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ALUMINUM SILICON CASTING ALLOYS

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This invention relates to new and improved aluminum casting alloys and more particularly to aluminum casting alloys adapted to overcome many of the problems arising in the use of such aluminum alloys in permanent mold casting and in die casting processes.

With reference first to sand and permanent mold casting, one of the difficulties which has heretofore been encountered stems from the high shrinkage that takes place in the cast metal during solidification and cooling. Such shrinkage tends to produce voids in the cast metal product and shrinkage cracks which render the product unusable for many of the uses for which it was intended. These shrinkage difficulties increase in proportion to cross-section of the article being cast and thus become a considerable factor in the casting of articles of large dimension and weight. Under these circumstances, excessive losses as scrap materially increase the cost of the casting process.

In the field of die casting, problems arise with respect to the inability of the metal completely to flow together during the casting operation whereby a casting can be secured with voids, discontinuities, surface roughness or other defects. This also results in the formation of a casting of low strength due to failure at the point of discontinuity when the casting is placed under stress. This also results in castings which are not pressure-tight because of the voids or discontinuities formed therein. Such discontinuities and surface roughness also impair the ability to provide a smooth and attractive finish since such discontinuities in the surface show through and cannot easily be removed or concealed. It has been found and believed that such discontinuities in die casting of aluminum base alloys result from the presence of a tenacious oxide skin or layer which forms almost instantaneously on the surface of the molten metal and that the surface tension characteristics of this oxide film are such as to resist wetting out by the meeting streams of molten metal flowing through the mold in the die casting operation. As a result the surfaces tend to separate one from the other and sometimes the fluidity is reduced or is so low that the metal solidifies before these separations can be forced together by the pressure of the plunger, with the result that these discontinuities will remain in the cast product.

To the present, fluidity has been imparted to the aluminum casting alloys by the addition of silicon. For this purpose, aluminum alloys used for die casting have been formulated to contain more than 7 percent silicon and preferably an amount of silicon within the range of 8.5 to 13 percent. An aluminum casting alloy with less than 7 percent silicon has not heretofore been considered suitable for use in die casting. Maximum fluidity is achieved in a formulation containing from 10 to 12 percent silicon but at 11.6 percent silicon, the eutectic composition is reached whereby the metal freezes almost instantaneously upon cooling. Thus the problem of discontinuity is aggravated rather than being decreased by the addition of optimum amounts of silicon for maximum fluidity.

Another problem often encountered in the casting of aluminum base alloys is often referred to in the trade as "soldering to the die," which refers to the sticking of the cast metal product in the die. To prevent soldering, it has been necessary to provide for an iron content in

the aluminum casting alloy in an amount in excess of 1 percent. Such high amount of iron in the aluminum casting alloy has posed a number of problems having to do with the foregoing in that the iron reacts in the presence of manganese and chromium, usually present in the aluminum casting alloy to form β-iron silicides. These represent hard spots in the casting and they materially lower the fluidity of the molten metal.

It is an object of this invention to produce and to provide a method for producing aluminum casting alloys wherein the problems of the types previously described are materially reduced in the use of the aluminum casting alloys in the fabrication of products by various of the casting techniques and it is a related object to produce a new and improved aluminum casting alloy.

More specifically, it is an object of this invention to produce aluminum casting alloys which substantially avoid shrinkage problems upon cooling; which embody high fluidity for use in die casting; which enable the silicon content to be reduced without corresponding loss in fluidity thereby to extend the solidification or freezing range of the metal; which enable reduction in iron content to below the level for harmful formation of β-iron silicides without loss in fluidity, which reduce die soldering even with alloys having conventional iron content, and which provide for an unexcepted increase in other physical and mechanical properties of the product cast from the aluminum base alloy including shock resistance, impact resistance and strength.

It has been found that these various improvements can be simply and effectively achieved by the combination to introduce calcium in elemental form into the molten aluminum casting alloy. The results secured are wholly unexpected since the presence of calcium in aluminum casting alloys has heretofore been considered and found to be most undesirable. Calcium has been defined as an impurity in such alloys and every effort has been made to reduce the calcium content to below a predetermined level. Usually 0.003 percent has been considered the maximum amount of calcium which could be tolerated in aluminum base casting alloys.

Calcium is brought into the aluminum casting alloys with the addition of silicon which has been used to provide fluidity in the aluminum alloy formulation to be supplied to the die casting art. Such calcium finds its presence in the aluminum alloy in the form of calcium silicides, calcium phosphides, calcium nitrides and the like and, when in this form, the calcium is still considered to be a harmful impurity which requires removal to levels below 0.003 and perferably below 0.001 percent.

Thus the presence of calcium introduced as elemental metal in accordance with the practice of this invention should not be confused with the presence of calcium in the form of the various silicides, nitrides, phosphides and the like, as previously found in such aluminum casting alloys. The latter are considered impurities and require removal to below a certain low level while the addition of elemental calcium has been found materially to improve the characteristics of the aluminum casting alloy. In accordance with the practice of this invention, the desired amount of elemental calcium is introduced after the calcium impurities, as heretofore described, are removed to below the maximum for these impurities. Removal of the calcium impurities to below 0.001 percent calcium can be effected by chlorination.

The desirable effects from the addition of elemental calcium can be secured when calcium is provided to be present in the alloy in an amount greater than 0.002 percent. No further beneficial results are secured by the

addition of calcium in a concentration greater than 0.020 percent. Within this range, it is preferred to formulate the aluminum casting alloy with the addition of elemental calcium to provide for a concentration of calcium within the range of 0.004 to 0.015 percent and more preferably about 0.004 to 0.010 percent. The elemental calcium can be added in the desired amounts directly to the molten alloy during refining and preferably after the calcium silicides, calcium nitrides, calcium phosphides and the like have been removed, as by chlorination.

The exact mechanisms by which the calcium operates in the alloy system to impart the unexpected improvements are not yet fully understood. The described presence of the calcium in the aluminum casting alloy within the amounts described appears to enhance the ability of the aluminum casting alloy to absorb larger amounts of gases while in the molten state. Such absorbed gases are released when the molten metal is converted to the solid state and the gases remain entrapped in the frozen metal to provide voids of pinhole porosity thereby to decrease the density of the cast product but more important to compensate for the shrinkage otherwise taking place during solidification and cooling. Thus the presence of calcium incorporated in accordance with the practice of this invention operates to avoid the porosity and shrinkage problems heretofore encountered in sand and in permanent mold casting. It is preferred to grain refine the alloy further to reduce the pinhole porosity effected by the release of gases thereby materially to increase the strength and other mechanical properties of the aluminum alloy casting and also to increase the pressure-tightness of the casting. These improvements may be due in part from the reduction in shrinkage defects and in part from the fine pinhole porosity and included gases within the alloy. The addition of elemental calcium appears to impart these beneficial effects in various of the formulations of die and permanent mold aluminum casting alloys.

The introduction of calcium in accordance with the practice of this invention has also been found to provide unexpected improvements in aluminum die casting alloys. Various reasons are ascribed for these improvements. It is believed that calcium in the amounts described becomes effective to modify the characteristics of the oxide film formed on the surface of the molten aluminum casting alloy or else to prevent its formation whereby meeting streams of molten alloy are more readily able to wet out one another for substantially complete and immediate mergence whereby the discontinuities heretofore experienced are greatly reduced and, in some instances, substantially completely eliminated.

Instrumental also is the marked increase in fluidity which is achieved by the presence of the calcium in the amounts described. In a die casting machine, it appears that the fluidity is increased by a factor of about three when calcium is incorporated in accordance with the practice of this invention. This marked and unexpected increase in fluidity greatly enhances the flow of the molten metal in die casting whereby complete filling of the mold can be achieved more rapidly and more effectively thereby to permit the fabrication of completely formed castings. This coupled with the desirable effect on the oxide film results in a dramatic decrease in discontinuities of the types heretofore experienced.

In one particular application for die casting gas regulator valves, rejects of up to 50 percent were experienced. When production was converted to the use of the same alloy with elemental calcium added to provide a calcium content of 0.010 percent, rejects were no longer experienced because of pressure-tightness. In another particular application of aluminum casting alloys for the die casting of washing machine covers, losses of 50 percent due to discontinuities were reduced to less than 20 percent rejects by the modification of the aluminum casting alloy by the introduction of elemental calcium to provide a calcium content of 0.006 percent.

The marked increase in fluidity which is experienced by the practice of this invention permits reduction to be made in the amount of silicon required to provide fluidity sufficient for die casting or otherwise molding the alloy. Reductions in the silicon content to amounts less than 11.6 percent enable the alloy to depart from its eutectic whereby a greater spread between the liquidus and solidus states is obtained. Thus there is more time in which the metal in the mushy state can be compacted by the pressure of the plunger. Thus, a cold chamber die casting machine can continue to operate to compact the alloy and to force the various streams to weld at points where discontinuity might otherwise form. Beneficial use has been experienced when calcium in the amounts described is incorporated into die casting alloys containing from 7 to 13 percent silicon, from 0 to 5 percent copper, and from 0 to 0.5 percent magnesium. While alloys containing less than 7 percent silicon have not been desirable for use as a die casting alloy, die castings can now be made with aluminum casting alloys formulated to contain as little as 3 percent silicon when elemental calcium in the amounts described has been incorporated in accordance with the practice of this invention.

The increase in fluidity, achieved by the practice of this invention, also enables the preparation of an aluminum casting alloy with an iron content less than 1 percent without experiencing any increase in die soldering. It appears that the calcium present in amounts within the range of from more than 0.003 to 0.020 percent markedly reduces die soldering. The iron content can be reduced to as low as 0.6 percent without experiencing difficulties in die soldering when 0.010 percent calcium is also present. Normally, an aluminum base alloy containing less than 0.3 percent iron would solder to the die so strongly as to make it impractical to cast the alloy. With the addition of elemental calcium to provide for a calcium content of 0.006 percent, die soldering of the same alloy containing less than 0.3 percent iron can be reduced to a point where the alloy can be employed as a die casting alloy.

Aside from the foregoing improvements which are unexpectedly secured, the reduction in iron and silicon, made possible by the practice of this invention, is instrumental in the further improvement of the alloy from the standpoint of shock resistance, impact resistance, and elongation. This is an important advantage particularly where shock resistance and high strength are material to the final products.

The following are examples of representative aluminum casting alloys formulated to embody the features of this invention in which elements other than aluminum are set forth:

Example 1

Element:	Amount (percent)
Ca	0.005.
Cu	0.6 max.
Si	11.0–13.0.
Mg	0.10 max.
Zn	0.50 max.
Fe	1.2 max.
Mn	0.3 max.
Ni	0.50 max.
Others each	0.20 max.

Example 2

Ca	0.007.
Cu	0.6 max.
Si	9.0–10.0.
Mg	0.45–0.6.
Zn	0.50 max.
Fe	1.0 max.
Mn	0.35 max.
Ni	0.50 max.
Others each	0.20 max.

Example 3

Element:	Amount (percent)
Ca	0.007.
Cu	3.0–4.0.
Si	8.5–9.5.
Mg	0.10 max.
Zn	1.0 max.
Fe	1.0 max.
Mn	0.50 max.
Ni	0.50 max.
Others each	0.30 max.

Example 4

Ca	0.006.
Cu	9.2–10.8.
Si	2.0 max.
Mg	0.20–0.35.
Zn	0.8 max.
Fe	1.2 max.
Mn	0.6 max.
Ni	0.50 max.
Others each	0.20 max.

Example 5

Ca	0.005.
Cu	9.5–10.5.
Si	3.5–4.5.
Mg	0.15–0.35.
Zn	1.5 max.
Fe	1.2 max.
Mn	0.6 max.
Ni	0.50 max.
Others each	0.20 max.

Example 6

Ca	0.007.
Cu	3.0–4.0.
Si	7.5–8.5.
Mg	0.10 max.
Zn	1.0 max.
Fe	1.0 max.
Mn	0.50 max.
Ni	0.40 max.
Ti	0.25 max.
Others each	0.20 max.

Example 7

Ca	0.007.
Cu	1.0–2.0.
Si	4.5–5.5.
Mg	0.40–0.6.
Zn	0.50 max.
Fe	0.8 max.
Mn	0.50 max.
Ni	0.30 max.
Ti	0.25 max.
Others each	0.20 max.

Example 8

Ca	0.007.
Cu	1.0–1.5.
Si	4.5–5.5.
Mg	0.40–4.6.
Zn	0.20 max.
Cr	0.25 max.
Fe	0.6 max.
Mn	0.30 max.
Ti	0.25 max.
Others each	0.05 max.

Example 9

Ca	0.010.
Cu	0.6 max.
Si	4.5–6.0.
Mg	0.10 max.
Zn	0.50 max.
Fe	0.8 max.
Mn	0.35 max.
Ni	0.50 max.
Others each	0.20 max.

Example 10

Element:	Amount (percent)
Ca	0.010.
Cu	0.30 max.
Si	4.5–6.0.
Mg	0.05 max.
Zn	0.30 max.
Fe	0.8 max.
Mn	0.50 max.
Ti	0.25 max.
Others each	0.20 max.

Example 11

Ca	0.010.
Cu	0.10 max.
Si	4.5–6.0.
Mg	0.05 max.
Zn	0.30 max.
Fe	0.8 max.
Mn	0.35 max.
Ti	0.25 max.
Others each	0.05 max.

Example 12

Ca	0.010.
Cu	4.0–5.0.
Si	2.0 max.
Mg	0.05 max.
Zn	0.50 max.
Fe	1.0 max.
Mn	0.50 max.
Ti	0.25 max.
Others each	0.10 max.

Example 13

Ca	0.010.
Cu	4.0–5.0.
Si	1.5 max.
Mg	0.03 max.
Zn	0.35 max.
Fe	0.8 max.
Mn	0.35 max.
Ti	0.25 max.
Others each	0.05 max.

Example 14

Ca	0.007.
Cu	3.0–4.0.
Si	5.5–6.5.
Mg	0.10 max.
Zn	1.5 max.
Fe	1.0 max.
Mn	0.6 max.
Ti	0.25 max.
Others each	0.30 max.

The elemental calcium may be introduced in various forms such as in the form of solid calcium, powdered calcium or alloys containing calcium in relatively high concentration. Introduction is made while the aluminum base casting alloy is in a molten state and preferably after the other impurities including the calcium nitrides, phosphides and silicides, which may previously have been brought in with silicon, have been removed.

It will be apparent from the foregoing that I have provided a new and improved aluminum casting alloy and method for the preparation of same wherein the alloy is greatly improved in its fluidity from the standpoint of casting by permanent mold or die casting and whereby further improvements can be achieved by the reduction of silicon and iron heretofore found to be detrimental to many of the characteristics of the casting processes but which have previously been essential for the purposes of introducing sufficient fluidity for die casting or sufficient resistance to soldering to permit removal of the casting from the mold. The concepts of this invention to introduce elemental calcium into aluminum base alloys has been found also effective to minimize shrinkage problems

and flow problems, especially from the standpoint of rapid and complete wet-out to eliminate discontinuities in the surfaces of products molded thereof.

It will be understood that changes may be made in the details of the formulation and methods of addition without departing from the spirit of the invention, especially as defined in the following claims.

I claim:

1. An aluminum die casting alloy consisting of essentially of from 3 to 13 percent silicon and calcium introduced as elemental calcium in an amount within the range of 0.004 to 0.015 percent, the balance being essentially aluminum.

2. An aluminum base die casting alloy consisting essentially of silicon in an amount within the range of 3 to 13 percent, calcium introduced as elemental calcium in an

amount greater than 0.002 percent but less than 0.020 percent and in which the calcium compound selected from the group consisting of calcium nitride, calcium phosphide and calcium sulphide brought in with the silicon is present in an amount less than 0.001 percent, the balance being essentially aluminum.

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