 to 0.5% balance aluminum and normal impurities; and to the process of producing said hot worked article.

These and other purposes and advantages of the novel article of the invention and the method of producing said article will become apparent from the following description thereof.

The present invention is predicated upon the discovery that by proper adjustment of the principal alloying constituents, namely, zinc, magnesium and manganese, the quench-rate sensitivity of the alloy may be sufficiently lowered to permit air hardening of the metal from the hot working temperature, above the solvus temperature, by cooling through the critical range 600–400° F. at a rate of 0.1 to 1.1° F./sec. This permits, then, a hot worked alloy article to be subsequently aged to attain a high strength without a solution heat treatment subsequent to working. Furthermore, the alloys of the invention exhibit a high resistance to stress corrosion cracking and additionally possess good extrudability and weldability characteristics. Alloy compositions of the invention whch are particularly adapted for extrusion consist essentially of Zn and Mg in the amounts of those alloys occurring in the ternary diagram of FIG. 1 within the zone bounded by the lines UX, XY, YZ and ZU; Mn 0.20–0.50%, balance Al and normal impurities. A general purpose alloy for hot working, particularly rolling, and which exhibits high stress corrosion resistance consists essentially of Zn and Mg in the amounts of those alloys occurring in the ternary diagram of FIG. 1 within the zone bounded by the lines AU, UV, VW, WD and DA; Mn 0.20–0.50%, balance Al and normal impurities.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is described with respect to FIG. 1 which is a ternary diagram upon which are plotted the zinc and

magnesium amounts of the aluminum alloys of the invention. The zone bounded by the lines AB, BC, CD and DA defines the zinc and magnesium contents of the alloys of the invention whereas the zones bounded by the lines AU, UV, VW, WD and DA; and lines UX, XY, YZ and ZU define zinc and magnesium contents of alloys (within the broader zone) which have particular properties and/or which are particularly adapted for a given hot working process.

FIG. 2 is a chart showing the effects of preheating conditions and alloying additions of Cr and Mn on the yield strength of an Al-Zn-Mg alloy, air cooled and artificially aged (—T5 temper) as 1 inch plate.

DETAILED DESCRIPTION

In accordance with the present invention, there is presented a broad range of Al-Zn-Mg-Mn alloy compositions which show minimal quench rate sensitivity, while maintaining high levels of strength, stress corrosion resistance, extrudability and weldability of the alloys.

Very low quench-rate sensitivity can be beneficial to the manufacture and fabrication of heat-treatable aluminum alloys, particularly in the case of articles of heavy section. For example, the cost of a furnace solution heat treatment can be eliminated if the semi-fabricated alloy can be solution heat treated by air cooling from a hot working temperature above the alloy solvus. In this regard, extrusions can be air cooled from the die, and plate can be air cooled from the hot rolling operation. The solvus temperature of Al-Zn-Mg-Mn alloys of the invention is generally below 700° F., a temperature which is in the range of the hot working operation. Further, large, hot-formed workpieces, such as cryogenic sphere segments, can be solution heat treated by air cooling from a hot working temperature above the alloy solvus. The problem of warpage from a severe water quench is eliminated. Also, the alloys of the invention can advantageously be used in complex welded structures, such as machine frames. After welding, the structure can be solution heat treated by air cooling from the solution temperature without incurring the warpage which would result from severe water quenching.

The composition of the alloys of the invention consists essentially of Zn and Mg in amounts, in percent by weight, of those alloys occurring in the ternary diagram of FIG. 1, within the zone bounded by lines AB, BC, CD and DA; Mn 0.2–0.5%, balance aluminum and normal impurities.

The alloys of the present invention are copper-free and chromium-free. By copper-free is meant that the copper is below 0.1%. By chromium-free is meant that the alloys contain less than 0.05% chromium. A general purpose alloy which has high short-transverse stress corrosion has a composition consisting essentially of zinc and magnesium in amounts, in percent by weight, of those alloys occurring in the ternary diagram of FIG. 1 within the zone bounded by lines AU, UV, VW, WD and DA; 0.20–0.50% Mn, balance aluminum and normal impurities. Alloys which are advantageously used for extrusion have compositions consisting essentially of Zn and Mg in amounts, in percent by weight, of those alloys occurring in the ternary diagram of FIG. 1 within the zone bounded by lines UX, XY, YZ and ZU; Mn 0.20–0.50%, balance Al and normal impurities.

In regard to the normal impurities occurring in the aluminum alloys, the following elements should be controlled within the following amounts:

Element	Maximum amount, percent	Desired amount, percent
Silicon	0.30	0.10
Iron	0.40	0.20
Titanium	0.10	0.04

Zirconium in small amounts, that is, 0.10% maximum, may be a desired constituent in preventing recrystallization particularly in extruded sections.

The invention is particularly adapted for producing a high strength article of an Al-Zn-Mg-Mn alloy of the invention, which article also possesses high resistance to stress corrosion cracking, wherein the section thickness of the article is 0.125 inch (⅛ inch) or greater.

The method of the present invention comprises the steps of subjecting a body of the Al-Zn-Mg-Mn alloy of the invention to a hot working treatment at a temperature above about the solvus temperature of the alloy but below the temperature of incipient fusion of any alloy phase that may be present, air cooling the hot worked article at a rate of from about 0.1–1.1° F. per second through the range of 600–400° F. and thereafter aging the metal article. Advantageously, prior to hot working of a metal ingot or billet of the alloy, the ingot may be preheated at a high temperature and long time, e.g. at a temperature in the range of 800° F. to 950° F. for a period of time ranging from 8 hours to 24 hours, to increase the strength of the final metal article. This preheating treatment homogenizes the metal ingots with respect to Zn and Mg. As shown hereinbelow and with reference to FIG. 2, the preheat treatment in the case of Al-Zn-Mg-Cr alloys drastically increases the quench sensitivity of this alloy when it contains as little as 0.2% chromium. Apparently, the preheat treatment distributes the chomium into a dispersion which nucleates non-strengthening precipitate containing Zn and Mg during cooling.

The hot worked metal articles of this invention may be air cooled at a rate of from about 0.1 to 1.1° F./sec. either by quiescent air or by a forced air blast or a forced air blast containing moisture. It has been found that metal articles of the present invention having thicknesses as great as 1 inch or more, e.g. 1¼ inches, will develop adequately high strength properties when cooled in quiescent air. With thicknesses greater than that, or when faster cooling of thinner sections is desired for increased strength, the metal article may advantageously be cooled from the hot working temperature by a forced air blast. (The forced air blast may desirably contain a small amount of moisture in order to increase the rate of cooling of these thick sections.)

The metal article after hot working and cooling is aged, either by natural aging or more preferably by a combination of natural aging and artificial aging. In this latter instance, the natural aging step can be from about 1 to 5 days, e.g. 2 days, and then followed by a suitable artificial aging treatment, such as one of the following typical aging conditions:

(a) 24 hours at 250° F.
(b) 48 hours at 240° F.
(c) 8 hours at 190° F. followed by 8 hours at 300° F.

The heat-up rate to temperature should preferably be less than 50° F. per hour. It has been found that faster heating rates produce lower strength in the article.

To further illustrate the improvements gained through the present invention, the following examples are given. The examples are not to be construed as limiting the invention, the scope of which is defined by the appended claims.

EXAMPLE I

To determine the relative effects of Mn and Cr additions on stress corrosion resistance as well as quench-rate sensitivity, ingots measuring 3 inches x 7 inches x 28 inches were cast containing 4.3% Zn and 1.7% Mg; 4.5% Zn and 2% Mg and 6% Zn and 1% Mg. The compositions of the ingots produced, A through H inclusive, are given in Table I. Both the intended compositions and the actual compositions are given.

TABLE I.—COMPOSITIONS OF ALLOYS USED TO DETERMINE THE RELATIVE EFFECTS OF CHROMIUM AND MANGANESE ADDITIONS

Ingot No.	Intended composition, percent by weight [1]			Actual composition, percent by weight							
	Mg	Zn	Minor	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
A	2.00	4.50	0.30 Mn	0.11	0.19	0.01	0.29	2.09	0.01	4.51	0.04
B	2.00	4.50	0.20 Cr	0.11	0.19	0.01	0.01	2.04	0.19	4.40	0.04
C	1.00	6.00	0.30 Mn	0.11	0.18	0.01	0.30	1.04	0.01	6.06	0.04
D	1.00	6.00	0.20 Cr	0.11	0.18	0.01	0.01	1.03	0.21	5.95	0.04
E	1.00	6.00	0.20 Cr	0.11	0.18	0.02	0.00	0.99	0.21	5.84	0.03
F	1.70	4.30	0.30 Mn	0.10	0.18	0.01	0.29	1.71	0.01	4.34	0.04
G	1.70	4.30	0.20 Cr	0.10	0.20	0.01	0.01	1.64	0.22	4.28	0.04
H	1.70	4.30	0.20 Cr	0.11	0.18	0.02	0.00	1.71	0.21	4.24	0.03

[1] Intended contents of other elements: 0.10% Si, 0.20% Fe, 0.00% Cu, 0.04% Ti.

After casting, the ingots were cut in half, and one segment of each ingot was preheated for 15 hours at 900° F. The other half-ingot of each composition was fabricated in the unpreheated condition. The half-ingots were rolled to a 1 inch thick plate at 850° F., and still-air-cooled to ambient temperature after the final pass. The cooling rate through the range 600–400° F. was about 0.16° F./sec. After five days of natural aging transverse plate specimens were artificially aged under either of the two following conditions prior to tensile and stress corrosion testing:

(a) 48 hours at 240° F.

(b) 8 hours at 195° F. followed by an 8 hours at 300° F.

In addition, plate specimens were tested after 60 days of natural aging.

Table II presents the tensile properties of the artificially aged alloys. It is noted in the table that with the alloys including the Cr addition, preheating seriously increased the quench-rate sensitivity of those alloys containing 1.7% and 2.0% Mg. The table further shows that preheating strengthened the Mn containing alloys. The three Al-Zn-Mg-Mn alloys developed similar strengths as shown in Table II.

TABLE II.—EFFECTS OF MINOR ALLOYING ELEMENTS, PREHEAT AND ARTIFICIAL AGING VARIATIONS ON THE TENSILE PROPERTIES OF AIR-HARDENABLE Al-Zn-Mg ALLOYS

Ingot No.	Alloy type	Minor addition	Preheat	Long transverse tensile properties of air-cooled 1-inch plate					
				Artificially aged 48 hrs. at 240° F.[1]			Artificially aged 8 hrs. at 195 F. +8 hrs. at 300° F.[1]		
				TS, k.s.i.[2]	YS, k.s.i.	Elong., percent in 2 in.	TS, k.s.i.	YS, k.s.i.	Elong., percent in 2 in.
A	4.5% Zn–2.0% Mg	0.3% Mn	Yes	52.5	40.8	14.5	53.7	43.5	13.0
A	4.5% Zn–2.0% Mg	0.3% Mn	No	52.2	39.9	13.5	53.5	43.0	12.5
B	4.5% Zn–2.0% Mg	0.2% Cr	Yes	42.6	27.2	17.5	43.7	29.7	16.2
B	4.5% Zn–2.0% Mg	0.2% Cr	No	53.9	43.5	14.0	54.8	45.8	13.2
C	6.0% Zn–1.0% Mg	0.3% Mn	Yes	55.3	45.5	14.0	53.1	44.7	13.7
C	6.0% Zn–1.0% Mg	0.3% Mn	No	51.1	41.0	13.7	49.6	40.7	14.0
D	6.0% Zn–1.0% Mg	0.2% Cr	Yes	51.8	41.7	15.0	49.7	41.1	15.0
E	6.0% Zn–1.0% Mg	0.2% Cr	No	55.2	46.8	14.5	52.9	45.5	14.7
F	4.3% Zn–1.7% Mg	0.3% Mn	Yes	52.5	41.9	14.7	53.8	44.4	13.7
F	4.3% Zn–1.7% Mg	0.3% Mn	No	50.0	38.7	14.2	51.7	42.0	13.7
G	4.3% Zn–1.7% Mg	0.2% Cr	Yes	41.4	27.5	17.7	44.2	31.7	16.2
H	4.3% Zn–1.7% Mg	0.2% Cr	No	51.7	42.2	14.2	53.1	44.3	14.0

[1] All plates naturally aged 5 days; heat-up rate was 35 F./hr.
[2] K.s.i.=p.s.i.×1000.

Table III depicts the tensile strength of the three Al-Zn-Mg alloys after sixty days of natural aging. The results show a similar trend to those obtained from the artifically aged samples in the following respects:

(a) The preheated alloys containing 0.2% Cr and 1.7%–2% Mg had the least strength;

TABLE III.—RELATIVE EFFECTS OF MANGANESE AND CHROMIUM ADDITIONS ON THE TENSILE PROPERTIES OF AIR-COOLED AND NATURALLY AGED AIR-HARDENABLE ALLOYS

[Natural aging time was 60 days]

Ingot No.	Base alloy	Minor addition	Preheat	Transverse tensile properties of air cooled and naturally aged 1-inch thick plates		
				TS, k.s.i.	YS, k.s.i.	Elong., percent in 2 in.
A	4.5% Zn–2.0% Mg	0.3% Mn	Yes	50.4	30.2	18.7
A	4.5% Zn–2.0% Mg	0.3% Mn	No	50.4	30.2	18.5
B	4.5% Zn–2.0% Mg	0.2% Cr	Yes	45.4	26.0	19.5
B	4.5% Zn–2.0% Mg	0.2% Cr	No	49.7	30.3	19.0
C	6.0% Zn–1.0% Mg	0.3% Mn	Yes	53.7	33.2	17.0
C	6.0% Zn–1.0% Mg	0.3% Mn	No	51.5	32.0	17.2
D	6.0% Zn–1.0% Mg	0.2% Cr	Yes	51.0	31.1	16.7
E	6.0% Zn–1.0% Mg	0.2% Cr	No	51.8	33.1	16.0
F	4.3% Zn–1.7% Mg	0.3% Mn	Yes	49.8	29.9	18.7
F	4.3% Zn–1.7% Mg	0.3% Mn	No	49.0	29.5	18.5
C	4.3% Zn–1.7% Mg	0.2% Cr	Yes	44.8	25.4	18.0
H	4.3% Zn–1.7% Mg	0.2% Cr	No	48.0	29.7	19.5

(b) Preheating increased the strength of the Mn containing alloys; and

(c) The 6% Zn-1% Mg–0.3% Mn alloy showed the best strength characteristics.

Stress corrosion tests were performed on the samples and the results are shown in Table IV.

(c) When neither Mn nor Cr (or an element with similar characteristics) is added to stronger hardenable alloys of the type described (e.g. ingot I) the alloys are shown to be extremely susceptible to stress corrosion cracking even when air cooled as 1 inch plate prior to artificial aging.

TABLE IV.—EFFECTS OF MANGANESE AND CHROMIUM ON THE STRESS CORROSION RESISTANCE OF AIR-HARDENABLE ALLOYS

[Short-transverse C-rings from 1-inch plate, continuously immersed in 6% NaCl solution for 6 months]

Ingot No.	Base alloy	Minor addition	Preheat	No. failures/No. samples in test; failure times			
				-T4 temper [1]		-T5 temper [2]	
				15 k.s.i.	25 k.s.i.	25 k.s.i.	30 k.s.i.
A	4.5% Zn-2.0% Mg	0.3% Mn	Yes	0/4	0/4	0/4	0/4
A	4.5% Zn-2.0% Mg	0.3% Mn	No	0/4	0/4	0/4	0/4
B	4.5% Zn-2.0% Mg	0.2% Cr	No	0/4	0/4	0/4	0/4
C	6.0% Zn-1.0% Mg [3]	0.3% Mn	Yes	0/4	0/4	4/4; 5, 73, 88, 117d	4/4; 1, 1, 1, 122d
C	6.0% Zn-1.0% Mg [3]	0.3% Mn	No	0/4	0/4	1/4: 12d	4/4; 5, 5, 5, 98d
D	6.0% Zn-1.0% Mg [3]	0.2% Cr	Yes	0/4	0/4	4/4; 5, 73, 111, 151d	4/4; 5, 26, 26, 45d
E	6.0% Zn-1.0% Mg [3]	0.2% Cr	No	0/4	0/4	1/4; 168d	3/4; 5, 98, 168d
F	4.3% Zn-1.7% Mg	0.3% Mn	Yes	0/4	0/4	0/4	0/4
F	4.3% Zn-1.7% Mg	0.3% Mn	No	0/4	0/4	0/4	0/4
H	4.3% Zn-1.7% Mg	0.2% Cr	No	0/4	0/4	0/4	0/4
I	4.3% Zn-1.7% Mg	None	No				3/3; 18, 42, 73hr

[1] Air cooled from rolling and naturally aged. -T4 temper designates natural aging at ambient temperature.

[2] With exception of I, plates were air cooled after hot rolling, naturally aged more than 1 month, then artificially aged 8 hours at 195 F., followed by 8 hours at 300 F. (35 F./hr. heat-up).

Plate from Ingot I was naturally aged 5 days after hot rolling, and was aged 48 hours at 240 F. (25 F./hr. heat-up).

[3] -T5 temper designates artificial aging above ambient temperature. The 6% Zn-1% Mg alloy showed much better stress corrosion resistance when artificially aged by a single-step treatment at 240 or 250 F.

A C-ring specimen is used to study short transverse stress-corrosion resistance of aluminum alloys at applied stress levels below the elastic limits. This provides a means of determining the threshold stress of stress-corrosion susceptible alloys in various forms, including plate, extrusions and forgings. The threshold stress level is defined as the highest sustained tensile stress at which stress corrosion cracking will not occur for a given testing period and environment.

In preparing C-rings a test block is cut from the metal material transverse to the working direction. The block is machined to a cylinder which is then end bored. A C-ring sample is finish-machined to final dimension and cut from the cylinder. While the C-ring sample is aligned in a jig to ensure that the short-transverse grain orientation coincides with the center line of the C-ring, through-bolt holes are bored and a 60 degree section is cut out of the sample to form the C. The bolt holes are diametrically opposed to each other and are located at the top and bottom of the C. An aluminum screw is positioned through the holes and a nut is threaded onto the screw. The screw is tightened until the predetermined reduction in outside diameter, for the desired level of applied stress, is obtained.

Dimensions of commonly used C-rings are shown in Table V.

TABLE V.—C-RING DIMENSIONS

	Outside dia., inches	Inside dia., inches	Thickness, inches	Bolt hole dia., inches	Width of C, inches
(1)	0.714	19/32	0.060	13/64	0.75
(2)	0.948	53/64	0.060	13/64	0.75
(3)	1.211	1 1/32	0.090	17/64	0.75
(4)	1.446	1 17/64	0.090	17/64	0.75
(5)	1.711	1 7/32	0.090	17/64	0.75

The stress corrosion tests or stress corrosion results shown in Table IV show that the Mn addition conferred stress corrosion resistance at least comparable to that afforded by the Cr additions.

Table IV reveals some additional important information, namely:

(a) In the T4 temper, the 1 inch plates were extremely resistant to short transverse stress corrosion showing no failures in six months of testing.

(b) In the T5 temper, the 5.4% Zn-2% Mg and 4.3% Zn-1.7% Mg alloys were much more resistant to stress corrosion cracking than the 6% Zn-1% Mg alloy.

EXAMPLE II

An aluminum alloy ingot weighing 40 pounds and being of 3 inches thickness having a composition of 6% Zn, 1% Mg and 0.46% Mn, balance Al and normal impurities was cast.

The ingot was preheated at 900° F. for 15 hours, scalped to 2.5 inches thickness and hot rolled at 850° F. In the hot rolling procedure, the ingot was rolled to 1 inch thickness and then air cooled. After test specimens were cut from the 1 inch plate, it was reheated to hot rolling temperature, rolled to 0.50 inch thickness, and again air cooled. Test specimens were cut from the 0.50 inch thick plate, after which it was reheated to the hot-rolling temperature, hot rolled to 0.25 inch thickness and air cooled.

The 1 inch, 0.50 inch and 0.25 inch specimens were kept at ambient temperature for about 5 days and then subjected to an artificial aging treatment by flash heating to 250° F. and holding at 250° F. for 24 hours. The yield strengths, tensile strengths and elongations for the various thicknesses of plate are given in Table VI.

TABLE VI.—TRANSVERSE TENSILE PROPERTIES OF 6%-1% Mg-0.46% Mn ALLOY

Naturally aged for 5 days and then artificially aged at 250° F. for 24 hours (flash heat-up)]

Plate thickness, in.	Yield strength, k.s.i.	Tensile strength, k.s.i.	Elongation, percent in 2 in.
0.25	46.9	55.8	15.5
0.50	43.8	53.8	16.6
1.0	38.3	49.7	15.5

Although the yield strengths and tensile strengths of the specimens given in Table VI are satisfactory, the fast heat-up in the aging treatment, as noted previously, lowers the strength of the alloys. A slower heat-up rate, for example, less than 50° F./hr. would have considerably increased the yield and tensile strengths of the metal specimens.

Having now described the invention;

What is claimed is:

1. A hot worked metal article of a Cu-free and Cr-free aluminum base alloy consisting essentially of Zn and

Mg in the amounts, in percent by weight, of those alloys occurring in the ternary diagram of FIG. 1 within the zone bounded by lines AB, BC, CD and DA; Mn 0.2–0.5%, balance Al and normal impurities, said article having a metallurgical structure produced by working a body of said alloy at a temperature above about the solvus temperature of the alloy but below the temperature of incipient fusion of any alloy phase, followed by air cooling such that the rate through the range of 600° F. to 400° F. is from about 0.1 to 1.1° F./sec., and subsequently aged, said article being characterized by having a minimum yield strength of about 30,000 p.s.i., said article further possessing high resistance to stress corrosion cracking.

2. An article according to claim 1 wherein the section thickness is in the range of ⅛ inch to 1¼ inches and the metallurgical structure of the article is produced by cooling, after hot working, in quiescent air.

3. An article according to claim 1 wherein the section thickness is greater than 1¼ inches and the metallurgical structure of the article is produced by cooling, after hot working, in a forced air blast.

4. An article according to claim 1 wherein the metallurgical structure is produced by preheating the body of said alloy, prior to said working, at a temperature in the range of 800 to 950° F. for a time ranging from 8 to 24 hours.

5. A hot worked metal article of a Cu-free and Cr-free aluminum base alloy consisting essentially of Zn and Mg in the amounts, in percent by weight, of those alloys occurring in the ternary diagram of FIG. 1 within the zone bounded by lines AB, BC, CD and DA: Mn .2–.5%, balance Al and normal impurities, said article having a metallurgical structure produced by working a body of said alloy at a temperature above about the solvus temperature of the alloy but below the temperature of incipient fusion of any alloy phase, followed by air cooling such that the rate through the range of 600° F. to 400° F. is from about 0.1 to 1.1° F./sec., and subsequently artifically aged, said article being characterized by having a minimum yield strength of about 40,000 p.s.i., said article further possessing high resistance to stress corrosion cracking.

6. An article according to claim 5 wherein the section thickness is in the range of ⅛ to 1¼ inches and the metallurgical structure of the article is produced by cooling, after hot working, in quiescent air.

7. An article according to claim 5 wherein the section thickness is greater than 1¼ inches and the metallurgical structure of the article is produced by cooling, after hot working, in a forced air blast.

8. An article according to claim 5 wherein the metallurgical structure is produced by preheating the body of said alloy, prior to said working, at a temperature in the range of 800 to 950° F. for a time ranging from 8 to 24 hours.

9. A hot worked metal article of a Cu-free and Cr-free aluminum base alloy consisting essentially of Zn and Mg in the amounts in percent by weight of those alloys occurring in the ternary diagram of FIG. 1 within the zone bounded by lines AU, UV, VW, WD and DA; 0.2–0.5% Mn, balance Al and normal impurities, said article having a structure produced by working a body of said alloy at a temperature above about the solvus temperature of the alloy but below the temperature of incipient fusion of any alloy phase, followed by air cooling such that the rate through the range of 600° F. to 400° F. is from about 0.1 to 1.1° F./sec., and subsequently aged, said article being characterized by having a minimum yield strength of 30,000 p.s.i., said article further possessing high resistance to stress corrosion cracking.

10. An article according to claim 9 wherein the section thickness is in the range of ⅛ to 1¼ inches and the metallurgical structure of the article is produced by cooling, after hot working, in quiescent air.

11. An article according to claim 9 wherein the section thickness is greater than 1¼ inches and the metallurgical structure of the article is produced by cooling, after hot working, in a forced air blast.

12. An article according to claim 9 wherein the metallurgical structure is produced by preheating the body of said alloy, prior to said working, at a temperature in the range of 800 to 950° F. for a time ranging from 8 to 24 hours.

13. A hot worked metal article of heavy section of a Cu-free and Cr-free aluminum base alloy consisting essentially of Zn and Mg in the amounts, in percent by weight, of those alloys occurring in the ternary diagram of FIG. 1 within the zone bounded by lines AU, UV, VW, WD and DA; 0.2–0.5% Mn, balance Al and normal impurities, said article having a structure produced by working a body of said alloy at a temperature above about the solvus temperature of the alloy but below the temperature of incipient fusion of any alloy phase, followed by air cooling such that the rate through the range of 600° F. to 400° F. is from about 0.1–1.1° F./sec., and subsequently artificially aged, said article being characterized by having a minimum yield strength of about 40,000 p.s.i., said article further possessing high resistance to stress corrosion cracking.

14. An article according to claim 13 wherein the section thickness is in the range of ⅛ inch to 1¼ inches and the metallurgical structure of the article is produced by cooling, after hot working in quiescent air.

15. An article according to claim 13 wherein the section thickness is greater than 1¼ inches and the metallurgical structure of the article is produced by cooling, after hot working, in a forced air blast.

16. An article according to claim 13 wherein the metallurgical structure is produced by preheating the body of said alloy, prior to said working, at a temperature in the range of 800 to 950° F. for a time ranging from 8 to 24 hours.

17. A hot worked metal article of a Cu-free and Cr-free aluminum base alloy consisting essentially of Zn and Mg in the amounts, in percent by weight, of those alloys occurring in the ternary diagram of FIG. 1 within the zone bounded by lines UX, XY, YZ, and ZU; Mn 0.2–0.5%, balance Al and normal impurities, said article having a metallurgical structure produced by working a body of said alloy at a temperature of above about the solvus temperature but below the temperature of incipient fusion of any alloy phase, followed by air cooling such that the rate through the range of 600° F. to 400° F. is from about 0.1 to 1.1° F./sec., and subsequently aged, said article being characterized by having a minimum yield strength of 30,000 p.s.i., said article further possessing high resistance to stress corrosion cracking.

18. An article according to claim 17 wherein the section thickness is in the range of ⅛ inch to 1¼ inches and the metallurgical structure of the article is produced by cooling, after hot working, in quiescent air.

19. An article according to claim 17 wherein the section thickness is greater than 1¼ inches and the metallurgical structure of the article is produced by cooling, after hot working, in a forced air blast.

20. An article according to claim 17 wherein the metallurgical structure is produced by preheating the body of said alloy, prior to said working, at a temperature in the range of 800° to 950° F. for a time ranging from 8 to 24 hours.

21. A hot worked metal article of a Cu-free and Cr-free aluminum base alloy consisting essentially of Zn and Mg in the amounts, in percent by weight, of those alloys occurring in the ternary diagram of FIG. 1 within the zones bounded by lines UX, XY, YZ and ZU; Mn 0.2–0.5%, balance Al and normal impurities, said article

having the metallurgical structure produced by working a body of said alloy at a temperature above about the solvus temperature but below the temperature of incipient fusion of any alloy phase, followed by air cooling such that the rate through the range of 600° F. to 400° F. is from about 0.1–1.1° F. per second, and subsequently artificially aged, said article being characterized by having a minimum yield strength of about 40,000 p.s.i., said article further possessing high resistance to stress corrosion cracking.

22. An article according to claim **21** wherein the section thickness is in the range of ⅛ inch to 1¼ inches and the metallurgical structure of the article is produced by cooling, after hot working, in quiescent air.

23. An article according to claim **21** wherein the section thickness is greater than 1¼ inches and the metallurgical structure of the article is produced by cooling, after hot working, in a forced air blast.

24. An article according to claim **21** wherein the metallurgical structure is produced by preheating the body of said alloy, prior to said working, at a temperature in the range of 800 to 950° F. for a time ranging from 8 to 24 hours.

25. A process of improving the strength and stress corrosion resistance of hot worked articles composed of a Cu-free and Cr-free aluminum alloy consisting essentially of Zn and Mg in the amounts, in percent by weight, of those alloys occurring in the ternary diagram of FIG. 1 within the zone bound by lines AB, BC, CD and DA; Mn 0.2–0.5%, balance Al and normal impurities, said process comprising:

(a) subjecting a body of the said alloy to a hot working at a temperature above about the solvus temperature of the alloy but below the temperature of incipient fusion of any alloy phase,

(b) air-cooling the hot worked article such that the rate through the range of 600 to 400° F. is from about 0.1 to 1.1° F./sec., and

(c) thereafter aging the article.

26. A process according to claim **25** wherein the section thickness of the article is in the range of ⅛ inch to 1¼ inches and the cooling step is carried out in quiescent air.

27. A process according to claim **25** wherein the section thickness of the article is greater than 1¼ inches and the cooling step is carried out in a forced air blast.

28. A process according to claim **25** wherein the body of said alloy, prior to working, is subjected to a preheating at a temperature in the range of 800 to 950° F. for a time ranging from 8 to 24 hours.

29. A process of improving the strength and stress corrosion resistance of hot worked articles composed of a Cu-free and Cr-free aluminum alloy consisting essentially of Zn and Mg in the amounts, in percent by weight, of those alloys occurring in the ternary diagram in FIG. 1 within the zone bounded by lines AB, BC, CD and DA; Mn 0.2–0.5%, balance aluminum and normal impurities, said process comprising:

(a) subjecting a body of the said alloy to a hot working at a temperature above about the solvus temperature of the alloy but below the temperature of incipient fusion of any alloy phase,

(b) air cooling the hot worked article such that the rate through the range of 600° to 400° F. is from about 0.1–1.1° F./sec., and

(c) thereafter artificially aging the article.

30. A process according to claim **29** wherein the section thickness of the article is in the range of ⅛ inch to 1¼ inches and the cooling step is carried out in quiescent air.

31. A process according to claim **29** wherein the section thickness of the article is greater than 1¼ inches and the cooling step is carried out in a forced air blast.

32. A process according to claim **29** wherein the body of said alloy, prior to working, is subjected to a preheating at a temperature in the range of 800 to 950° F. for a time ranging from 8 to 24 hours.

33. A process of improving the strength and stress corrosion resistance of hot worked articles composed of a Cu-free and Cr-free aluminum alloy consisting essentially of Zn and Mg in amounts, in percent by weight, of those alloys occurring in the ternary diagram of FIG. 1 within the zone bounded by lines AB, BC, CD and DA; Mn 0.2–0.5%, balance Al and normal impurities, said process comprising:

(a) subjecting a body of the said alloy to hot working at a temperature above about the solvus temperature of the alloy but below the temperature of incipient fusion of any alloy phase,

(b) air cooling the hot worked article such that the rate through the range of 600° to 400° F. is from about 0.1–1.1° F./sec.,

(c) natural aging of the article for a period of time of from 1 to about 5 days, and

(d) then artificially aging the article by heating the article for 24 hours to 250° F.

34. A process according to claim **33** wherein the section thickness of the article is in the range of ⅛ inch to 1¼ inches and the cooling step is carried out in quiescent air.

35. A process according to claim **33** wherein the section thickness of the article is greater than 1¼ inches and the cooling step is carried out in forced air blast.

36. A process according to claim **33** wherein the body of said alloy, prior to working, is subjected to a preheating at a temperature in the range of 800 to 950° F. for a time ranging from 8 to 24 hours.

37. A process of improving the strength and stress corrosion resistance of hot worked articles composed of a Cu-free and Cr-free aluminum alloy consisting essentially of Zn and Mg in the amounts, in percent by weight, to those alloys occurring in ternary diagram of FIG. 1 within the zone bounded by lines AB, BC, CD and DA; Mn 0.2–0.5%, balance Al and normal impurities, said process comprising:

(a) subjecting a body of the said alloy to hot working at a temperature above about the solvus temperature of the alloy but below the temperature of incipient fusion of any alloy phase,

(b) air cooling the hot worked article such that the rate through the range of 600° to 400° F. is from about 0.1–1.1° F./sec.,

(c) natural aging of the alloy for a period of time of from 1 to 5 days, and

(d) then artificially aging the article by heating the article at 240° F. for a period of 48 hours.

38. A process according to claim **37** wherein the section thickness of the article is in the range of ⅛ inch to 1¼ inches and the cooling step is carried out in quiescent air.

39. A process according to claim **37** wherein the section thickness of the article is greater than 1¼ inches and the cooling step is carried out in a forced air blast.

40. A process according to claim **37** wherein the body of said alloy, prior to working, is subjected to a preheating at a temperature in the range of 800 to 950° F. for a time ranging from 8 to 24 hours.

41. A process of improving the strength and stress corrosion resistance of hot worked articles composed of a Cu-free and Cr-free aluminum alloy consisting essentially of Zn and Mg in amounts, in percent by weight, of those alloys occurring in the ternary diagram of FIG. 1 within the zone bounded by lines AB, BC, CD and DA; Mn 0.2–0.5%, balance Al in normal impurities, said process comprising:

(a) subjecting a body of the said alloy to a hot working temperature above about the solvus temperature of the alloy but below the temperature of incipient fusion of any alloy phase,

(b) air cooling the hot worked article such that the rate through the range of 600–400° F. is from about 0.1–1.1° F./sec.,

(c) natural aging of the article for a period of time from 1 to about 5 days, and

(d) then artificially aging the article by subjecting it to a temperature of 190° F. for a period of 8 hours followed by subjecting the article at a temperature of 300° F. for a period of 8 hours.

42. A process according to claim **41** wherein the section thickness of the article is in the range of ⅛ inch to 1¼ inches and the cooling step is carried out in quiescent air.

43. A process according to claim **41** wherein the section thickness of the article is greater than 1¼ inches and the cooling step is carried out in a forced air blast.

44. A process according to claim **41** wherein the body of said alloy, prior to working, is subjected to a preheating at a temperature in the range of 800 to 950° F. for a time ranging from 8 to 24 hours.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,542,606 Dated November 24, 1970

Inventor(s) Edwin J. Westerman and Maurice C. Fetzer

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

Column 5, line 51, "by an 8 hours" should be --by 8 hours--;
Column 8, line 62, Table VI, "53.8" should be --53.6--; and
Column 11, line 29, "bound" should be --bounded--.

Signed and sealed this 29th day of June 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER,
Commissioner of Pate