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ALUMINUM ALLOY CONTAINING MISCHMETAL

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This invention relates to aluminum alloys and particularly to aluminum alloys containing cerium and other alloying additions.

Since metallic cerium is quite expensive and difficult to obtain, the cerium used in the alloys of this invention was added in the form of mischmetal, a by-product of the thorium industry consisting of cerium and other rare-earth elements. The mischmetal used in the experimental work leading to this invention contained approximately 50% cerium and 45% lanthranum, balance, other rare-earth metals. Thus, the term "mischmetal" is used throughout this specification to indicate that composition, although it will be understood that minor variations in the quantitative composition may be made without changing the properties of the material and thus without taking it outside the scope of the term "mischmetal" as used in defining this invention.

The general object of this invention is to provide a new series of aluminum alloys which will have improved mechanical properties.

Another object is to provide such alloys which will be of the non-age hardening type.

Another object is to provide such alloys that will have improved mechanical properties at the high temperatures encountered in certain special types of service, e. g., internal combustion engine pistons.

It is the particular object to provide such alloys that will have high resistance to long-time stresses at high temperatures.

Accordingly, this invention comprises a series of alloys of aluminum and mischmetal with other metals in the particular qualitative and quantitative relationships as will hereinafter appear.

The proportion of mischmetal in the aluminum alloy is limited to between about 6% and about 14%. This minimum required for substantial effect has been determined empirically, and the maximum by the experimentally observed fact that it corresponds to the approximate eutectic composition. Presence of the "proeutectic" phase results in a decrease in properties.

In Table I below are examples of the alloys comprising this invention. Table II and Table III show the mechanical properties of the respective specific examples, and also corresponding properties for several standard high-temperature aluminum alloys.

Following the tables is a detailed discussion of the individual alloying elements and the composition range of each which marks the limit of the invention. Also the manner of adjusting the proportion of the individual elements within the range specified in order to emphasize properties which may be desired for particular service conditions is indicated.

Silicon is present in quantities ranging from

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residual up to 6%. The most desirable quantity was found to be around 1–3%. Although the silicon content probably does not bear a strong direct relation to the mechanical properties of the finished alloy, its presence effects other properties such as fluidity in casting and hot strength. Since these alloys are designed to be used in either wrought or cast condition a considerable range of silicon content is specified. In general, silicon should be on the high side for casting alloys and lower for wrought alloys.

Alloys containing up to almost 10% magnesium were investigated. With respect to stress-rupture properties this addition has a cumulative derogatory effect as is seen from the accompanying tables. Thus the alloys having the best stress-rupture properties contained little or no magnesium, and in those with the larger quantities of magnesium said properties were uniformly bad, in spite of the variety of other addition elements. However, the tensile properties both at room temperature and at 400° C. are somewhat enhanced by magnesium in lower proportions and depending on the service desired from zero to about 2% magnesium is recommended. It may be pointed out that the case of magnesium is a good illustration of the unpredictability of high-temperature properties on the basis of property-composition relationship at ordinary temperatures.

Copper, when present with manganese or nickel or both, is found to have a general strengthening effect on the alloys, both as to stress-rupture and tensile properties, which is greater than a mere cumulative effect. For maximum stress-rupture properties the optimum copper content is from about 2 to 3% and for tensile properties around 4%. The recommended quantities of manganese and nickel are roughly 1–2% for each.

Chromium is surprisingly effective as a strengthening addition in these mischmetal alloys in quantities less than 1%. With larger amounts of chromium the ductility drops rapidly. Cobalt appears to have a similar though weaker effect. The presence of the specified quantities of chromium and cobalt, and the improvement in properties incidental thereto, is believed to be one of the more important features of the invention which distinguish it from the prior art.

Titanium is present in small quantities in most of the experimental alloys. It is believed to contribute to strength through formation of one or more intermetallic compounds of aluminum, and perhaps with other elements present. That vanadium in combination with other elements contributes to ultimate strength at 400° C., but detracts at room temperature is seen by comparison of alloys 5 and 6.

TABLE I

Chemical composition

A—EXPERIMENTAL ALLOYS

No.	M*	Si	Mg	Cu	Mn	Ti	Ni	Cr	Co	W	Mo	V	Zr	Fe
1	9.61	2.35	------	1.66	1.73	.04	1.78	0.07	------	------	------	0.04	0.24	.15
2	9.30	2.12	0.72	0.59	1.64	.04	------	0.49	------	0.32	------	------	------	.13
3	10.92	2.38	------	1.49	0.84	.05	1.26	0.30	------	------	------	------	------	.34
4	10.69	2.37	------	1.58	1.69	.06	1.39	0.33	------	------	------	------	------	.33
5	10.77	2.20	------	1.52	1.46	------	1.32	0.30	------	0.27	------	------	------	.32
6	10.67	2.34	------	1.78	0.91	.02	1.43	0.32	------	0.34	------	0.26	------	.33
7	12.11	2.08	0.93	0.85	1.19	.02	------	1.05	------	------	------	0.46	------	.35
8	11.45	2.13	0.83	0.89	1.43	.03	------	0.06	------	------	------	0.05	0.28	.35
9	12.18	2.36	0.54	0.81	1.30	.03	------	1.12	------	0.18	------	------	------	.36

B—STANDARD REFERENCE ALLOYS

No.	M*	Si	Mg	Cu	Mn	Ti	Ni	Cr	Co	W	Mo	V	Zr	Fe
R-1	(18S)	0.08	0.97	3.97	------	------	1.80	------	------	------	------	------	------	.09
R-2	(A132)	12.48	1.00	1.06	------	------	2.34	------	------	------	------	------	------	.19
R-3	(122)	0.22	2.14	10.76	------	------	------	------	------	------	------	------	------	1.19
R-4	(German)	0.13	------	4.47	------	------	1	1	------	------	1	------	------	0.27
R-5	(254)	0.31	5.94	0.65	1	------	1.53	------	------	------	------	------	------	0.48

M*=Mischmetal.

TABLE II

Tensile properties at 400° C. and at room temperature

A—EXPERIMENTAL ALLOYS

No.	400° C.						Room Temperature					
	Cast			Forged			Cast			Forged		
	T. S. p. s. i.	Y. S. p. s. i.	Percent el. in 2"	T. S. p. s. i.	Y. S. p. s. i.	Percent el. in 2"	T. S. p. s. i.	Y. S. p. s. i.	Percent el. in 2"	T. S. p. s. i.	Y. S. p. s. i.	Percent el. in 2"
1	6,180	6,020	0	--------	--------	--------	10,050	--------	0	--------	--------	--------
2	7,780	7,190	--------	4,920	4,000	75	22,200	--------	0	31,900	28,100	7.5
3	6,970	5,470	2	4,530	3,800	42	12,000	11,380	0	21,900	19,700	12
4	7,520	--------	1	4,800	4,000	42.5	12,500	--------	0	22,200	17,500	13
5	7,040	5,310	1.5	4,600	3,750	39	13,760	10,620	0	--------	--------	--------
6	7,730	6,250	1.5	--------	--------	--------	10,000	8,430	0	--------	--------	--------
7	6,410	6,310	1	--------	--------	--------	14,820	--------	1	--------	--------	--------
8	6,960	6,280	1	--------	--------	--------	15,200	--------	0	--------	--------	--------
9	6,670	6,350	3	--------	--------	--------	17,560	--------	0	--------	--------	--------

B—REFERENCE ALLOYS

No.	Cast T. S. p. s. i.	Cast Y. S. p. s. i.	Cast Percent el. in 2"	Forged T. S. p. s. i.	Forged Y. S. p. s. i.	Forged Percent el. in 2"	Cast T. S. p. s. i.	Cast Y. S. p. s. i.	Cast Percent el. in 2"	Forged T. S. p. s. i.	Forged Y. S. p. s. i.	Forged Percent el. in 2"
R-1	--------	--------	--------	3,540	2,670	108	--------	--------	--------	53,070	30,210	16
R-2	--------	--------	--------	3,010	1,810	54	--------	--------	--------	50,150	44,310	2
R-3	--------	--------	--------	4,530	3,590	110	--------	--------	--------	66,400	--------	0
R-4	--------	--------	--------	3,370	2,700	55	--------	--------	--------	39,090	29,440	7
R-5	6,120	5,320	30	4,220	2,970	159	31,400	19,800	2.7	47,600	28,800	7

TABLE III

Stress-rupture properties at 370° C.

A—EXPERIMENTAL ALLOYS

No.	Stress applied in p. s. i.	Duration in hrs. (to rupture)	Percent elong. in 2.25" at rupture
1	3,000	784.6	2
2	3,000	489.2	2
3	3,600	1065.8	2
4	3,000	767.7	2
5	3,000	807.7	2
6	3,000	508.7	4
7	3,000	507.3	2
8	3,600	403.9	2
9	3,000	448.0	2

B—STANDARD REFERENCE ALLOYS

No.	Stress applied in p. s. i.	Duration in hrs. (to rupture)	Percent elong. in 2.25" at rupture
R-1	2,400	2.7	77.8
R-2	2,400	11	19.5
R-3	2,400	8.5	15.1
R-4	2,400	162.72	30.2
R-5	2,400	33	44.4

Tungsten, molybdenum and zirconium were tested in some of the materials and found to have favorable effects particularly on tensile properties. They are present in more than grain refining amounts. As would be expected, tungsten and molybdenum are substantial equivalents in these alloys.

Iron was found to be desirable in all of the mischmetal alloys in quantities less than 1.5%. This favorable effect is contrary to general aluminum technology and is one of the critical features of this invention.

Alloys coming within the invention may contain about 10 to 12% mischmetal, about 1 to 3% silicon, up to about 5% copper, about 0.5 to 3% manganese, up to about 3% nickel, with the combined content of manganese and nickel not exceeding 5%, and the balance aluminum. The alloys may further contain up to about 1% chromium and up to about 1.5% iron. Titanium, cobalt, tungsten, molybdenum, vanadium and zirconium may also be present in the alloys in small amounts, for example, up to about 0.25%

Ti, up to about 1% Co, up to about 1% W, up to about 0.5% Mo, with the combined content of tungsten and molybdenum being not more than 1%, up to about 1% V and up to about 0.3% Zr. Particular alloys of the invention are those containing 10 to 12% mischmetal, 2 to 3% silicon, 1 to 2% copper, 0.5 to 1% manganese, .01 to 0.1% titanium, 1 to 2% nickel, 0.2 to 0.4% chromium, 0.2 to 0.4% iron and the balance aluminum.

The best particular composition from the point of view of all the properties investigated in this work is believed to be that of alloy 3. This material has outstanding stress-rupture strength at 370° C. and very good tensile properties at room temperature and at 400° C., in both the cast and wrought condition. Note that invariably the properties of the cast material exceed those of the wrought material at 400° C. and vice versa at room temperature.

The average mischmetal-containing experimental alloy is seen to be superior to four of the five standard reference alloys in every property tested except room temperature strength. The reference alloys are materials which are at present or recently have been used as standard high-temperature aluminum alloys.

The foregoing observations and discussions are based on analysis of the experimental data and are presented to suggest possible variations in compositions within the ranges defined by the claims which may be desirable for obtaining optimum properties for special service requirements. It is not pretended that all the specific compositions falling within the ranges disclosed and claimed are strict equivalents, but rather that they constitute a continuum, within which no structural division is possible, and substantially beyond which either no new and unforseen results were found or no improvements were obtained.

The invention disclosed herein may be manufacured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. An aluminum base alloy having high temperature strength in the cast condition consisting essentially of about 10 to 12% mischmetal containing about 50% cerium and the balance other rare earth metals, about 1 to 3% silicon, up to about 5% copper, about 0.5 to 3% manganese and the balance aluminum.

2. An aluminum base alloy having high temperature strength in the cast condition consisting essentially of about 10 to 12% mischmetal containing about 50% cerium and the balance other rare earth metals, about 1 to 3% silicon, up to about 5% copper, about 0.5 to 3% manganese, up to 3% nickel, with the combined con-

tent of manganese and nickel not exceeding 5%, and the balance aluminum.

3. An aluminum base alloy having high temperature strength in the cast condition consisting essentially of about 10 to 12% mischmetal containing about 50% cerium and the balance other rare earth metals, about 1 to 3% silicon, up to about 5% copper, about 0.5 to 3% manganese, up to 3% nickel with the combined content of manganese and nickel not exceeding 5%, up to about 1% chronium and the balance aluminum.

4. An aluminum base alloy having high temperature strength in the cast condition consisting essentially of about 10 to 12% mischmetal containing about 50% cerium and the balance other rare earth metals, about 1 to 3% silicon, up to about 5% copper, up to about 3% each of manganese and nickel but not exceeding a total of 5% for both, up to about 1% chromium, up to about 1.5% iron and the balance aluminum.

5. An aluminum base alloy having high temperature strength in the cast condition consisting essentially of about 10 to 12% mischmetal containing about 50% cerium and the balance other rare earth metals, about 1 to 3% silicon, up to about 5% copper, about 1 to 2% manganese, about 1 to 2% nickel and the balance

6. An aluminum base alloy having high temperature strength in the cast condition consisting essentially of about 10 to 12% mischmetal containing about 50% cerium and the balance other rare earth metals, about 1 to 3% silicon, about 2 to 4% copper, about 1 to 2% manganese, about 1 to 2% nickel and the balance aluminum.

7. An aluminum base alloy having high temperature strength in the cast condition consisting essentially of about 10 to 12% mischmetal containing about 50% cerium and the balance other rare earth metals, about 1 to 3% silicon, about 2 to 4% copper, about 1 to 2% manganese, about 1 to 2% nickel, up to about 1% chromium and the balance aluminum.

8. An aluminum base alloy having high temperature strength in the cast condition consisting essentially of about 10 to 12% mischmetal containing about 50% cerium and the balance other rare earth metals, about 2 to 3% silicon, about 1 to 2% copper, about 0.5 to 1% manganese, about 1 to 2% nickel, about 0.2 to 0.4% chromium and the balance aluminum.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,272,779	Sarbey	Feb. 10, 1942

OTHER REFERENCES

Hackh's Chemical Dictionary, 3rd ed., 1944, page 541.