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## ALUMINUM BASE ALLOY

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This invention relates to the composition of aluminum base alloys having characteristics which adapt them for service at elevated temperatures.

It is well known that certain aluminum base alloys have been satisfactorily used for many years for such parts of internal combustion engines as pistons, cylinder heads, connecting rods, etc. However, with the advent of more powerful engines and other apparatus imposing greater stress upon the parts or operating at higher temperatures than encountered in the usual internal combustion engine, it was found that the former alloys did not meet the new requirements. As a result of an investigation to find aluminum base alloys better suited to meet the new needs, I have discovered a combination of elements which when added to aluminum yields a product having superior strength and improved resistance to creep and fatigue at elevated temperatures.

My invention is based on the discovery that the addition of 0.05 to 0.70% magnesium to an aluminum base alloy composed of 5 to 13% copper, 0.2 to 1.7% manganese, 0.05 to 0.20% vanadium, 0.05 to 0.30% zirconium and the balance aluminum, with or without certain grain refining elements, increases the strength and resistance to creep and fatigue of the base composition at elevated temperatures, when the alloy has received appropriate solution and precipitation hardening treatments. It has been found that the improved properties are particularly evident within the temperature range of 400 to 500° F. Heat treated and precipitation hardened alloys within the foregoing range of composition possess at 400° F. a tensile strength on the order of 46,000 p. s. i. after a 100 hour exposure, a minimum creep rate of 0.00001 in./in./hr. under a stress of 25,000 p. s. i. and a fatigue strength of 23,000 p. s. i. at a million cycles.

The iron and silicon impurities of the alloy should be limited in order that the desired properties be obtained, the iron not exceeding 0.75% and the silicon not over 0.40%. It is preferred, however, to restrict the iron to a maximum of 0.50% and the silicon to 0.30% to obtain the best results.

The best combination of properties at elevated temperatures is achieved by using from 5 to 9% copper, 0.20 to 1.20% manganese, 0.05 to 0.15% vanadium, 0.05 to 0.25% zirconium and from 0.25 to 0.50% magnesium. The iron and silicon impurities should be limited in such compositions in accordance with the preferred practice referred to in the preceeding paragraph. Also, the manganese content should be confined to a proportion of between 3 and 13% of the copper content.

In addition to the alloying elements which form the base composition it may be desirable to include from 0.01 to 0.25% of one or more high melting point metals of the group consisting of cobalt, nickel, molybdenum, tungsten, chromium, titanium, boron, tantalum, and niobium, the total amount of such elements not exceeding 0.25%. These elements serve to refine the grain size or enhance minor characteristics of the alloys but



they do not change the basic characteristics of the composition.

The thermal treatment required to develop the desired properties at elevated temperatures consists of an initial solution heat treatment for 1 to 24 hours at 960 to 1020° F. followed by quenching and precipitation hardening for 1 to 50 hours at 350 to 450° F. The length of time at the solution temperature will be determined by the condition of the alloy, whether it is cast or wrought, as well as the size of the article being treated. The selection of the precipitation hardening temperature and period of treatment will also be determined by similar considerations. It will be further appreciated by those skilled in the art that shorter periods of time at a temperature within the upper portion of the temperature range will give approximately the same results as obtained by a longer exposure at a lower temperature.

In respect to quenching, the alloys may be immersed in any liquid which will provide a drastic chill and thus retain the dissolved constituents in solution. Ordinarily a quench in water at room temperature will be sufficient, but where internal stress must be minimized it may be desirable to use water at a temperature of 150° F. or higher or some medium designed to reduce the severity of the chill.

The alloy herein described may be used in either cast or wrought form but for most purposes the wrought product is preferred. Forgings, in particular, have been found to be especially useful.

The minimum creep rate values mentioned herein are those obtained in the following manner: Standard ½" diameter bars are placed in small electrically heated air furnaces having automatic temperature controls and are maintained under a constant load throughout the test period by means of a dead weight. Measurements of extension or creep are made at predetermined intervals throughout the test period to the nearest 0.000005 inch. To obtain the minimum creep rate, the measured values of creep are plotted against time on Cartesian coordinates and the minimum slope of the resulting curve determined. The minimum creep rate thus found is also known as the secondary creep rate.

Stresses for specific creep rates are determined in customary manner from graps in which the creep rates are plotted logarithmically against stress. Stress rupture values are obtained in a similar manner by determining the time required for rupture to occur at a given stress for each of several specimens under different stresses.

My invention can be better appreciated by reference to the following test results. The composition of each of the alloys used in the tests is given on Table I below. It is to be understood that aluminum constitutes the balance of the alloy in each case.

### TABLE I

*Percentage composition of alloys*

| Alloy | Cu | Fe | Si | Mn | V | Zr | Mg |
|---|---|---|---|---|---|---|---|
| A | 5.98 | 0.11 | 0.07 | 0.21 | 0.10 | 0.23 | ---- |
| B | 6.09 | 0.15 | 0.11 | 0.32 | 0.18 | 0.20 | 0.25 |
| C | 12.12 | 0.14 | 0.10 | 0 41 | 0.10 | 0.26 | ---- |
| D | 12.12 | 0.16 | 0.10 | 0.40 | 0.10 | 0.25 | 0.24 |

The foregoing compositions were cast in the form of ingots and forged to 1" square bars in accordance with those practices normally used in the art. The bars were given a solution heat treatment of 2 hours at 990–1000° F., quenched in cold water and precipitation hardened by heating them for 12 hours at 375° F. The average tensile properties of bars of the respective alloys at room temperature and at 400° F. after a 100 hour exposure at that temperature are given in Table II.

### TABLE II

*Tensile properties at room temperature and at 400° F.*

| Alloy | At Room Temperature | | | At 400° F. | | |
|---|---|---|---|---|---|---|
| | Tensile Strength, p. s. i. | Yield Strength, p. s. i. | Percent Elong. | Tensile Strength, p. s. i. | Yield Strength, p. s. i. | Percent Elong. |
| A | 61,600 | 43,000 | 17 | 35,000 | 26,100 | 24 |
| B | 71,100 | 55,700 | 13 | 45,900 | 38,400 | 21 |
| C | 63,400 | 47,800 | 10 | 39,300 | 30,200 | 14 |
| D | 66,500 | 52,200 | 8 | 46,000 | 36,300 | 13 |

It is to be seen that the addition of magnesium served to increase the strength of both the low and high copper-containing alloys.

The creep and fatigue characteristics of the alloys were determined at 400° F. The results of the tests are presented in Tables III and IV.

### TABLE III

*Creep characteristics at 400° F.*

| Alloy | Stress (p. s. i.) for Minimum Creep Rate, in in./in./hr. | | | Stress (p. s. i.) for Rupture in— | | |
|---|---|---|---|---|---|---|
| | 0.00001 | 0.0001 | 0.001 | 10 hrs. | 100 hrs. | 1,000 hrs. |
| A | 19,500 | 23,500 | 27,500 | 29,000 | 25,500 | ---------- |
| B | 29,000 | 34,000 | ---------- | ---------- | 34,000 | 27,000 |
| C | ---------- | 23,000 | 27,000 | 29,000 | 26,000 | ---------- |
| D | 23,000 | 30,000 | ---------- | ---------- | 33,000 | 25,000 |

### TABLE IV

*Fatigue strength at 400° F.*

| Alloy | Stress (p. s. i.) for Failure in— | |
|---|---|---|
| | $10^6$ Cycles | $10^7$ Cycles |
| A | 20,000 | 14,500 |
| B | 23,000 | 17,500 |
| C | 20,000 | 15,500 |
| D | 26,500 | 18,500 |

The benefit derived from the addition of magnesium is clearly evident. It is of particular interest that both high strength and resistance to creep and fatigue are obtained in my alloy and that the values are much superior to those of compositions used in the past for pistons and cylinder heads of internal combustion engines.

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

1. A solution heat treated and precipitation hardened aluminum base alloy consisting essentially of aluminum, from 5 to 13% copper, 0.2 to 1.7% manganese, 0.05 to 0.20% vanadium, 0.05 to 0.30% zirconium, and 0.05 to 0.70% magnesium, the maximum iron impurity content of said alloy being 0.75% and the maximum silicon impurity being 0.40%, said alloy having an internal structure established by a solution heat treatment of from 1 to 24 hours at 960° F. to 1020° F. and a subsequent precipitation hardening treatment of 1 to 50 hours at 350



to 450° F., said thermally treated alloy being characterized by a higher strength, a greater resistance to creep and a higher fatigue strength at elevated temperatures on the order of 400° F. than the same alloy devoid of magnesium.

2. A solution heat treated and precipitation hardened aluminum base alloy consisting essentially of aluminum, from 5 to 9% copper, 0.2 to 1.20% manganese, the manganese being limited to the proportion of 2 to 13% of the copper content, 0.05 to 0.15% vanadium, 0.05 to 0.25% zirconium and 0.25 to 0.50% magnesium, the maximum iron impurity content of the alloy being 0.50% and the maximum silicon impurity being 0.30%, said alloy having an internal structure established by a solution heat treatment of from 1 to 24 hours at 960 to 1020° F. and a subsequent precipitation hardening treatment of 1 to 50 hours at 350 to 450° F., said thermally treated alloy being characterized by a higher strength, a greater resistance to creep and a higher fatigue strength at elevated temperatures on the order of 400° F. than the same alloy devoid of magnesium.

3. A solution heat treated and precipitation hardened aluminum base alloy consisting of aluminum, from 5 to 13% copper, 0.2 to 1.7% manganese, 0.05 to 0.20% vanadium, 0.05 to 0.30% zirconium, 0.05 to 0.70% magnesium, and 0.01 to 0.25% of at least one metal of the group consisting of cobalt, nickel, tungsten, chromium, titanium, boron, tantalum, molybdenum and niobium, total amount of said elements not exceeding 0.25%, the maximum iron impurity content of said alloy being 0.75% and the maximum silicon impurity being 0.40%, said alloy having an internal structure established by a solution heat treatment of from 1 to 24 hours at 960° F. to 1020° F. and a subsequent precipitation hardening treatment of 1 to 50 hours at 350 to 450° F., said thermally treated alloy being characterized by a higher strength, a greater resistance to creep and a higher fatigue strength at elevated temperatures on the order of 400° F. than the same alloy devoid of magnesium.

4. A solution heat treated and precipitation hardened aluminum base alloy consisting of aluminum, from 5 to 9% copper, 0.2 to 1.2% manganese, the manganese being limited to the proportion of 3 to 13% of the copper content, 0.05 to 0.15% vanadium, 0.05 to 0.25% zirconium, 0.25% to 0.50% magnesium and 0.01 to 0.25% of at least one metal of the group consisting of cobalt, nickel, tungsten, chromium, titanium, boron, tantalum, molybdenum and niobium, the total amount of said elements not exceeding 0.25%, the maximum iron impurity content of the alloy being 0.50% and the maximum silicon impurity being 0.30%, said alloy having an internal structure established by a solution heat treatment of from 1 to 24 hours at 960° F. to 1020° F., and a subsequent precipitation hardening treatment of 1 to 50 hours at 350 to 450° F., said thermally treated alloy being characterized by a higher strength, a greater resistance to creep and a higher fatigue strength at elevated temperatures on the order of 400° F. than the same alloy devoid of magnesium.

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