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ALUMINUM BASE ALLOY DIE CASTING

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This invention relates to the composition of a die cast aluminum base alloy which has superior strength and ductility.

Die castings of aluminum base alloys have been on the market for many years and have been used for a variety of purposes where light weight, a smooth as-cast surface and accurate dimensions are required and where large quantities of castings must be made at a relatively low cost. For the most part, the castings have not been employed where they are subjected to high stresses but have been extensively used for parts of equipment which are lightly stressed or are under substantially no stress. The alloy which up to the present has been considered to offer potentially the best combination of strength and elongation is one composed of aluminum and 8% magnesium. This alloy has only fair casting characteristics, and castings are not only rejected for surface cracks, shrinkage and incomplete filling of the die, but under production conditions the maximum strength and elongation are not generally realized. The loss occasioned by rejections is reflected in a higher cost for the castings that pass inspection as compared to those made with the lower strength aluminum-silicon and aluminum-silicon-copper alloy types.

Another disadvantage which has attended aluminum base alloy die castings has been their poor response to those thermal treatments which are commonly used to increase the strength and hardness of sand and permanent mold casting compositions. It has been the general feeling that the rapid chilling of the casting during solidification and the fine grain size developed thereby has left little room for further improvement in the mechanical properties. With the increased demand for aluminum base alloy die castings, there has been a greater insistence upon obtaining castings which not only possess a higher strength and elongation in the as-cast condition than heretofore available with the aluminum-silicon and aluminum-silicon-copper alloys, but which are amenable to thermal treatments which will increase their strength.

It is an object of my invention to provide an aluminum base alloy die casting which not only possesses a combination of high strength and high ductility, but which can be cast more easily than the commercial aluminum-8% magnesium composition. Another object is to provide an aluminum base alloy die casting which will undergo an increase in strength when subjected to a low temperature thermal treatment. Still another object is to provide an aluminum base alloy die

casting which can tolerate the usual iron impurity without sacrifice of ductility.

The foregoing objects as well as other advantages are realized in a die casting composed of an aluminum base alloy containing as its essential components aluminum, from 6 to 11% silicon, 0.1 to 0.6% chromium and 0.01 to 0.10% beryllium. It is often desirable to add from 0.1 to 0.5% magnesium to the foregoing alloy to increase the elongation in the as-cast condition and to improve the strength of the casting when given a low temperature thermal treatment. To obtain the best properties the alloy should contain from 7.5 to 9.5% silicon, 0.2 to 0.4% magnesium, 0.25 to 0.50% chromium and 0.02 to 0.04% beryllium and the balance aluminum. It is to be understood, of course, that the alloy will also contain impurities, especially iron. Die castings of the base alloy in the as-cast condition possess a tensile strength of not less than 41,000 p. s. i., a minimum yield strength of 21,000 p. s. i. and an elongation of over 5.0%. When subjected to an artificial aging, as more fully described hereinbelow, the minimum tensile strength can be increased to 43,000 p. s. i., and the yield strength raised to 31,000 p. s. i. while the elongation is not reduced below 2.5%. The combination of high strength and elongation, together with the excellent castability of the alloy, provides advantages over any other aluminum base alloy die castings with which I am acquainted. I attribute these results to the combined effect of beryllium and chromium in the alloy. Neither element alone achieves the desired result, but together they have a surprising effect on the strength and elongation.

It is well recognized in the art that iron is a common impurity in aluminum base alloys, particularly in die castings since the alloys are often held in contact with ferrous metal melting pots and handled in ferrous metal equipment. Some iron is dissolved with a resultant increase in the quantity found in the final composition. It is also well known that a small amount of iron impurity is beneficial to the castability of the aluminum base alloys. However, it does have an adverse effect upon ductility. Generally, the iron content must be kept below 2% and preferably less than 1.5%. In spite of such relatively high maximum limits, the ductility of my alloy does not suffer and, in fact, is superior to that found in die castings made from well known commercial aluminum base alloys of the prior art.

In addition to the iron impurity, other elements may be present as impurities in relatively small amounts. For example, copper can be tolerated in quantities up to 0.2% while a maximum of 0.10% is applicable to any manganese, zinc, nickel and tin impurities.

The unique combination of properties obtained in die castings of my alloy are illustrated in the following Table I which shows average tensile properties of both experimental and standard aluminum base alloys as determined from standard ¼ inch diameter die cast test bars. Alloys A, B and C represent compositions having less than the number of elements required in my alloy, while alloys D and E typify my invention. Alloys F and G are representative of two commercial compositions and the property values listed are typical for these alloys in the die cast condition.

TABLE I

Tensile properties of die cast test bars in the as-cast condition

Alloy	Alloy Composition					Tensile Strength, p. s. i.	Yield Strength, p. s. i.	Percent Elongation
	Percent Si	Percent Fe	Percent Mg	Percent Cr	Percent Be			
A	9.38	1.02	0	0	0	42,250	19,700	5.9
B	9.36	1.01	0	0.20	0	40,500	21,750	5.2
C	8.28	0.98	0	0	0.034	39,820	19,600	10.1
D	9.46	1.13	0	0.31	0.030	41,540	21,650	7.9
E	8.72	0.98	0.28	0.33	0.035	41,460	21,820	9.6
F	9.5	1	0.5	0	0	44,000	27,000	3.0
G	0	0	8.0	0	0	45,000	27,000	8.0

From an inspection of the above tensile properties, it is evident that although an aluminum-silicon alloy with an iron impurity of about 1% had a fairly high tensile strength it also possessed a low yield strength. The addition of chromium to the foregoing binary alloy lowered the tensile strength and elongation but raised the yield strength. The addition of beryllium to the binary base composition lowered the tensile strength, but increased the elongation. However, the presence of both chromium and beryllium in alloys D and E increased the tensile strength above that of the alloys B and C containing either chromium or beryllium and at the same time produced a higher elongation than alloys A and B. Thus, alloy D has a combination of strength and elongation not possessed by the preceding alloys. The addition of magnesium, as in alloy E, caused some increase in the elongation. It also serves to improve the strength of thermally treated castings as illustrated hereinbelow.

The foregoing test results are more significant when viewed in the light of typical properties of the well-known aluminum die casting alloy, alloy F. Die castings of that alloy have high tensile and yield strengths but a relatively low elongation. Alloy G has a desirably high tensile strength and elongation, but as pointed out hereinabove, the alloy is deficient in casting characteristics.

The tensile and yied strengths of die castings made with my alloy may be increased by a low temperature thermal treatment consisting of heating the castings to a temperature between 300 and 400° F. for a period of 7 to 12 hours. The advantage gained by such treatment is illustrated in the following Table II representing averages obtained on standard die cast test bars of two alloys which had been artificially aged at 340° F. for 10 hours.

TABLE II

Tensile properties of die cast test bars in artificially aged condition

Alloy	Alloy Composition					Tensile Strength, p. s. i.	Yield Strength, p. s. i.	Percent Elongation
	Percent Si	Percent Fe	Percent Mg	Percent Cr	Percent Be			
H	9.32	0.99	0.30	0.24	0.040	47,850	34,590	4.5
I	8.41	1.00	0.26	0.21	0.040	46,030	32,950	6.6

The increase in tensile strength and yield strength as compared to the standard F and G alloys is evident, especially the increase in yield strength. In spite of this, the elongation is still above that of the F alloy in the as-cast condition.

Although die castings of my alloy in either the as-cast or artificial aged conditions possess attractive tensile properties, it has also been found that the alloy is readily cast and is relatively free from such defects as incomplete filling of the mold, surface cracks and surface shrinkage. Moreover, the die castings have a satisfactory resistance to corrosion.

Having thus described my invention and certain embodiments thereof, I claim:

1. An aluminum base alloy die casting having a composition consisting essentially of, aluminum, 6 to 11% silicon, 0.1 to 0.6% chromium and 0.01 to 0.10% beryllium, with a maximum of 0.2% copper, 2% iron and 0.1% each of manganese, nickel, zinc and tin as impurities, said die casting in the as-cast condition being characterized by a minimum tensile strength of 41,000 p. s. i. and a minimum elongation of 5.0%.

2. An aluminum base alloy die casting having a composition consisting of 6 to 11% silicon, 0.1 to 0.6 chromium, 0.01 to 0.10% beryllium and 0.1 to 0.5% magnesium, with a maximum of 0.2% copper, 2% iron and 0.1% each of manganese, nickel, zinc and tin as impurities and the balance substantially all aluminum, said die casting in the as-cast condition being characterized by a minimum tensile strength of 41,000 p. s. i. and a minimum elongation of 5%.

3. An aluminum base alloy die casting having a composition consisting of 7.5 to 9.5% silicon, 0.20 to 0.40% magnesium, 0.25 to 0.50% chromium and 0.02 to 0.04% beryllium, with a maximum of 0.2% copper, 1.5% iron and 0.1% each of manganese, nickel, zinc and tin as impurities and the balance substantially all aluminum, said die casting in the as-cast condition being characterized by a minimum tensile strength of 41,000 p. s. i. and a minimum elongation of 5%.

4. An artificially aged aluminum base alloy die casting having a composition consisting of 6 to 11% silicon, 0.1 to 0.5% magnesium, 0.1 to 0.6% chromium and 0.01 to 0.10% beryllium, with a maximum of 0.2% copper, 2% iron and 0.1% each of manganese, nickel, zinc and tin as impurities and the balance substantially all aluminum, said casting having a structure resulting from heating the casting from 7 to 12 hours at 300 to 400° F., said artificially aged casting being characterized by a minimum tensile strength of 43,000 p. s. i. and a minimum elongation of 2.5%.

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