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METHOD OF TREATING ALUMINIUM
ALLOY AND PRODUCT

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This invention relates to aluminum base alloys containing magnesium, silicon and copper, and it is especially concerned with this type of alloy wherein the magnesium and silicon sustain a fixed proportion to each other in respect to the amounts employed.

Aluminum base alloys composed of aluminum and less than 4 per cent each of magnesium and silicon have been widely used in recent years for structural purposes because of their excellent mechanical working characteristics, and superior corrosion resistance combined with a moderate strength when heat treated. Such alloys must be given so-called solution and aging heat treatments to develop their full strength and since most of the applications where these alloys find a use require as high a strength as possible which is consistent with the other desired properties, the articles made from these alloys are usually heat treated. Although the strength of heat treated aluminum-magnesium-silicon alloys is satisfactory for many purposes, it is nevertheless lower than that normally obtained in the well known aluminum-copper type of duralumin alloy in the heat treated condition. This deficiency has served to limit the utility of the alloy for certain types of service where ease in mechanical working and a high degree of corrosion resistance are of prime importance and must be combined with a high strength. Various elements have been added to the simple ternary alloy to overcome the foregoing disadvantage, but these additions in general tend to lower the corrosion resistance and hence have been used only sparingly where this property is an important consideration.

In the production of aluminum-magnesium-silicon alloys some attempts have been made to restrict the quantity of magnesium and silicon employed to the relative proportions found in the intermetallic compound, magnesium silicide, which has the formula Mg_2Si . Where this has been done, the amount of Mg_2Si has been generally limited to less than 1 per cent in order to avoid an excess of the compound beyond the limit of its solid solubility in aluminum. It has been generally believed that more than 1 per cent of Mg_2Si was neither necessary nor desirable from the standpoint of improved mechanical properties and corrosion resistance.

One of the objects of our invention is to improve the strength of heat treated aluminum-magnesium-silicon alloys without substantially altering their corrosion resistance and workability. A further object is to so control the propor-

tions of magnesium and silicon as to insure a saturated solid solution of Mg_2Si in aluminum at the temperature of heat treatment. Another object is to increase the strength of the alloy beyond that obtainable from the presence of Mg_2Si alone. Still another object is to control the grain size of the alloy in order to obtain a fine grained structure in the heat treated product.

Our invention is predicated upon the discovery that the addition of from 0.1 to 4 per cent of copper to an aluminum base alloy containing about 1.5 to 3 per cent of Mg_2Si yields a product which exhibits the workability and corrosion resistance found in aluminum-magnesium-silicon alloys but at the same time possesses a much higher strength in the heat treated condition. We have found that in order to obtain this result the magnesium and silicon must be added in substantially the proportion existing in the compound magnesium silicide, Mg_2Si , and that there must be at least 0.5 per cent of this compound in excess of the maximum amount which is soluble in aluminum at the particular heat treating temperature employed. Contrary to what has heretofore been believed concerning the effect of an extra amount of a soluble constituent over and beyond the limit of solid solubility, it has been discovered that an excess of Mg_2Si does not reduce the corrosion resistance or adversely affect the working quality of the alloy. The added amount of this constituent serves to insure maximum solution when the alloy is heat treated. The most recently determined limits of solid solubility of Mg_2Si in aluminum vary between about 1 per cent at 500° C. and 1.85 per cent at the eutectic temperature of 595° C. The eutectic temperature is lowered when copper is added to the alloy, but the solid solubility of Mg_2Si remains virtually unchanged as far as has been ascertained.

The amount of Mg_2Si which would be required to yield an excess of at least 0.5 per cent beyond the maximum quantity which is soluble at the heat treating temperature may be readily determined through reference to an equilibrium diagram, or for all practical purposes it may be obtained by assuming that the solubility increases linearly from 1 to about 1.85 per cent within the temperature range between 500° C. and the melting point of the eutectic. For example, if the solution heat treating temperature should be 500° C., at least 1.5 per cent Mg_2Si would be required to produce an alloy having the desired characteristics. Or if a temperature of 520° C.

should be employed, at least about 1.7 per cent of Mg_2Si would be needed to provide an excess of 0.5 per cent of this compound beyond the limit of solid solubility. Within the range of heat treating temperature used in commercial practice we prefer to have from about 1.5 to 2 per cent of Mg_2Si in the alloy. As much as 2 per cent Mg_2Si in an alloy heat treated at 520° C. is not deleterious to the properties of the alloy and under some circumstances it may be desirable to have more than the minimum 0.5 per cent excess constituent present.

The copper content of the alloy serves to increase the strength beyond that of an alloy containing only Mg_2Si as a solution and age hardening constituent. While from 0.1 to 4 per cent copper may be advantageously employed it has been found that from 1 to 3 per cent of this element yields the most satisfactory results in combination with Mg_2Si . The use of copper in conjunction with Mg_2Si has produced an alloy having much better working qualities than the common aluminum-copper alloys. The corrosion resistance of our improved alloy is also superior to that of the familiar aluminum-copper type of heat treated alloys.

Although the foregoing alloys are satisfactory for many purposes it has nevertheless been found that they are prone to develop a coarse grained structure upon being annealed or heat treated after cold working. A structure of this character is very undesirable under certain conditions, particularly where the alloy is to be drawn into final shape, because the coarse grained material develops a rough surface with an unsightly appearance. This difficulty may be overcome, we have found, through the addition of relatively small amounts of certain related elements which are members of a larger and well recognized group of elements. It has been ascertained that the presence of from about 0.1 to 1 per cent of at least one of the class of chemically and physically related elements chromium, molybdenum, tungsten and uranium in alloys of the class described hereinabove will prevent the formation of coarse grains, with consequent improvement in the drawing quality of the alloy. If more than one of these elements is added the total amount should not exceed about 1 per cent.

The heat treatment herein referred to comprises heating the alloy at a temperature between about 500° C., the lowest practicable limit for commercial operation, and the temperature of incipient fusion of the lowest melting point eutectic. Since diffusion of the soluble constituents increases with the temperature it is the usual commercial practice to use as high a temperature as possible and yet avoid any incipient fusion of any alloy constituents. In any case the article being treated is held at the elevated temperature for a sufficient length of time to dissolve virtually the maximum possible amount of the soluble constituents, Mg_2Si and copper. The time required to accomplish this result may vary between 5 minutes and 20 hours depending on the nature of the article. Upon attaining this condition the article is rapidly cooled to a much lower temperature such as by quenching in hot or cold water. This state of solid solution which normally does not exist at room temperatures is preserved by the rapid cooling. Although there is some increase in strength by this treatment as compared to its strength prior to heating yet the full or maximum strength is only attained by a subsequent aging, which usually comprises re-

heating to a temperature between about 140 and 200° C. for a period time ranging from 3 to 36 hours. Since the increase in strength is dependent upon first obtaining a solid solution and later causing the dissolved material to precipitate in very finely divided form, it is essential that a maximum solution be effected in order that there be an abundant uniformly distributed precipitate. According to prevailing theories regarding the hardening of heat treated aluminum base alloys of this character, the ultimate strength of the article is directly connected with the form and distribution of the precipitate from a supersaturated solid solution which is unstable at ordinary temperatures.

A preferred composition which exhibits the properties referred to hereinabove consists of aluminum, about 1.6 per cent Mg_2Si , 1 per cent copper and 0.25 per cent chromium. An alloy of this composition when heat treated at 515° C., quenched and aged 18 hours at 160° C., had a tensile strength of about 56,600 pounds per square inch, a yield strength of 45,500 pounds per square inch, and an elongation of 15.5 per cent in two inches. When the copper content was increased to 2 per cent, the other constituents remaining unchanged, and the alloy heat treated and aged as in the former case, a tensile strength of 62,200 pounds per square inch was obtained, also a yield strength of 48,700 pounds per square inch, and an elongation of 16 per cent. By way of contrast, a similar alloy containing no copper, after heat treating and aging, had a tensile strength of 38,000 pounds per square inch, a yield strength of 33,000 pounds per square inch, and an elongation of 15 per cent. The benefit to be derived from the addition of copper to the alloy thus becomes apparent. In the foregoing alloys about 1.1 per cent of Mg_2Si is soluble at the temperature of heat treatment but an excess of 0.5 per cent of this constituent was employed to develop the maximum strength. The alloys containing copper were found to fabricate as easily as the well known aluminum-magnesium-silicon alloys.

The herein described alloys may be compounded in any manner known to those skilled in the art, but it is our preferred practice to add a "rich" alloy to the molten aluminum to incorporate the desired alloying ingredients.

The term aluminum as here employed refers to the metal of commercial quality which contains the usual impurities of iron and silicon.

We claim:

1. A method of improving aluminum base alloys composed of aluminum, magnesium silicide and about 0.1 to 4 per cent copper, said method comprising adding at least 0.5 per cent magnesium silicide in excess of the amount soluble at the temperature of heat treatment, heating the alloy to a temperature above 500° C. but below the temperature of incipient fusion until substantially the maximum amount of soluble constituents has been dissolved, and rapidly cooling from the elevated temperature to ordinary temperatures.

2. A method of improving aluminum base alloys composed of aluminum, magnesium silicide and about 0.1 to 4 per cent copper, said method comprising adding at least 0.5 per cent magnesium silicide in excess of the amount soluble at the temperature of heat treatment, heating the alloy to a temperature above 500° C. but below the temperature of incipient fusion until substantially the maximum amount of soluble constituents has been dissolved, and rapidly cooling from the elevated temper-

ature to ordinary temperatures and aging by reheating to a temperature between about 140 and 200° C.

3. A method of improving aluminum base alloys composed of aluminum, magnesium silicide, from about 0.1 to 4 per cent copper and from about 0.1 to 1 per cent of at least one of the group of metals, chromium, molybdenum, tungsten and uranium, the total amount of said chromium, molybdenum, tungsten, and uranium being not in excess of 1 per cent comprising adding at least 0.5 per cent magnesium silicide in excess of the amount soluble at any heat treating temperature lying between about 500° C. and the temperature of incipient fusion, heating the alloy to the desired temperature within said range until substantially the maximum amount of soluble constituents has been dissolved, and rapidly cooling the alloy to ordinary temperatures.
4. A method of improving aluminum base alloys composed of aluminum, from about 1.5 to 3 per cent of magnesium silicide, from about 0.1 to 4 per cent of copper, and from about 0.1 to 1 per cent of at least one of the group of metals, chromium, molybdenum, tungsten and uranium, the total amount of said chromium, molybdenum, tungsten, and uranium being not in excess of 1 per cent, comprising heating the alloy at a temperature, between about 500° C. and the temperature of incipient fusion, such that at least 0.5 per cent of magnesium silicide remains undissolved beyond the maximum amount soluble at the temperature of heat treatment, and rapidly cooling the alloy to ordinary temperatures.
5. A heat treated and aged aluminum base alloy

containing from about 1.5 to 3 per cent of magnesium silicide, from about 0.1 to 4 per cent of copper and from about 0.1 to 1 per cent of at least one of the class of elements, chromium, molybdenum, tungsten and uranium, the total amount of said chromium, molybdenum, tungsten, and uranium being not in excess of 1 per cent, characterized by having at least 0.5 per cent magnesium silicide in excess of the amount soluble at a heat treating temperature between about 500° C. and the temperature of incipient fusion.

6. A heat treated and aged aluminum base alloy consisting of about 1.6 per cent magnesium silicide, 2 per cent of copper and 0.25 per cent of chromium, the balance being aluminum.

7. A heat treated and aged aluminum base alloy consisting of about 1.6 per cent magnesium silicide, 1 per cent of copper and 0.25 per cent of chromium, the balance being aluminum.

8. A method of improving aluminum base alloys composed of aluminum, from about 1.5 to 3 per cent magnesium silicide, from about 0.1 to 4 per cent copper and from about 0.1 to 1 per cent of at least one of the group of metals, chromium, molybdenum, tungsten and uranium comprising heating to such a temperature between 500° C. and the temperature of incipient fusion that at least 0.5 per cent of magnesium silicide remains undissolved, rapidly cooling the alloy to ordinary temperatures, and thereafter aging the alloy for 3 to 36 hours at 140 to 200° C.

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