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# ALUMINUM ALLOY FOR HIGH TEMPERATURE SERVICE

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The present invention is directed to a new and improved aluminum base casting alloy for elevated temperature service having certain desirable property combinations not found among other alloys of this type.

There exists a relatively few aluminum base casting alloys acceptable for use at elevated temperatures of 600° F. or slightly over, while at lower operating temperatures the selection is markedly greater. The reason is that the most rapid decrease in the mechanical properties of any aluminum alloy occurs in the region of 400° F. to 600° F. and only those which retain the highest values in relation to temperature-property curves may be regarded as suitable for use within a fixed range.

The few available domestic and foreign alloys designed for elevated temperature applications of 600° F. plus, all exhibit the common characteristic of little or no ductility (1.0% or less) in their heat treated conditions at room temperature. This particular room temperature property reflects in a most favorable manner at elevated temperatures by retaining low deformation under applied loads. This and other related features, however, are offset most frequently by the lack of ductility at room temperature. This results in limited application due to their inability to withstand the stresses, strains and torques applied in the course of certain mechanical finishing operations.

In connection with the types of procedures followed in finishing the alloy castings, metallic inserts, such as steel bearing sleeves for shaft mountings, must be applied to the castings for strengthening and wear-resistant purposes. A further example of mechanical finishing procedures includes the use of inserts for interconnecting castings, all types of inserts being applied to the castings by machine operations. In order to prevent a high rate of rejection of finished items, it is considered essential that the ductility at room temperature of the cast alloy be adequate to allow efficient completion of the machine operations. In this respect, many known alloys fall short of efficient use.

It has been found that it is often the case that improving of the low or room temperature ductility of an alloy in its cast condition results in a loss of desirable, and often required, high temperature properties. With the cast item being designed for primarily high temperature use, such as in present-day missile development work, loss of the requisite high temperature properties cannot be to any appreciable degree. Known high temperature service aluminum base alloys have not been found capable of accommodating improved properties at room temperatures for machine operations without a degree of high temperature property loss of a nature affecting the suitability of the cast alloy item. This plus the degree of damage loss experienced as a result of the machining operations has made it extremely important to develop an improved alloy.

Another factor restricting the unlimited use of presently available elevated temperature alloys is their common rating in the field of pressure tightness. Measured in terms of an aluminum-silicon type alloy, all are inferior, and since many new applications involve high initial operating pressures plus surge pressures several times over, an improved alloy is essential.



It is an object of the present invention to provide a new and improved aluminum base alloy capable of high temperature service in the cast condition while further exhibiting improved room temperature properties, such as improved ductility, which particularly adapt the alloy for machine operations.

Another object is to provide a new and improved aluminum base alloy for use in forming cast items exhibiting excellent high temperature properties in addition to low or room temperature ductility on the order allowing extensive machining for finishing to any desired degree without damage to the castings.

Still a further object is to provide a new and improved aluminum base alloy of broad temperature range use in the cast condition, the alloy including no more than about 2.75% silicon which is at least partially modified from needle-like crystalline structure to nodular-like crystalline structure to an extent that the ductility of the alloy at room temperatures is increased.

Another object is to provide a new and improved aluminum base casting alloy of the type described which further exhibits improved pressure tightness at elevated temperatures under initial high pressure surge conditions.

Other objects not specifically set forth will become apparent from the following detailed description of the invention.

Typical compositions of the aluminum base alloy of the present invention are as follows:

| | Percent By Weight | | |
|---|---|---|---|
| | Nominal | Minimum | Maximum |
| Copper | 5.00 | 4.50 | 5.50 |
| Iron | 0.15 | 0.00 | 0.20 |
| Silicon | 2.50 | 2.25 | 2.75 |
| Magnesium | 0.30 | 0.20 | 0.45 |
| Nickel | 0.50 | 0.35 | 0.65 |
| Chromium | 1.25 | 1.00 | 1.50 |
| Molybdenum | 0.25 | 0.15 | 0.40 |
| Vanadium | 0.25 | 0.15 | 0.40 |
| Others | Additions for Refinement | | 0.35 |

An important feature of the alloy of the present invention resides in the inclusion therein of both molybdenum and vanadium. These constituents will preferably each be present in quantities of from about 0.15 to 0.40% by weight. The importance of these constituents will subsequently be described in greater detail.

General commercial practices are followed in formulating the alloy by introducing the various constituents in solid form into a melt at known temperatures adequate to form a molten mass. The copper constituent will combine with aluminum and with quenching the copper aluminide ($CuAl_2$) is retained in solid solution. This particular compound provides one of the several hardening constituents as a result of low temperature aging and precipitating treatment in the known manner. Certain portions of the silicon and magnesium constituents form magnesium silicide ($Mg_2Si$). In this respect sufficient silicon must be present to assure formation of the silicide but, in line with an important feature of the alloy of the present invention, the silicon present should preferably not exceed 2.75% as an excess of this amount has been found to adversely affect the elevated temperature properties of the alloy. The silicide is a hardener subject to aging and the amount of silicide present should be sufficient to provide adequate fluidity during pouring of the casting as well as provide added assurance of pressure tightness over the entire operative temperature range which includes temperatures in excess of 600° F. as well as room temperatures or the like.

It is believed that the chromium, at least to a certain

extent, combines with aluminum to form a chromium-aluminum combination such as ($CrAl_7$). This combination functions as an elevated temperature constituent to provide the requisite high temperature properties without adversely affecting room temperature properties of a type to be described. The nickel will, at least to a small extent, combine with aluminum to form nickel aluminide ($NiAl_3$). It is believed that very little nickel aluminide is formed and such in certain compositions will combine with the copper aluminide. This combination is a high temperature constituent commonly present in known compositions but not in such small percentages as present in the compositions of the present invention. It is further believed that certain quantities of the elements chromium, molybdenum, nickel and vanadium combine with aluminum at solution temperatures and with quenching and aging provide the high temperature compounds establishing the desired elevated temperature properties of the alloy. At any rate, these elements are present for high temperature purposes solely. It has been found upon testing of the alloy of the present invention that these constituents provide improved high temperature resistance thereby allowing use of the alloy in cast form at even higher temperatures than are suitable in connection with known alloys. In this respect, the presence of chromium, molybdenum, nickel and vanadium can increase the temperature resistance of a casting to about 25° or more, thus providing a high temperature resistance in excess of 600 to 625° F.

Titanium may be present as a grain refinement element and is a standard addition to the extent necessary each time that the alloy is subject to melting. Other recognized grain refinement elements, such as zirconium and boron, may be used in place of, or in addition to, titanium and it has further been found that in order to merely provide a workable alloy of the type described, the addition of any one of these elements is not absolutely necessary. However, it is preferred that a grain refinement element such as titanium, zirconium and/or boron or combinations thereof should be present in the alloy along the lines specified above.

As previously described, an important feature of the alloy of the present invention resides in the extent to which silicon is present in the mix. While silicon can be present in relatively small quantities adequate to impart to the melt requisite fluidity for handling of the same, it is preferred that an excess of silicon be present not to exceed about 2.75% of the total weight of the alloy. As previously described, excess silicon is added assurance of pressure tightness over the entire operative temperature range. Still further, with sufficient silicon present it is possible to modify the structure of the silicon from needle-like crystalline arrangement to nodular-like crystalline arrangement resulting in an important increase in ductility of the alloy at room temperatures. Quantities of silicon exceeding to any substantial extent the 2.75% preferred limit referred to adversely affect the high temperature properties of the alloy. However, sufficient silicon allows modification to nodular crystalline form to substantially increase ductility at room temperatures without in any respect adversely affecting the high temperature properties of the alloy.

The offered values of importance of the alloy of the present invention include the following:

| | Typical | Minimum |
|---|---|---|
| Tensile Strength, p.s.i. | 40,000 | 35,000 |
| Yield Strength, p.s.i. | 30,000 | 25,000 |
| Elongation (Room Temperatures), Percent in 2 inches | 2.5 | 2.0 |
| Brinell Hardness | 90-105 | 85 |

The alloy exhibits adequate hardness at all temperatures within the operative range of use of the same. While the ductility of the alloy at room temperatures is increased over that of known commercial alloys, this property does not adversely affect the high temperature properties of the alloy. The ductility at high temperatures is important from the standpoint of creep and the degree of recovery. The alloy of the present invention has on the order of 0.29% deformation at 600° F. and 1,000 hours with a 2500 pound load. From these representative figures it is apparent that an alloy of the present invention exhibits improved wide temperature range properties of an extent not present in known aluminum base alloys.

The alloy can be heat treated to increase the tensile and yield strength as well as other related properties without any appreciable loss in ductility from the as cast condition. As previously described, the low order of ductility of known aluminum base alloys of the high temperature type has materially limited efficient use of castings of such alloys insofar as machine operations on the castings at room temperatures are concerned. Considerable breakage and failure of the cast items at room temperatures have occurred upon subjecting the same to machine operations for the inclusion of inserts for strengthening and wear purposes, such as involved in standard procedures followed to interconnect castings as well as provide shaft mountings. As set forth above, the improved aluminum base alloy of the present invention exhibits in its heat treated condition an elongation value at room temperatures adequate to accommodate machine operations without undue breakage or failure. In this respect, cast items of the alloy can be efficiently worked at room temperatures without loss of high temperature properties which are required to withstand the conditions of operative use of the castings. The above disclosure deals with an alloy produced from high purity materials melted under specifically controlled conditions.

Certain variations in the composition of the alloy of the present invention can be made without departing from the scope of the invention, such scope being specified in the appended claims.

I claim:

1. An aluminum base alloy consisting essentially of from 4.5 to 5.5% copper, from 2.25 to 2.75% silicon, from 0.2 to 0.45% magnesium, from 0.35 to 0.65% nickel, from 1.0 to 1.5% chromium, from 0.15 to 0.40% molybdenum, from 0.15 to 0.40% vanadium, and the balance consisting essentially of aluminum.

2. An aluminum base alloy consisting essentially of about 5% copper, about 2.5% silicon, about 0.30% magnesium, about 0.50% nickel, about 1.25% chromium, about 0.25% molybdenum, about 0.25% vanadium, and the balance consisting essentially of aluminum.

3. An aluminum base alloy consisting essentially of about 5% copper, about 2.5% silicon, about 0.3% magnesium, about 0.5% nickel, about 1.25% chromium, about 0.25% molybdenum, about 0.25% vanadium, with iron at a maximum of about 0.2% and the balance consisting essentially of aluminum.

4. An aluminum base alloy consisting essentially of from 4.5 to 5.5% copper, from 2.25 to 2.75% silicon, from 0.2 to 0.45% magnesium, from 0.35 to 0.65% nickel, from 1.0 to 1.5% chromium, from 0.15 to 0.40% molybdenum, from 0.15 to 0.40% vanadium, with iron at a maximum of about 0.2%, and the balance consisting essentially of aluminum.

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