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ALUMINUM ALLOY

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This invention relates to alloys of aluminum and manganese with or without the addition of other metals. It relates more in particular to methods of preparing aluminum alloys containing manganese by which enhanced properties are obtained.

In the known art, alloys of aluminum and manganese have been made and it has been established that, from the standpoint of corrosion resistance, manganese is far superior to any other metal as an addition to pure aluminum to increase its strength and hardness. It has been found impossible, however, to use more than about 1.25 percent manganese in wrought alloys without too great a decrease in ductility; in commercial cast alloys 2 percent has been the limit. Corson, an authority in this field, states that 3% is undoubtedly the maximum which can be alloyed with aluminum without badly affecting its ductility. It is recognized that other elements such as copper, nickel, silicon and magnesium, which are added to aluminum to give increased strength, do so at the sacrifice of corrosion resistance. My invention permits the obtaining of high strength by the addition of manganese alone and without the sacrifice in corrosion resistance which marks the addition of other elements.

I have found that the large needle-like crystals which develop in alloys of manganese and aluminum containing more than 2% manganese when made by the prior art are responsible for the lack of ductility in these alloys. My investigations lead me to believe that these crystals are the compound $MnAl_6$. I have further found that the formation of the structure containing these crystals is favored by the presence of iron and silicon and by slow cooling. With alloys made in the heretofore known way from silicothermic manganese or aluminothermic manganese, I have found that no practical rate of cooling is great enough to suppress entirely the formation of the brittle structure. However, with alloys made from materials containing only very small amounts of iron, chill casting produces alloys of entirely different properties than have heretofore been obtained. My invention comprises preparing an alloy of aluminum and manganese wherein the iron is less than 0.5% of the manganese content and the silicon preferably is less than 0.1% of the manganese content, and wherein the non-metallic impurities introduced by the use of manganese of aluminothermic or silicothermic origin are obviated, and casting this alloy in a chill mold from a temperature well above the liquidus.

In a preferred form of my invention, I take a pure manganese containing not over .01% of any other metal and reduce it to a coarse powder. The best results are obtained with electrolytic manganese of high purity. The flakes stripped from the cathodes are easily broken up to produce the coarse powder. I place the pure manganese powder in an alumina crucible with the desired amount of high purity aluminum. I have found that Hoopes' process aluminum is very satisfactory. I then heat the mixture at 850–900 degrees C. with stirring until a homogeneous alloy is obtained. The alloy is then cast directly in a steel mold.

Alloys prepared in accordance with my invention are entirely different in properties and appearance from those made from aluminothermic or silicothermic manganese. The latter particularly begin to show the needle-like crystals of the manganese aluminum compound to the naked eye at about 3% manganese and at more than 5% manganese the alloys become coarsely crystalline and mechanically worthless. Alloys made in accordance with my invention remain finely crystalline and ductile even when containing more than 10% manganese. My conception of the theory which accounts for this difference in behavior is that the needle-like compound which causes brittleness is formed by the decomposition on cooling of another compound $MnAl_4$ which forms first; and that the decomposition of this compound is so greatly accelerated by the impurities introduced by the ordinary methods of preparing the alloys that it is impossible to suppress its formation by a practicable rate of cooling.

The properties of alloys containing 1.25–10% manganese prepared in accordance with my invention are such as make the alloys useful for purposes that could not be fulfilled by the heretofore known alloys of the same nominal composition.

Example 1.—I have found that an alloy containing 2% electrolytic manganese, balance aluminum, made in accordance with my invention, is highly ductile and can be rolled into sheet or shapes. Its tensile strength in the annealed state is 18,000 pounds per square inch and its elongation in 2 in. 20%. In the hard rolled state it shows a tensile strength of 35,000 pounds per square inch. This alloy can also be cast as is the practice with heretofore known alloys of this nominal composition and a much more ductile casting obtained.

Example 2.—I have found that an alloy of 3% electrolytic manganese, balance aluminum, has very valuable properties. In the cast and annealed state, it has a tensile strength of 20,000 pounds per square inch. It can be readily rolled without preliminary or intermediate heating to fine gauge sheet. At 50% reduction in thickness from the ingot it shows a tensile strength of 27,000 pounds per square inch and an elongation of 7%. With 95% reduction, it shows a tensile strength of 50,000 pounds per square inch

and an elongation of 3%. This alloy is useful as both a die cast and a wrought alloy.

Example 3.—An alloy of 5% electrolytic manganese, balance aluminum, has a tensile strength as cast of 24,000 pounds per square inch and can be rolled to fine gauge sheet with a tensile strength of 60,000 pounds per square inch and 2% elongation.

Example 4.—An alloy of 7.5% electrolytic manganese, balance aluminum, has a tensile strength as cast of 30,000 pounds per square inch. This alloy is still sufficiently ductile to roll with light passes and intermediate anneals. Full hard, it has a tensile strength of 63,000 pounds and an elongation of 1%. The intermediate anneals should be for a short time at about 500 degrees C.

Example 5.—An alloy of 10% electrolytic manganese, balance aluminum, has a tensile strength as cast of 37,000 pounds and an elongation of 5%. This alloy is quite ductile but will find its greatest value in castings rather than as a wrought alloy.

Alloys containing somewhat more than 10% electrolytic manganese are generally similar to the 10% alloy but suffer a gradual decrease in ductility with increased manganese and are more difficult to make because of the increased melting point. However, my invention may be applied successfully up to about 20% electrolytic manganese.

All manganese-aluminum alloys, made in accordance with my invention containing more than 2% pure or electrolytic manganese, may be hardened by suitable heat treatment. The preferred heat treatment is to quench from 600 degrees C., cold work and then reheat to 180 degrees C. In this way, the strength is increased by about 10,000 pounds per square inch. Lesser increases are obtained by reheating the quenched but unworked alloys.

The properties of all alloys of aluminum and pure or electrolytic manganese alone up to about 20% manganese will be clear from the above examples. I have found that the great enhancement of properties obtained by the practice of my invention in making the binary aluminum-manganese alloys is also obtained when ternary and quaternary alloys are made by adding other elements to the aluminum manganese alloys. This is especially true of alloys containing magnesium. I have found that the manganese content of many alloys, especially those of the hardening type, may be advantageously increased by the practice of my invention. These alloys usually contain 0.5 to 0.8% manganese. I have found that this may be increased to as much as 2% with a definite improvement in mechanical properties and corrosion resistance. Some of the alloy compositions in which I have found it advantageous to practice my invention are as follows:

Example 6.—I produce an alloy containing .5% magnesium, 3.5% copper, .5% silicon, .5% to 2% electrolytic manganese, and balance aluminum. This alloy, through the range of manganese given, has substantially the same properties of the same alloy without the manganese, but with improved mechanical properties, and even some improvement in corrosion resistance.

Example 7.—I produce an alloy consisting of 4.5% copper, .5% to 2% electrolytic manganese, and balance aluminum. The resulting alloy has desirable working properties, is ductile, and possesses substantially higher tensile strength and greater resistance to corrosion than a binary alloy of aluminum and electrolytic manganese.

Example 8.—High purity aluminum is alloyed with copper, magnesium and electrolytic manganese in accordance with the following proportions:

	Per cent
Copper	4
Magnesium	2
Manganese	.5
Aluminum	93.5

This alloy has desirable mechanical properties and the resistance to corrosion is improved over a similar alloy without the manganese. The manganese may be increased to about 1%, with a corresponding reduction in aluminum, and a useful alloy obtained. Cast into a chill mold, it produces a casting of good machining properties and desirable tensile strength.

Example 9.—Alloys were produced containing in the range 1% to 2% electrolytic manganese, and containing in addition about 7% silicon, .3% magnesium, and balance aluminum. In the range of manganese given, corrosion resistance was high, and mechanical properties good. The alloy is particularly adapted for casting in a chill mold.

The terms "pure manganese" and "high purity manganese" as employed in the claims are used to identify electrolytic manganese, or manganese having substantially the same percentage and character of impurities as electrolytic manganese.

What I claim as new and desire to protect by Letters Patent of the United States is:

1. The method of preparing an alloy consisting substantially entirely of aluminum and manganese, which comprises producing a liquid solution of electrolytic manganese, having a purity of at least 99.9%, in high purity aluminum, the manganese comprising from 1.25% to 20% of the whole, and the product having less than .5% iron based upon the manganese content, chill casting the alloy from a temperature well above the liquidus, quenching the alloy from a relatively high temperature in the solid range, and reheating the alloy to a temperature of approximately 180 degrees C., the resultant alloy being relatively free from the large needle-like crystals characteristic of ordinary alloys of aluminum with upwards of 2% manganese.

2. The method of preparing an alloy consisting substantially entirely of aluminum and manganese, which comprises producing a liquid solution of electrolytic manganese, having a purity of at least 99.9%, in high purity aluminum, the manganese comprising from 1.25% to 20% of the whole, and the product having less than .5% iron based upon the manganese content, chill casting the alloy from a temperature well above the liquidus, quenching the alloy from a relatively high temperature in the solid range, cold working the alloy, and reheating the alloy to a temperature of approximately 180 degrees C., the resultant alloy being relatively free from the large needle-like crystals characteristic of ordinary alloys of aluminum with upwards of 2% manganese.

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