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ALUMINUM BASE ALLOY

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This invention relates to aluminum base alloys that are especially adapted for use at elevated temperatures.

Most of the applications where aluminum base alloys are employed involve exposure to the usual atmospheric temperature range. However, there are places where it is necessary to use aluminum alloy parts at elevated temperatures, for example, in internal combustion engines. Some of the parts are exposed to temperatures within the range of 400 to 600° F. The demand for light alloys which can be employed at elevated temperatures has been increased by the demand for more powerful motors for aircraft. It is an object of this invention to provide an alloy composition which exhibits high strength and resistance to deformation at elevated temperatures, especially at the higher temperatures found in the newer aircraft motors. A particular object is to provide an alloy which possesses a high thermal conductivity along with the high strength at elevated temperatures. Another object is to provide an aluminum base alloy which has a higher modulus of elasticity than the common commercial aluminum base alloys now in use.

We have discovered that aluminum base alloys containing from about 20 to 40 per cent beryllium, from 1 to 8 per cent magnesium, and the balance substantially aluminum possess the aforementioned properties. More particularly, we have found that some of the alloys within this range possess a tensile strength at elevated temperatures which is considerably greater than that of alloys heretofore used for such service. Furthermore, this increase in strength is accompanied by a lower density than aluminum, a relatively high thermal conductivity, and high modulus of elasticity. It is this combination of properties, especially that of high strength and relatively high thermal conductivity, that makes the alloys outstanding and particularly useful for such articles as valve push rods, pistons, and the like which are highly stressed at elevated temperatures. The high modulus of elasticity of these alloys makes it possible to design a structure having a greater resistance to distortion under a load with a given section thickness or the same resistance to distortion with a lighter section as compared to a structure made from alloys having lower modulus values. Our alloys may be used in either cast or wrought form but we prefer to use them in wrought form.

The tensile properties at an elevated temperature of two of our improved alloys and the thermal conductivity at room temperature of one of these

alloys, together with the corresponding properties of certain well known aluminum base alloys which have been used heretofore for high temperature service, are given in Table I below. The first of the two alloys which contained no beryllium, i. e. the Al-Cu-Ni-Mg alloy, may be considered as being typical of prior aluminum base alloys designed for service at elevated temperatures. The balance of the composition of each of the alloys appearing in the table was aluminum and the usual impurities. The beryllium-containing alloys were cast as ingots and extruded in the form of rods.

The thermal conductivity and tensile property tests were made on specimens taken from these extruded rods while the tensile property determinations on the first two alloys containing no beryllium were made on specimens taken from forged rods, and the specimens of the third alloy were sand cast. The difference in fabricating practices used in making the wrought material is considered to have no significant effect upon the test results reported here. The last alloy in the table possesses about the highest tensile strength at elevated temperatures of any aluminum base alloy known heretofore but it also has a relatively low thermal conductivity. This alloy was tested in the form of a sand casting because that is the form in which it has been employed for high temperature service. The specimens of the other two alloys without beryllium received the conventional solution heat treatment and artificial aging, while those of the third alloy (sand cast) were heated at 600° F. for three hours, before being subjected to any of the treatments and tests herein described in order to duplicate the condition of the alloys in many commercial applications. The tensile test bars of all the wrought alloys were subjected to a short time test at elevated temperatures consisting of first stabilizing the bars by heating them for 16 hours at 700° F. This preliminary treatment served to accelerate any changes which would have occurred on exposure to a lower temperature over a long period of time. We have found from a number of other tests that such preliminary stabilizing treatment for a relatively short period of time at a temperature higher than encountered in service affects properties to a comparable extent as more extended periods at the temperature of service operation. Following the preliminary stabilizing treatment the bars were cooled to room temperature and then reheated to the testing temperature, in this case 600° F., held at this temperature for one-half hour, and finally

broken in tension at 600° F. in the usual manner. The sand cast alloy specimens were first heated at 700° F. for four hours to stabilize them and then cooled in air to 600° F., at which temperature they were held for 99 days before being tested.

The thermal conductivity values were calculated from electrical resistivity measurements made at room temperature. The calculations were based on the well recognized Wiedemann-Franz-Lorenz relationship between the thermal conductivity and electrical resistivity of metals. It is generally true that there is such a small change in thermal conductivity of aluminum base alloys over the range of room temperature to about 600° F. that values at room temperature are very close to those at elevated temperatures such as exist in internal combustion engines. The test specimens for electrical resistivity measurements were in the same temper as that of the specimens used for tensile tests prior to the stabilizing treatment.

TABLE I

Tensile properties at 600° F. and thermal conductivity at room temperature

Alloy composition						Tensile strength	Elongation in 2 inches	Thermal conductivity (C. G. S. units)
Be	Mg	Cu	Ni	Si	Mn			
Percent	Percent	Percent	Percent	Percent	Percent	Lbs./sq.in.	Percent	
24.77	2.80	---	---	---	---	14,100	12.0	0.32
21.43	6.22	---	---	---	---	18,100	34.0	---
---	0.5	4.0	2.0	---	---	6,000	75.0	0.37
---	1.0	0.9	0.9	12.5	---	5,600	54.0	0.32
---	6.0	---	1.5	---	1.0	13,700	10.5	0.20

It will be noted that the tensile strength of the beryllium-containing alloys at the elevated temperature far exceeds that of the two wrought aluminum base compositions but is not much above that of the cast alloy. The lower elongation values of the beryllium alloys also indicate a greater resistance to deformation at elevated temperatures. These tensile properties therefore indicate that these alloys are much better adapted for service at such high temperatures as 600° F. than the two wrought aluminum base alloys which have been widely employed heretofore for that purpose. It is to be observed also that the thermal conductivity of the alloy containing beryllium is identical with that of one of the wrought alloys used for comparison and is close to the conductivity value of the other alloy, while it significantly exceeds that of the cast alloy. It is the low thermal conductivity of the cast alloy which has seriously restricted its commercial use. The cast alloy does illustrate how, in the past, strength at elevated temperatures has been achieved at the expense of thermal conductivity while in the case of the wrought alloys described above, a relatively high thermal conductivity has been associated with a low strength. It is the combination of a high strength and a relatively high thermal conductivity which characterizes our alloys. A thermal conductivity of 0.3 C. G. S. units, or more, is considered to be relatively high for alloys employed in service at elevated temperatures and is also high with respect to the thermal conductivity of the cast alloy.

Modulus of elasticity determinations at room temperature were made on the above alloy containing 21.43 per cent beryllium, in the as-extruded condition, and compared with the values

for two other aluminum base alloys in the solution and artificially aged condition, as described above. As is well recognized, such a difference in condition of the alloys would not affect the modulus values. The test results are given below in Table II.

TABLE II

Modulus of elasticity at room temperature

Alloy composition					Modulus
Be	Mg	Cu	Ni	Si	
Per cent	Per cent	Per cent	Per cent	Per cent	Lbs./sq.in.
21.43	6.22	---	---	---	17,350,000
---	0.5	4.0	2.0	---	10,300,000
---	1.0	0.9	0.9	12.5	10,300,000

The superiority of the beryllium-containing alloy over the other alloys is readily apparent from these data. From other determinations we have made at elevated temperatures we have

found that the alloys containing beryllium retain this superiority by a wide margin. The relatively high modulus at elevated temperatures means that structures made from such alloys are much more resistant to distortion and hence may be expected to give longer service.

It has been our experience that a substantial amount of beryllium must be present in the alloys to obtain the combination of a high modulus, a relatively high thermal conductivity, and a high strength at elevated temperatures. A minimum of about 20 per cent of this element has been found to be necessary to obtain the combination of properties desired, but if more than 40 per cent is employed, the alloy becomes very difficult to work. The presence of magnesium in the alloy considerably enhances the strength at elevated temperatures. We have found that at least 1 per cent of this element is desirable to achieve this purpose, while on the other hand, if more than 8 per cent is used, fabricating difficulties are encountered. Alloys which contain from 22 to 30 per cent beryllium and 1.5 to 5 per cent magnesium are preferred because they possess the most satisfactory combination of strength and workability.

The expression "balance substantially aluminum," as used hereinabove and in the appended claims, means that small amounts of the usual impurities as well as other elements may be present in the alloys without affecting the high temperature properties described above. The presence of any elements which substantially impair the strength and thermal conductivity properties of these alloys at elevated temperatures is therefore excluded from the scope of this invention.

In referring to certain properties of our alloys

at elevated temperatures, we mean that these properties are particularly outstanding in the range of 400 to 600° F., however, the advantageous properties of our alloys are not confined to that temperature range.

The examples of the beryllium-containing alloys given hereinabove are for the purpose of illustrating our invention and are not to be regarded as limiting its scope. Other alloy compositions within the range set forth above possess equally satisfactory combinations of properties.

We claim:

1. An aluminum base alloy consisting of from about 20 to 40 per cent beryllium, 1 to 8 per cent 15

magnesium, and the balance substantially aluminum, said alloy being characterized by a high tensile strength at elevated temperatures combined with a relatively high thermal conductivity.

2. An aluminum base alloy consisting of from 22 to 30 per cent beryllium, 1.5 to 5.0 per cent magnesium, and the balance substantially aluminum, said alloy being characterized by a high tensile strength at elevated temperatures combined with a relatively high thermal conductivity.

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