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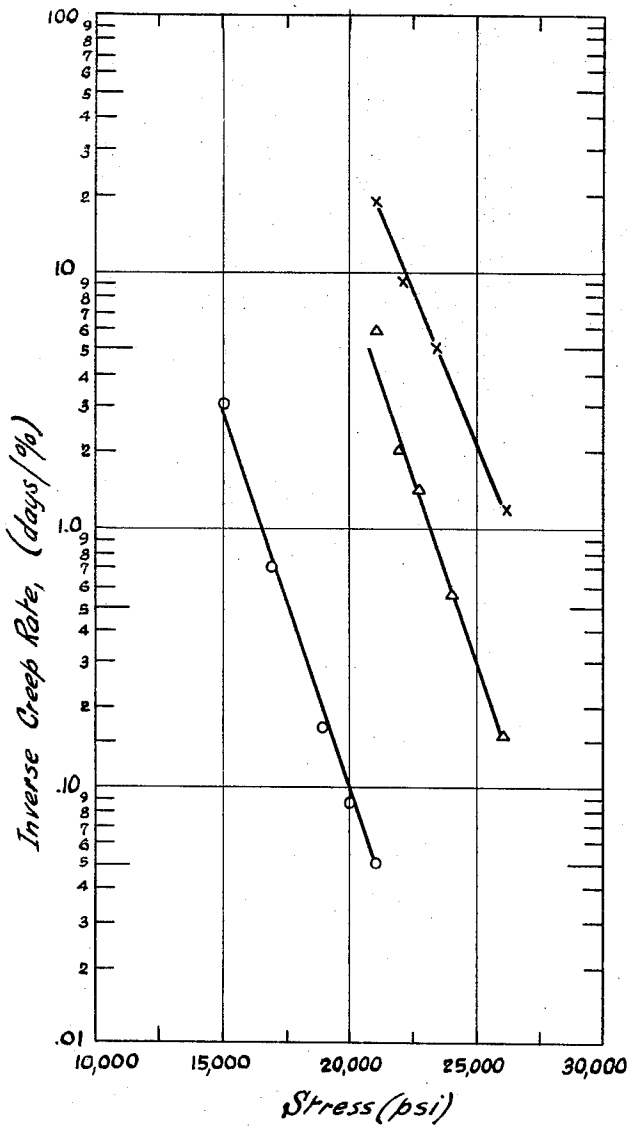
ZINC BASE ALLOYS

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△ Zn-0.96% Cu - 0.25% Ti - 0.065% Mg.

x Zn-0.95% Cu - 0.21% Ti - 0.07% Mg - 0.054% Cr

○ Zn-0.42% Cu - 0.18% Ti - 0.0095% Mn - 0.008 Cr



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ZINC BASE ALLOYS

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This invention relates to zinc base alloys and a process for producing such alloys. More particularly the invention relates to zinc base alloys containing relatively small amounts of copper, titanium and magnesium with chromium being preferably also included. The alloys of this invention in wrought form are characterized by improved tensile strength and high stress-rupture strength among other desirable properties qualifying the material particularly in rolled strip and sheet form for various uses as, for example, in structural applications for making of gutters, downspouts, roofing, sidings, flashings, corrugated sheets and the like. The alloys are also useful in other sheet metal applications or in the making of extruded products such as tubing, rods and strips as well as wire, rust-proof nails, etc.

In recent years, considerable research effort has been directed to improving the various properties of zinc base alloys to provide increased strength and better creep resistance properties without seriously impairing the desired fabrication qualities of the material. Although considerable progress has been made in improving properties to the extent that one or more properties in various zinc base alloys are good if not outstanding, the deficiency in respect of creep resistance and stress-rupture properties possessed by virtually all of the heretofore known zinc base alloys has proven extremely difficult to overcome. Within applicants' knowledge, no zinc base alloy has been previously made available possessing, in addition to good tensile strength, hardness and adequate ductility, a stress-rupture strength sufficient to withstand, for example, a static loading of say 26,000 p.s.i. or thereabouts for even as long as 20 hours without fracture.

It is a primary object of the present invention to provide zinc base alloys which in wrought form have higher tensile and stress-rupture strengths than other zinc base alloys currently used, together with sufficient ductility and other desired properties to enable their use in a wide variety of applications.

Another object of this invention is to provide zinc base alloys of markedly improved creep resistance at room and moderately elevated temperatures.

A further object of this invention is to provide zinc base alloys possessing, in the wrought form, a superior combination of tensile strength, hardness, elongation and creep resistance properties than heretofore attainable with zinc base alloys.

A still further object of this invention is to provide a process for making new and novel zinc base alloys that can be readily formed into rolled strip or sheet material possessing markedly superior structural strength, stability and corrosion resistance.

Other objects and advantages of the invention will be apparent from the following description and appended claims.

In accordance with the present invention, a zinc base alloy is provided consisting essentially by weight of from 0.5 to 2% copper, from 0.1 to 0.4% titanium, and from 0.03 to 0.2% magnesium and the balance substantially all zinc. Although the quaternary alloys within the above specified composition possess markedly improved creep resistance and stress-rupture strength in addition to other desired properties, it has been found highly beneficial to additionally include chromium in an amount ranging

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from 0.005 to 0.2% to provide quinary alloys possessing even better creep resistance and stress-rupture strength without impairment of other desired properties.

The preferred range of essential constituents of the zinc base alloys comprising the present invention consists essentially of from 0.8 to 1.2% copper, from 0.15 to 0.25% titanium and from 0.04 to 0.08% magnesium and, when included, from 0.03 to 0.06% chromium, the balance being high purity zinc. The preferred composition of the alloy is 1% copper, 0.2% titanium, and 0.06% magnesium, with the optional addition of chromium being about 0.05%, and the balance high purity zinc.

We have found that zinc base alloys produced in accordance with the present invention have good mechanical working properties and significantly improved creep resistance and stress-rupture properties. By way of illustration, tests conducted on representative alloy specimens using standard testing procedures have shown the quaternary Zn-Cu-Ti-Mg alloy to be capable of withstanding static loading of up to as much as 26,000 p.s.i. for longer than 70 hours without rupture. With the addition of chromium, the time to rupture under the same loading was found to be extended to more than 240 hours. Such stress-rupture values are vastly superior to those obtainable with any other known zinc base alloy. Creep resistance of the zinc base alloys comprising the present invention is likewise enhanced with the chromium-containing embodiment being appreciably more creep resistant than the quaternary alloy.

The desired alloy composition is suitably obtained by melting preferably high purity zinc together with copper, the latter being added, if desired, in the form of a zinc-copper master alloy. The required amount of magnesium is added with the melt being at a temperature of about 500° C. after which the temperature of the melt is raised to about 750° C. and the titanium then added suitably as sponge metal. The optional addition of chromium may be included along with the titanium, the desired amount of chromium being added preferably in the form of copper-chromium master alloy making due allowance for any additional copper introduced thereby. The melt is held at about 750° C. for from 10 to 20 minutes with periodic agitation, if desired, after which the alloy is cast to shape in appropriate molds. No difficulties are encountered in making either the quaternary or chromium-containing quinary alloys using the alloying procedure hereinabove described, it being understood, however, that the use of the aforesaid master alloys or hereinabove described alloying sequence is not essential in that the various alloying ingredients may be added otherwise either as elemental metals or in the form of other appropriate master alloys. The alloying procedure is preferably carried out under a protective atmosphere of argon or any other suitable inert gas.

The zinc base metal used in making the alloys of this invention should preferably be of at least 99.9% purity. The use of the commercially available grades of zinc known as "high grade" or "special high grade" give completely satisfactory results.

The alloys of this invention are readily amenable to hot and cold working. The alloys may be hot worked as by rolling at metal temperatures of 160 to 250° C. with about 200° C. providing very satisfactory results. For making sheet material, it is preferred to subject the preheated alloy to hot rolling using an appropriate number of passes, heat treating the hot rolled material suitably at temperatures ranging from 150 to 325° C. and preferably from 200 to 300° C. for approximately one hour and then subjecting the heat treated alloy to cold rolling to provide the final thickness using intermittent heat treating if desired. For some applications of the

alloy, the material may be cold rolled after hot rolling without intermediate heat treating.

By subjecting the alloy to cross-rolling during the hot and cold working cycles, directionality is minimized thereby enabling bending and folding of the material at sharp angles without fracture. Heat treating at temperatures of about 200° C. prior to final cold working further improves the folding and bending characteristics of the alloy. The material is readily cold worked to reductions of 75% or even more. A final reduction of at least 30% by cold working has been found to be beneficial for enhancing various properties of the alloy. In the cold worked condition, the alloys of this invention not only possess good formability in addition to the aforementioned superior strength and creep resistance properties, but they are further characterized by excellent corrosion resistance.

By way of illustrating the superior combination of properties of the alloys of this invention, reference is made to Table I wherein various properties of a representative quaternary (I) and quinary alloy (J) as tested in accordance with standard procedures are listed along

perature under static loadings of 21,000 and 26,000 p.s.i. respectively, show the quaternary and quinary alloys of this invention as differing in stress-rupture strength by such a magnitude that the superiority of these alloys is clearly indicated as being primarily attributable to the alloy composition rather than to the type of treatment given the alloy.

Although the properties of the alloys comprising the present invention are such that the material in the mechanically worked condition may be readily fabricated for making metal products therewith without encountering excessive edge cracking or undue brittleness, the ductility of the quaternary and quinary alloys may be readily enhanced, if desired, by subjecting the material, after final cold working, to mild heating at temperatures ranging from 75 to 125° C. or thereabouts and preferably at about 100° C. for a period of approximately an hour. This simple heating treatment results in an appreciable increase in the elongation value of the alloy with only a relatively minor decrease in the proportional limit value being effected thereby as will be apparent from the data shown in Table II.

Table II

Alloy	Condition	Tensile Strength (p.s.i.)	Proportional Limit (p.s.i.)	Elongation (Percent in 2")	Hardness (V.P.N.)	Elec. Cond. (Percent IACS)
Zn-0.96% Cu-0.25% Ti-0.065% Mg.	Cold worked (60% red.)...	52,000	21,700	24	121	27
Zn-0.96% Cu-0.25% Ti-0.65% Mg.	Same as above + heated at 100° C. for 1 hr.	42,000	19,000	34	108	26
Zn-0.95% Cu-0.21% Ti-0.07% Mg-0.05% Cr.	Cold worked (60% red.)...	53,500	23,300	17	128	25
Zn-0.95% Cu-0.21% Ti-0.07% Mg-0.05% Cr.	Same as above + heated at 100° C. for 1 hr.	44,000	21,000	38	121	25

with those of zinc and various other zinc base alloys containing one or more of the alloying ingredients used in the present alloys. The test specimens were all prepared from castings of 0.5" thickness that were preheated to 200° C. for one hour, hot rolled to 0.25" thickness (50% reduction), heat treated at 300° C. for one hour, cold rolled (75% reduction), again heat treated at 300° C. for one hour and cold rolled (30% reduction) resulting in a final sheet thickness of 0.039".

The alloys of this invention have creep resistance properties superior to any other prior art zinc base alloy known to applicants. In the accompanying drawing is presented a semi-logarithmic plot showing the inverse creep rate measured at room temperature and expressed in terms of the number of days required to produce an elongation or creep of 1% of the test strips subjected to various static loadings (with the grain). The test pieces of the representative quaternary and quinary alloys of

Table I

Composition	Tensile Strength (p.s.i.)	Proportional Limit (p.s.i.)	Elongation (percent in 2")	Time for rupture (hrs.)		Hardness (V.P.N.)	Elec. Cond. (percent IACS)
				21,000 (p.s.i.)	26,000 (p.s.i.)		
(A) Pure Zn.....	14,700	4,000	33	0	0	35	30.8
(B) Zn-0.98% Cu.....	30,400	11,000	32	<1	86	29.8	
(C) Zn-0.17% Ti.....	18,000	5,500	48	0	54	29.6	
(D) Zn-0.069% Mg.....	43,000		2	6	105	30.1	
(E) Zn-0.98% Cu-0.21% Ti.....	34,000	17,000	29	<1	87	28.6	
(F) Zn-1.0% Cu-0.059% Mg.....	46,800	21,000	14	13	113	29.6	
(G) Zn-0.18% Ti-0.054% Mg.....	42,600	19,000	17	1	104	28.8	
(H) Zn-0.42% Cu-0.15% Ti-0.008% Cr-0.007% Mn.....	31,000	14,000	34	<1	71	27.8	
(I) Zn-0.96% Cu-0.25% Ti-0.065% Mg.....	56,400	23,000	14	380	76	131	28.5
(J) Zn-0.95% Cu-0.21% Ti-0.07% Mg-0.05% Cr.....	58,000	25,000	12	¹ 1,700	242	149	27.0

¹ Test still in progress at the time.

The data of Table I illustrate that the nominal composition alloys (I) and (J) representative of the alloys of the present invention possess a highly desirable combination of properties including high tensile strength, proportional limit and hardness and also satisfactory elongation. The superiority of these alloys in respect to their stress-rupture strength compared with other zinc base alloys having one or more but not all of the same alloying constituents, however, is seen to be notably outstanding. The stress-rupture tests conducted at room tem-

the composition designated on the drawing were prepared by annealing sheet material of 0.054" thickness at 300° C. for one hour and cold rolling the annealed alloy to 0.039" thickness (30% reduction). For purposes of comparison, a commercially available zinc base alloy of the composition similarly designated on the drawing and purported to be in zinc base alloy having excellent creep resistance was included, the test pieces thereof being likewise in the cold worked condition and of 0.039" thickness.

It will be readily apparent from the inverse creep rate data shown in said accompanying drawing that each of the representative quaternary and quinary alloys of the present invention possess markedly improved creep resistance properties compared with the manganese-containing quinary zinc base alloy. It will also be seen therefrom that the addition of chromium to the magnesium-containing quaternary alloy contributes to enhancing still further the marked improvement in resistance to creep exhibited by the Zn—Cu—Ti—Mg alloy. Extrapolation of the creep data indicates that a 1% creep of the quinary alloy of this invention at 10,000 p.s.i. will not occur for over ten years.

From the foregoing it will be apparent that the incorporation within the specified range of each of the alloying constituents consisting of copper, titanium and magnesium in zinc imparts to the resulting zinc base alloy a combination of properties characterizing the material, particularly in wrought form, as especially suitable for various and sundry applications requiring good strength and creep properties. With the further addition of chromium, the outstanding properties characterized by excellent stress-rupture strength and high creep resistance not previously attained with any zinc base alloys coupled with improved hardness, tensile strength and satisfactory elongation are extended to make the alloy even more suitable especially for applications wherein stress-rupture strength and creep resistance are of prime concern.

Although the alloys of the present invention have been described as particularly suitable for use in sheet form, it will be understood that said alloys may also be employed to considerable advantage in other forms as castings, extrusions, rod, wire, tubing and also as metal powder for use in powder metallurgy applications.

We claim:

1. A zinc base alloy consisting essentially of from 0.5 to 2% by weight copper, from 0.1 to 0.4% titanium, from 0.03 to 0.2% magnesium and the balance substantially all zinc, said alloy optionally containing as an additional ingredient up to 0.2% chromium.

2. A zinc base alloy capable of being mechanically worked to produce a wrought product characterized by superior creep resistance, stress-rupture and tensile strength properties, said alloy consisting essentially by weight of from 0.5 to 2% copper, from 0.1 to 0.4% titanium, from 0.03 to 0.2% magnesium and optionally including 0.005 to 0.2% chromium, the balance being substantially all zinc.

3. A zinc base alloy capable of being mechanically worked to produce a wrought product characterized by superior creep resistance, stress-rupture and tensile strength properties, said alloy consisting essentially by weight of from 0.5 to 2% copper, from 0.1 to 0.4% titanium, and from 0.03 to 0.2% magnesium, the balance being substantially all zinc.

4. A zinc base alloy characterized in the worked condition by superior creep resistance, stress-rupture and tensile strength properties, said alloy consisting essentially by weight of from 0.8 to 1.2% copper, from 0.15 to 0.25% titanium, from 0.04 to 0.08% magnesium and the balance substantially all zinc.

5. A zinc base alloy containing about 1% copper, about 0.2% titanium, about 0.06% magnesium, and the balance substantially all zinc, said alloy in the heat treated and cold worked condition being characterized by a tensile strength of at least 50,000 p.s.i. and a rupture time in excess of 300 hours under a stress of 21,000 p.s.i.

6. A zinc base alloy containing from 0.5 to 1.2% copper, from 0.1 to 0.4% titanium, from 0.03 to 0.1% magnesium, from 0.005 to 0.2% chromium, and the balance substantially all zinc.

7. A zinc base alloy containing from 0.8 to 1.2% copper, from 0.15 to 0.25% titanium, from 0.04 to 0.08% magnesium, from 0.03 to 0.06% chromium, and the balance substantially all zinc.

8. A zinc base alloy containing about 1% copper, about 0.2% titanium, about 0.06% magnesium, about 0.05% chromium, and the balance substantially all zinc, said alloy being characterized in the heat treated and cold worked condition by a tensile strength greater than 50,000 p.s.i. and a rupture time in excess of 200 hours under a stress of 26,000 p.s.i.

9. The process of making wrought material possessing improved stress-rupture strength and superior creep resistance which comprises alloying high purity zinc base metal with from 0.5 to 2% copper, from 0.1 to 0.4% titanium, from 0.03 to 0.2% magnesium and from 0.005 to 0.2% chromium, and casting the resulting alloy, preheating and hot rolling the cast material, heat treating the hot rolled alloy at a temperature of about 300° C. for about an hour and cold rolling the heat treated alloy to desired thickness.

10. The process of claim 9 wherein the heat treated and cold rolled alloy is annealed at about 100° C. for about an hour.

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