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ALUMINUM-CHROMIUM-TITANIUM ALLOYS

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3 Claims. (Cl. 75—138)

This application is a division of my pending application for patent filed February 18, 1937, Serial No. 126,386.

My invention relates generally to aluminum-zinc alloys in which aluminum is the major constituent, and particularly to complex light alloys containing chromium, titanium and magnesium as well as zinc and aluminum, besides the usual traces of iron, silicon, and other impurities found in ordinary high-grade aluminum.

Castings containing the correct proportions of zinc, chromium, titanium, and magnesium in relation to aluminum, simply aged at room temperature for four or five days, are decidedly stronger than other cast aluminum alloys, and have strengths comparable to those of the more expensive quenched and tempered aluminum alloy castings. The fact that no quenching treatment, or even heating, is required for developing high strength in my improved aluminum-zinc alloys is an important advantage. This alloy is also readily machinable and highly resistant to corrosion.

Although the examples and test-results hereinafter described apply to castings, it is obvious that my improved aluminum-zinc alloy, which does not require heat-treatment to develop high strength, would also be highly useful in wrought form. Hence my invention is not confined to castings alone.

Aluminum-zinc alloys have also been highly recommended for their excellent mechanical properties, but in order to obtain tensile strengths as high as 30,000 pounds per square inch in sand castings, the zinc content must be up to about 20%. Such zinc content has been found in practice to be too high for good casting properties, strength at high temperatures, or corrosion resistance, so that these plain aluminum-zinc alloys have not been very much used in industrial practice. Substantially the same objections apply when part of the zinc is replaced by copper, which, although improving the stiffness or yield point appreciably, impairs the ductility rather seriously.

According to my invention, the zinc content is held to about 10% or less, and the hardening and strengthening effects of chromium, titanium, and magnesium are utilized to obtain a superior combination of yield point, ultimate tensile strength, and ductility. These last-mentioned elements all improve the corrosion resistance also, and in addition the titanium is advantageous in refining the grain, while the magnesium promotes age-hardening at room temperature.

The preferred composition for my new alloy is about 8% zinc, 0.5% chromium, 0.15% titanium, 0.8% magnesium, less than 0.8% iron, and less than 0.3% silicon, copper or manganese, with balance substantially aluminum.

Permissible limits in composition within which the properties do not vary seriously are about as follows:

	Per cent
Zinc	5 to 10
Chromium	.2 to .6
Titanium	.1 to .35
Magnesium	.3 to 2.5

Balance substantially aluminum.

The magnesium content should vary inversely with the zinc, since when both are low, the yield point is low, and when both are high the ductility is low.

To illustrate this relation, the following tensile tests results are set forth, each value being the average of two tests (with very few exceptions, due to flaws), made on castings not heat-treated but merely aged about four days at room temperature.

Table 1

Heat No.	Percent added				Lbs. per sq. in.		Percent elongation
	Zn	Cr	Ti	Mg	Yield point	Tensile strength	
1	15	0.47	0.15	0	17290	21300	2.0
2	12.5	.4	.1	0	17250	23200	4.0
3	10	.49	.26	0	11900	23700	11.3
4	10	.5	.15	0	11250	24000	12.0
5	10	.5	.15	.2	19500	28800	5.5
6	10	.5	.15	.3	23400	32500	4.7
7	10	.5	.15	.6	27000	32600	2.5
8	9	.5	.15	.4	24200	32700	5.2
9	8.5	.45	.15	.6	25000	33400	3.8
10	8	.5	.15	.8	27900	35300	4.5
11	7.5	.5	.15	.56	22400	32100	5.5
12	7.5	.5	.15	.84	26100	34000	4.5
13	7.5	.5	.15	1.0	25800	32200	2.5
14	7.5	.5	.15	1.5	31500	34400	1.5
15	7	.5	.15	1.2	27300	33200	2.8
16	5	.5	.15	1.0	21200	30700	5.5
17	5	.5	.15	2.0	27300	33400	2.7

Comparing heat 7 in Table 1 with heats 16 and

17, it will be seen that as much as 0.6% magnesium gives a rather low elongation with 10% zinc, but with 5% zinc, 1 or 2% magnesium may be added without reducing the elongation to an equally low value. The yield point is seen to be quite low in heats 1 to 5 with low magnesium, or in heat 16 with low zinc; but taking heat 16 as a starting point, it was raised appreciably either by increasing the zinc as in heats 7 and 10, or by increasing the magnesium as in heat 17. The best combinations of yield point and strength with reasonable elongation were obtained in heats 9, 10 and 12 with 7.5 to 8.5% zinc and 0.6 to 0.9% magnesium, the yield points being 25,000 or more, the tensile strength over 33,000, and the elongation at least 3.8%.

The best proportions of chromium and titanium in my improved alloys were determined by some preliminary experiments which indicated that with more than about 0.5% chromium, the alloys were embrittled so that both strength and ductility were reduced. Likewise I found that no particular advantage was obtained with over 0.15% titanium, although 0.1% was barely sufficient. These relations are illustrated by the following results:

Table 2

Heat No.	Per cent added				Lbs. per sq. in.		Per cent elongation
	Zn	Cr	Ti	Mg	Yield point	Tensile strength	
18	10	0.44	0	0	9480	21075	11.0
19	10	.5	.1	0	10450	21300	10.0
4	10	.5	.15	0	11250	24000	12.0
20	10	.5	.2	0	10300	22600	10.8
3	10	.49	.26	0	11900	23700	11.3
21	10	.71	.19	0	12400	18550	4.2
22	10	.5	0	.56	26600	28500	1.0
7	10	.5	.15	.6	27000	32600	2.5
23	10	.25	.15	.56	26300	31700	2.5
9	8.5	.45	.15	.6	25000	33400	3.8
24	8.5	0	.15	.6	24900	31600	3.0
25	8.5	0	0	.6	23800	27900	2.8
26	8	.45	.15	.75	24500	31300	4.0
27	8	.5	0	.75	23300	29900	4.5

The effect of variations in titanium content is shown by the first five samples listed in Table 2, in the comparison between samples 22 and 7, and by the last four samples listed. The addition of about 0.15% titanium produced a decided improvement in strength and yield point, and the grain size of the castings without titanium could be observed plainly to be coarser than the grain size of those containing titanium.

The effect of variations in chromium is also shown in Table 2. Sample 21, when compared with 3 and 4, shows that higher chromium content reduced both strength and ductility with only a slight improvement in yield point. Sample 23 is very similar to 7, showing that 0.25% chromium is almost as effective as 0.5%; but sample 24, when compared with 9, shows that in the absence of chromium the tensile properties are inferior.

It is considered advisable in these alloys to keep the chromium content close to 0.5% so as to secure the maximum benefit in resistance to corrosion without impairment of physical properties.

The addition of silicon, copper, or cadmium to these alloys is detrimental to the tensile properties of castings as illustrated by the tests reported in Table 3. Silicon was added as calcium silicide, containing about 65% silicon, except in one instance when 90% ferrosilicon was used with inferior results.

Table 3

Heat No.	Per cent added							Lbs. per sq. in.		Per cent elongation
	Zn	Cr	Ti	Mg	Si	Cu	Cd	Yield point	Tensile strength	
7	10	0.5	0.15	0.6	0	0	0	27000	32600	2.5
28	10	.5	.15	.6	.3	0	0	27200	30700	2.2
29	10	.5	.15	.6	.3(FeSi)	0	0	25100	27900	2.2
13	7.5	.5	.15	1.0	0	0	0	25800	32200	2.5
30	7.5	.5	.15	1.0	.5	0	0	23000	29200	3.5
16	5	.5	.15	1.0	0	0	0	21200	30700	5.5
31	5	.5	.15	1.0	.5	0	0	21800	27700	3.5
32	12.5	.4	.1	0	0	0	0	14100	21000	4.5
33	12.5	.4	.1	0	0	3	0	20200	20925	0.7
9	8.5	.45	.15	.6	0	0	0	25000	33400	3.8
34	8.5	.45	.15	.6	0	2	0	26600	28600	1.5
8	9	.5	.15	.4	0	0	0	24200	32700	5.2
35	9	.5	.15	.4	0	0	2	22500	30800	6.2
36	7	.5	.15	.4	0	0	2	15500	27800	12.0
37	5	.5	.15	.4	0	0	5	11800	23100	16.7

The first seven tests listed in Table 3 show that silicon decreases the strength of these alloys, with small irregular effects on the yield point and elongation. The addition of iron as in heat 29, which showed 1% iron on analysis, had a further detrimental effect. Heat 33 as compared with 32, and heat 34 as compared with 9, show that copper seriously decreased both strength and elongation, but with an increase in yield point. Cadmium as shown by the last four tests listed in this Table 3, whether substituted for aluminum or for zinc in the alloys, decreased the strength and yield point with an improvement in ductility.

It is evident therefore that a good grade of aluminum, low in silicon and copper, should be used for making my improved high-strength aluminum casting alloy. Iron up to 0.8% does not seem to be detrimental. The aluminum for these experiments was of at least 99% purity, and was melted in clay-bonded graphite crucibles in a gas-fired furnace. When the melt had reached a temperature of 1425° F., the chromium and titanium were added, either in the form of separate aluminum alloys containing respectively 6 to 7% chromium, and 6 to 7% titanium, or in the form of a single master alloy containing about 2.9% titanium and 8.5% chromium.

This last mentioned master alloy may be made by adding gradually to molten aluminum superheated to 2250° F. a mixture of green chromic oxide, pure white titanium oxide, and cryolite in about the following proportions: For 9 lbs. aluminum, I used ¾ lb. TiO_2, 1½ lbs. Cr_2O_3 and 2½ lbs. cryolite. Each small addition of the mixed oxides and flux should be thoroughly stirred into the aluminum before the next addition is made. When all the charge is completed, an extra stirring should be given and after ten minutes the alloy may be poured into ingot molds and cut up into convenient pieces for use. This alloy may also be made by adding the oxides, one after the other, instead of both mixed together. Alloys made by these methods have contained 2 to 4% titanium and 8 to 10% chromium. After the titanium and chromium are added to the aluminum at about 1425° F. in the production of my new high strength alloy, and are fully dissolved, the zinc is added as the pure metal, stirred well, and finally the magnesium is added in the same way.

The molten alloy should be fluxed with a little zinc chloride, stirred, skimmed, and allowed to cool to a suitable temperature for pouring the castings desired. For cast-to-size tensile test bars in dry sand molds, the pouring temperature was about 1300° F.

This new aluminum-zinc alloy can be remelted repeatedly without serious deterioration, provided its composition is maintained substantially constant. With careful melting practice, small additions of magnesium should be the only adjustment required. Sodium has also been used as a preventive of oxidation losses on remelting, but magnesium I have found to be preferable.

Some results obtained on remelting are presented below:

Table 4

Heat No.	Times melted	Original alloy charge					Added on remelt		Lbs. per sq. in.		Percent elongation
		Zn	Cr	Ti	Mg	Si	Na	Mg	Yield point	Tensile strength	
28	1	10	0.5	0.15	0.6	0.3	-----	-----	27200	30700	2.2
38	3	10	.5	.15	.6	.3	0.1	0	26800	33300	3.5
39	1	10	.5	.15	.45	0	-----	-----	25200	32500	3.6
40	3	10	.5	.15	.45	0	0	0	24400	35000	6.0
41	3	10	.5	.15	.45	0	.3	0	24200	32700	5.5
42	5	10	.5	.15	.45	0	0	0	21000	29450	4.5
43	6	10	.5	.15	.45	0	0	.5	28200	33400	2.8
44	1	8.5	.5	.15	.6	0	-----	-----	26000	34000	4.8
45	3	8.5	.5	.15	.6	0	0	0	22900	31400	5.3
46	4	8.5	.5	.15	.6	0	0	0	21200	32000	6.8
47	5	8.5	.5	.15	.6	0	0	.35	27500	33700	3.0

I might state that heat 39 as given in Table 4 is really an average of heats 6 and 7 (Table 1), both of which were remelted together to obtain heats 40 to 43 inclusive. Heat 44 is likewise an average from heats 8 and 10, which were similarly remelted together in equal proportions. A gradual drop in yield points on remelting without additions may be noticed from the above results, but this was corrected on further remelting when magnesium is added.

All the test results presented in Tables 1, 2, 3 and 4 were obtained from tests made three to five days after the alloys were cast. Immediately after casting the strength is lower, and two weeks later it is higher, without much change in ductility. Examples of these changes on ageing I will now describe:

Table 5

Heat No.	Ageing time, days	Percent added				Lbs. per sq. in		Percent elongation
		Zn	Cr	Ti	Mg	Yield point	Tensile strength	
6	3	10	0.5	0.15	0.3	23400	32500	4.7
6	16	10	.5	.15	.3	29000	34800	3.0
7	3	10	.5	.15	.6	27000	32600	2.5
7	16	10	.5	.15	.6	31500	35200	2.3
10	1	8	.5	.15	.8	22800	29800	4.0
10	4	8	.5	.15	.8	27900	35300	4.5
10	15	8	.5	.15	.8	29200	37000	4.0
14	1	7.5	.5	.15	1.5	27300	31600	2.0
14	5	7.5	.5	.15	1.5	31500	34400	1.5
14	16	7.5	.5	.15	1.5	35500	38400	1.5
16	1	5	.5	.15	1.0	16800	28200	7.5
16	5	5	.5	.15	1.0	21200	30700	5.5
16	16	5	.5	.15	1.0	25100	32600	4.5
17	1	5	.5	.15	2.0	24400	29400	3.5
17	5	5	.5	.15	2.0	27300	33400	2.7
17	16	5	.5	.15	2.0	31200	35700	2.0

It is evident from Table 5 that yield points above 30,000 lbs. per sq. in. with tensile strengths over 35,000 are obtainable in these cast alloys after ageing two weeks at room temperature, with as much elongation as is shown by the common aluminum casting alloys of about 22,000 lbs. per sq. in. tensile strength. If more than 3% elongation is required after ageing, the zinc content should not be as high as 10%, nor the magnesium over 1%, and the yield point then will not be quite up to 30,000 lbs. per sq. in.

The various alloys described above have been distinguished on the basis of the materials added in the melting crucible. Owing to melting losses or absorption of impurities, the compositions of the alloys tested may have been somewhat different. To obtain an idea of the degree of these differences, I made some chemical annalyses of the test bars, and the results are shown in Table 6.

Table 6

Heat No.	Percent added				Chemical analysis							
	Zn	Cr	Ti	Mg	Zn	Cr	Ti	Mg	Fe	Si	Cu	Mn
3	10	0.49	0.26	0	10.44	0.40	0.248	-----	-----	-----	-----	-----
4	10	.5	.15	0	-----	-----	.150	-----	-----	-----	-----	-----
9	8.5	.45	.15	.6	8.08	.49	.172	0.65	0.75	-----	-----	-----
10	8	.5	.15	.8	7.94	.50	.165	.74	.6	0.1	0.07	0.03
26	8	.45	.15	.75	7.91	.49	.135	.69	-----	-----	-----	-----
32	12.5	.4	.1	0	-----	.43	.238	-----	-----	-----	-----	-----
43 (remelt)	10	.5	.15	.95	10.21	.49	.165	.62	.76	.15	.08	.05

The iron contents were found to have been derived from the aluminum ingots used as a basis for these experimental alloys. This lot of ingot contained 0.49% iron. Although that amount of chromium, titanium, or magnesium would have an important effect on the properties of these alloys, iron is much less powerful in its influence, and may be present in the alloys in any amount from the usual low value of about 0.3% up to 0.8% without making much difference.

I claim as my invention:

1. A metallurgical alloy composed of about 2% to 5% titanium, about 7% to 12% chromium with the balance commercial aluminum having impurities not in excess of 1.0%.

2. A metallurgical alloy composed of about 2% to 4% titanium, about 8% to 10% chromium with the balance commercial aluminum having impurities not in excess of 1.0%.

3. A metallurgical alloy composed of about 2.9% titanium, about 8.5% chromium with the balance commercial aluminum having impurities not in excess of 1.0%.

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