April 21, 1942. P. T. STROUP 2,280,171

ALUMINUM ALLOY

Original Filed Oct. 27, 1939

Fig. 1.

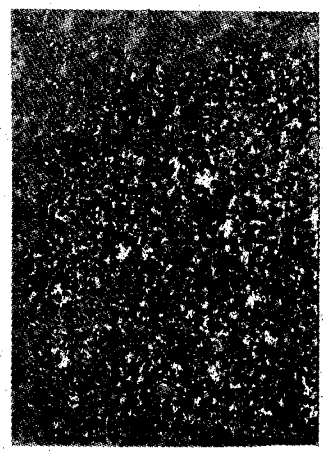

Fig. 2.

Fig. 3.

Fig. 4.

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ALUMINUM ALLOY

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Original application October 27, 1939, Serial No. 301,594. Divided and this application October 1, 1940, Serial No. 359,241

4 Claims. (Cl. 75—139)

This invention relates to aluminum base alloys, and it is particularly concerned with controlling the grain size in castings. This is a divisional application of my copending application, Serial No. 301,594, filed October 27, 1939.

Among the factors which affect the properties and behavior of both wrought and cast aluminum base alloy articles, one of the most important is the grain size of the metal. The term "grain size" refers to the dimensions of the individual crystals which compose the metallic body. The grain size is usually referred to as being fine, medium, or coarse, and the shape of the grains is described as being equi-axed or elongated, depending upon the relative dimensions of the grain. Generally, a fine equi-axed grain size is considered to be most desirable in an alloy both from the standpoint of strength and hardness, as well as workability. Since some aluminum base alloys do not inherently exhibit a small grain size in the as-cast condition, and, furthermore, since thermal conditions during solidification of the molten metal exercise such a great influence upon the size of grains, it is necessary to exercise some control of the alloy composition or freezing conditions in order to insure a uniform structure in the product. This need is most apparent in the case of ingots and other castings which have cross sections of considerable thickness, because the slow cooling tends to promote the development of large grains.

A satisfactory means for controlling the size of grains in aluminum base alloy castings should possess the following characteristics: (1) convenience in application; (2) uniformity in effect; and (3) a minimum of undesired effect on other important properties.

It is the principal object of my invention to provide a simple means for producing small equi-axed grains in cast aluminum base alloys. Another object is to provide a means for effecting this control of grain size which has the above-mentioned characteristics. These and other objects will become apparent from the following description of my invention.

I have discovered that the addition of small amounts of one or both of the elements, columbium and tantalum, to aluminum base alloys produces a small grain size in the as-cast product. While the presence of either element alone in an alloy has a pronounced effect upon the grain size, an even greater effect is obtained if both elements are present. As far as I have observed, the addition of these elements to aluminum base alloys does not adversely affect other properties which are generally desired, such as hardness, strength, ductility, workability, and resistance to corrosion. I have also observed that the grain-refining effect obtained through the addition of these elements is substantially uniform throughout the entire article. This uniformity in effect is particularly advantageous in the casting of ingots or other articles of relatively large cross sectional dimension.

The benefit derived from adding columbium and/or tantalum to aluminum base alloys as mentioned hereinabove is particularly evident in the reduction of the grain size of the as-cast metal. However, the addition of these elements may also have other beneficial effects both in the casting and in the wrought product made from the cast article. By emphasizing the effect upon the grain size of the cast alloys, I do not wish to minimize any advantages gained in other respects.

Only relatively small amounts of columbium and tantalum are required to produce a fine grain size in castings, from 0.01 to 0.1 per cent of either one generally being sufficient for the purpose. In certain cases it may be necessary to employ even more, but in no event should the amount exceed 0.5 per cent, and preferably not over 0.4 per cent. Although either element is effective when used separately, I have found that an even more pronounced grain-refining effect is obtained if both are simultaneously employed. In such a case the total amount should not be less than about 0.02 per cent, nor should it exceed about 0.5 per cent.

The elements columbium and tantalum, for the purposes of my invention, are regarded as being equivalent to each other, that is, one may be substituted for the other although not necessarily in the same proportions, and therefore they constitute a group. In addition to having a similar grain refining effect on aluminum base alloys, these elements resemble each other in that both of them occur in the same subgroup of group V of the periodic table, both have body-centered space lattices, and both form the same type of alloy constitutional diagram with aluminum.

The aluminum base alloys which are particularly benefited by the addition of at least one of the elements of the columbium-tantalum group are those containing from 0.25 to 12 per cent copper, or 0.5 to 15 per cent magnesium, or 0.25 to 14 per cent silicon, or 0.5 to 20 per cent zinc, or 0.1 to 3 per cent manganese, or combinations of two or more of these elements. These alloys may also contain one or more of the following elements, often referred to as "hardeners," in the following percentages: 0.05 to 0.5 per cent chromium, 0.01 to 0.5 per cent titanium, 0.25 to 2.5 per cent nickel, 0.01 to 0.5 per cent boron, 0.002 to 2 per cent beryllium, 0.1 to 0.5 per cent molybdenum, and 0.1 to 0.5 per cent zirconium. The total amount of the latter elements, however, should not exceed about 3 per cent. As exemplary of the variety of alloys whose grain size has been found to be reduced by the addition of columbium and/or tantalum, the following compositions are cited, wherein aluminum constitutes the balance of the alloy in each case: 1.25 per cent manganese; 2.5 per cent magnesium, 0.25 per cent chromium; 2 per cent Mg_2Si, 0.25 per cent chromium; 4 per cent copper; 5 per cent silicon; 5.25 per cent $MgZn_2$; 1.25 per cent magnesium, 0.5 per cent zinc, 0.15 per cent copper; and 4.4 per cent copper, 0.65 per cent manganese, 1.5 per cent magnesium.

The effect of adding columbium or tantalum, or both elements, to a particular alloy is illustrated in the accompanying figures, where

Fig. 1 is a photomicrograph of an as-cast alloy composed of 2.5 per cent magnesium, 0.25 per cent chromium, the balance commercially pure aluminum;

Fig. 2 is a photomicrograph of the same alloy to which 0.03 per cent columbium had been added;

Fig. 3 is a photomicrograph of the same alloy to which 0.06 per cent tantalum had been added; and

Fig. 4 is a photomicrograph of the same alloy to which 0.02 per cent columbium alloy and 0.07 per cent tantalum had been added.

The alloy employed for the test was one which is widely used in wrought form, and has a nominal composition of 2.5 per cent magnesium, 0.25 per cent chromium, and the balance aluminum containing a maximum of 0.3 per cent iron and silicon as impurities. A quantity of the alloy was first melted and a specimen poured at a temperature of 1350° F. into a cold, thin-walled iron mold having the shape of a frustum of an inverted cone with a diameter of about three inches at the base of the cone. About five minutes was required for the metal to completely solidify, which tended to promote the formation of large grains. The remaining melt was divided into three portions, 0.03 per cent columbium being added to one, 0.06 per cent tantalum being added to the second, and 0.02 per cent columbium and 0.07 per cent tantalum being added to the third. Specimens were cast at a temperature of 1350° F. in the same iron mold as the alloy without the columbium or tantalum additions, the mold in each case being at room temperature, or "cold," when the metal was poured into it. The specimens were sectioned in a vertical plane, polished, and etched in an aqueous solution of nitric and hydrochloric acids. A representative section of each specimen was then photographed at a magnification of three diameters.

In Fig. 1 the large grains of the untreated alloy may be plainly seen. Grains of this size are regarded as being too coarse for a satisfactory casting as well as promoting cracking and checking in a body that is to be subsequently worked. The criss-cross markings on some of the grains illustrate a common solidification phenomenon known as "dendritic formation." The grain-refining effect of adding columbium to the alloy is seen in Fig. 2. In comparison to Fig. 1, the grains are very small and equi-axed. In Fig. 3, the grain size of the alloy to which tantalum had been added may be seen. Since 0.06 per cent tantalum was employed, as compared to 0.03 per cent columbium in the preceding example, it is not surprising that the grain size should be smaller than in Fig. 2. The very marked effect of both columbium and tantalum on the grain size is shown in Fig. 4. The grain size is so small as to be scarcely distinguishable at a magnification of three diameters, which is the same magnification that was used in the other photomicrographs.

The tantalum and columbium may be added to molten aluminum base alloys in any convenient manner. I have found that the ferro-alloys of these two elements provide a satisfactory source. The ferro-alloy is preferably diluted with aluminum at a high temperature, and this diluted alloy containing, for example, 2 to 5 per cent of columbium or tantalum is used for making additions. This diluted alloy may be referred to as a hardening or rich alloy. Generally speaking, since the amount of tantalum and columbium used is so small, the amount of iron which is also introduced along with these elements from the ferro-alloys is likewise small and has no significant effect in the case of most alloys. Another advantage obtained through using the ferro-alloys as a source of columbium and tantalum is that both of these elements will usually be present and therefore tend to produce an even finer structure than if only one is employed.

In referring to aluminum base alloys herein, I mean those which contain at least 50 per cent aluminum. The term "aluminum" as herein employed refers to the metal as commercially produced which contains impurities.

Where, in the appended claims, the balance of an alloy is said to be "substantially aluminum," it is intended that this expression shall permit the inclusion in the alloy composition of one or more of the hardening elements mentioned hereinabove as well as the usual impurities.

I claim:

1. A cast article composed of an aluminum base alloy containing from 0.25 to 12 per cent copper, 0.1 to 3 per cent manganese, and at least 0.01 per cent of each of the metals tantalum and columbium, the total amount of said two metals not exceeding 0.5 per cent, said alloy being characterized in the as-cast condition by a finer grain size than the same alloy containing either tantalum or columbium alone.

2. A cast article composed of an aluminum base alloy containing from 0.25 to 12 per cent copper, 0.1 to 3 per cent manganese, and at least one of the hardeners of the group composed of 0.05 to 0.5 per cent chromium, 0.01 to 0.5 per cent titanium, 0.25 to 2.5 per cent nickel, 0.01 to 0.5 per cent boron, 0.002 to 2 per cent beryllium, 0.1 to 0.5 per cent molybdenum, and 0.1 to 0.5 per cent zirconium, the total amount of said hardeners not exceeding about 3 per cent, and at least 0.01 per cent of each of the metals tantalum and columbium, the total amount of said two metals not exceeding 0.5 per cent, the balance of the alloy being aluminum.

3. A cast article composed of an aluminum base alloy containing from 0.25 to 12 per cent copper, 0.1 to 3 per cent manganese, 0.25 to 14 per cent silicon, and at least 0.01 per cent of each of the metals tantalum and columbium, the total amount of said two metals not exceeding 0.5 per

cent, the balance of the alloy being substantially aluminum, said alloy being characterized in the as-cast condition by a finer grain size than the same alloy containing either tantalum or columbium alone.

4. A cast article composed of an aluminum base alloy containing from 0.25 to 12 per cent copper, 0.1 to 3 per cent manganese, 0.5 to 15 per cent magnesium, and at least 0.01 per cent of each of the metals tantalum and columbium, the total amount of said two metals not exceeding 0.5 per cent, the balance of the alloy being substantially aluminum, said alloy being characterized in the as-cast condition by a finer grain size than the same alloy containing either tantalum or columbium alone.

PHILIP T. STROUP.

CERTIFICATE OF CORRECTION.

Patent No. 2,280,171. April 21, 1942.

PHILIP T. STROUP.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 36, after "columbium" strike out --alloy--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 23rd day of June, A. D. 1942.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.