Patented May 31, 1932 1,860,947

UNITED STATES PATENT OFFICE

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ALUMINUM ALLOY CASTING AND PROCESS OF MAKING THE SAME

No Drawing. Application filed February 24, 1928, Serial No. 256,820, and in Germany March 22, 1927. Renewed March 25, 1932.

This invention relates primarily to the production of heat-treated castings of aluminum-base alloy, and its chief object is to provide a more economical and more flexible process for producing such articles. A further object is to provide a method of accelerating the heat-treatment of aluminum alloy castings, whereby the expected results of heat-treatment, and in some cases even better results, can be obtained in less time than by prior processes. In some cases useful results can be obtained at lower temperatures. Another object is to provide an improved article of the kind indicated, having high tensile strength and elongation and increased hardness. To these and other ends the invention comprises the novel article and process hereinafter described.

In the making of heat-treated castings of aluminum-copper alloys as heretofore carried out to obtain maximum results it has been necessary to heat the castings for a prolonged period. For castings of small or medium dimensions the minimum time was about seven hours, and for pieces of larger dimensions the time required in practice was often as long as twenty hours. These long periods necessarily added to the cost of manufacture. It is also known that to develop the best properties of the casting the temperature of the heat-treatment must be close to the melting point of the lowest-melting eutectic. This requirement demands accurate control of temperature, which is a matter of some difficulty in the case of long periods of heat-treatment, and need has therefore been felt for a simpler, more economical and more flexible method, which can be carried out with ease and certainty, and this need my present invention is designed to meet.

The invention is based on the discovery that the presence of a suitable amount of titanium in aluminum-base casting alloys containing copper affects the susceptibility of the casting alloys to heat-treatment in a way not hitherto recognized, despite the fact that the art contained numerous examples of aluminum-copper-titanium alloys for making articles which were to be worked before heat-treatment. No practical advantage, however, resulted from such suggestions, and indeed, so far as I have been able to learn, the titanium was not used for the purpose of improving or in any way modifying the heat-treating properties of the alloy but only for improving the alloy in one way or another independently of heat-treatment. I have found, however, that when titanium is used in aluminum-copper casting alloys in small amounts, instead of the relatively large amounts required or recommended for the purpose last mentioned, it has the highly advantageous effect of greatly accelerating the heat-treatment of castings made of the alloy, making it possible in most cases to decrease the normal time of heat-treatment by several hours and in some cases enabling lower temperatures to be used, thus permitting wider variations of furnace temperatures without disadvantageous results. In fact as good results are possible with my invention in three hours heat-treatment as could be obtained with the best prior practice in a period more than twice that long. Moreover, the results obtained by the use of the titanium in my invention is to a large extent independent of the pouring temperature and the thickness of the cast section, thus permitting the pouring temperature to be adjusted to suit casting conditions without loss of desirable physical properties. This latter phenomenon is a factor of great commercial importance.

According to my invention the range of titanium content is from 0.05 (five hundredths) of one per cent to 0.5 (one-half) of one per cent, approximately, but the preferred range is from about 0.1 per cent to about 0.3 per cent; whereas the prior proposals for the use of titanium in alloys which were to be worked before heat-treatment have called for about 1 per cent of titanium or even more.

In preparing the alloy I have found it advantageous to introduce the titanium in the presence of an alkali metal fluoride. One convenient method of doing this is to first prepare an aluminum-titanium alloy by the introduction of titanium oxide along with alumina in the well-known method of pro-

ducing aluminum by electrolytic reduction of alumina in a fused bath of natural or artificial cryolite, so that titanium oxide is reduced also. If titanium bearing alumina is available, it can be advantageously used for this purpose. The desired copper content can be supplied later by the addition of a suitable aluminum-copper alloy containing say, from 20 to 50 per cent of copper. Another method of introducing titanium which I have found useful is to allow a double fluoride of titanium, such as sodium or potassium-titanium fluoride, to react with molten aluminum or molten aluminum-copper alloy. This method is more expensive, but has the advantage that it can be carried out in any foundry without the use of the electrolytic cell. Titanium may also be supplied in the form of a copper titanium alloy, such as the cupro-titanium of commerce, which contains about 5 to 10 per cent titanium. In the latter case the titanium is added without contact with molten fluoride. While a substantial effect is secured by the introduction of titanium in this way, I have found in general that better results are secured when the titanium is alloyed with the aluminum or the aluminum-copper alloy through the medium of or in association with alkali metal fluorides. Why this should be so, I am unable at present to state, but nevertheless I have found that method distinctly advantageous. In practice it has been found convenient to prepare first an aluminum-titanium alloy containing about 0.25 per cent titanium, and then make up the final alloy by adding in the proper amount an aluminum-copper alloy rich in the latter metal, together with magnesium, manganese, or any other constituent that may be desired in the finished casting.

The copper content of the alloy is preferably held between about 3 and 5.5 per cent. If a greater proportion of copper is employed, as for example to increase the hardness and raise the yield point of the casting, at the expense, perhaps, of ductility, it will be difficult if not impossible to dissolve the excess copper constituent ($CuAl_2$) by heating. Even under these conditions, however, the presence of titanium in suitably controlled amounts is effective in improving the properties of the alloy and accelerating the heat treatment. Magnesium in amounts up to about 0.5 per cent can be added to the alloy with a consequent increase of strength and hardness but with lessened ductility.

The alloy may be cast in sand or other suitable molds and the subsequent heat-treatment may be carried out by any known means, as for example a gas fired or an electrically heated furnace. As will appear hereinafter, one is in general permitted considerable variations in pouring temperatures instead of being held strictly to narrow limits.

In addition to the soluble elements, such as copper, magnesium, zinc, and silicon, which are added to aluminum alloys for the purpose of making them susceptible to improvement by heat-treatment, relatively insoluble elements have been added, such as manganese and chromium, for example. These elements form hard intermetallic compounds with the aluminum, which when disseminated throughout the aluminum matrix produce some further hardening of the alloy, although they apparently have no particular effect upon the susceptibility of the alloy to heat-treatment. Titanium, which is quite insoluble, has been previously used in aluminum alloys for its hardening effect, just as have the elements iron, manganese and chromium. In my invention, however, the function of the titanium is quite different from that of the hardening elements just referred to. The amount employed is small and its effect is not only different but is out of all proportions to the amount added. Its presence apparently produces a solidification-structure which makes the casting peculiarly susceptible to heat-treatment, perhaps by causing the copper and other soluble constituents to take a form in which they go into solid solution more readily; and as before stated, the effect is to a large extent independent of the temperature at which the alloy is poured and the thickness of the cast section.

As an example of the invention, the following table shows the tensile strength and elongation of sand-cast half-inch cylindrical test bars of alloy having the composition: copper, 4.4 per cent; iron, 0.7 per cent; silicon, 0.7 per cent, and titanium 0.23 per cent. For comparison the table gives the tensile strength and elongation of similar bars of the same alloy without titanium. The bars were poured at a temperature of 1400° F. (760° C.), then heat-treated at 960° F. (515° C.) for the indicated periods, quenched, and aged at 212° F. (100° C.) for one-half hour.

Time of heating	With 0.23% titanium		Without titanium	
	Tensile strength lbs./sq. in.	Elongation per cent in 2 inches	Tensile strength lbs./sq. in.	Elongation per cent in 2 inches
3 hours	35,370	8.6	29,140	5.5
5 hours	34,860	10.0	29,800	6.0
8 hours	35,980	10.5	31,200	6.8
30 hours	35,680	10.2	32,650	7.8

It is seen from the above that substantially maximum properties of the test bars containing 0.23 per cent of titanium were developed after only three hours' high temperature treatment, whereas without the titanium the properties were less satisfactory, even after heating for thirty hours.

In the case of bars of similar composition but cast in 1¾ inch sections instead of ½ inch sections, the superiority of the bars containing titanium was especially marked. After heating for three hours, the bar with 0.2 per cent added titanium was about 4120 pounds stronger per square inch, and after thirty hours' heating (followed by quenching and aging as before) was still 3300 pounds stronger than the bar without titanium, though in neither case was the tensile strength per unit cross section as high as in the ½ inch sections. Examination of the polished cross-section of these 1¾ inch bars showed marked differences in structure between those with and those without added titanium. The former were sound and substantially free from the minute cavities expected in thick sand-cast sections of the alloy, while such cavities were present in large numbers in the bar poured without titanium. Even with only four hours heating, the titanium-containing bars were as nearly free from undissolved intergranular $CuAl_2$ as were the others after much longer treatment.

Even when poured at 1250° F. (675° C.), the alloy with added titanium shows its superiority, especially in the thicker section, as for example, the 1¾ inch bars just cited. In this case bars with added titanium were 4,000 pounds stronger per square inch after four hours' heating, quenching and aging, and were still 2,000 pounds stronger after thirty hours' heat treatment.

The presence of the titanium makes it possible in some cases to obtain useful improvement of physical properties with lower temperatures in heat treatment than heretofore, for example 925° F. (495° C.). It is generally preferable, however, to heat-treat at higher temperatures, say from 950° F. (510° C.) to 970° F. (520° C.), but for only a short period as compared with the time required for castings of the same aluminum-copper alloy without titanium. After heating and quenching or other rapid cooling, the casting may be allowed to age naturally, or it may be aged artificially by heating at temperatures of about 212° F. (100° C. to 300° F. (150° C.) in the usual way.

Although the advantages of my invention are apparent even when the iron content of the alloy is relatively high, as evidenced by the results exhibited in the table, still more improvement in the physical properties of the casting can be obtained if the iron content is lessened. For instance, sand-cast test bars ½ inch in diameter were cast at 1400° F. (760° C.) from an alloy of the following composition: copper, 5.1 per cent; iron, 0.15 per cent; silicon, 0.15 per cent, and titanium 0.22 per cent. Similar bars were cast from an alloy of the same composition but without the titanium. The latter bars showed a tensile strength of only 28,300 pounds per square inch and an elongation of only 2.8 per cent in 2 inches, after heating for twenty hours at a temperature of 960° F. (515° C.), quenching, and aging for two days at room temperature. On the other hand, the titanium-containing bars showed a tensile strength of 36,820 pounds per square inch and an elongation of 5.5 per cent in 2 inches after heating for only five hours, quenching and aging, and a tensile strength of 42,200 pounds per square inch and elongation of 8.2 per cent after twenty hours' heating, quenching and aging.

Although my invention is particularly directed to the production of aluminum-copper alloy castings and their heat treatment, nevertheless it is not necessarily limited thereby. The alloy can be rolled, forged or otherwise worked as circumstances may require.

I claim—

1. Process of producing articles of aluminum-copper alloy, comprising incorporating in the molten alloy at an appropriate stage of its production, titanium in amounts sufficient to accelerate subsequent heat treatment, casting the alloy, and heat-treating the casting under conditions sub-normal for a similar casting of a similar alloy devoid of titanium.

2. In a process of producing aluminum-copper-titanium alloy castings containing between about 3 and 5.5 per cent copper and 0.05 to 0.5 per cent titanium, the steps comprising alloying the titanium in the presence of an alkali metal fluoride, casting the alloy, heating the casting to produce substantial solution of intergranular constituent, and thereafter cooling the casting.

3. An aluminum base alloy casting containing about 3 to 5.5 per cent of copper and between 0.1 and 0.5 per cent of titanium and produced by incorporating titanium in the molten alloy at an appropriate stage of its production, casting the alloy and heat treating the casting under conditions subnormal for a similar casting of a similar alloy devoid of titanium.

In testimony whereof I hereto affix my signature.

ALADAR PACZ.