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METHOD OF MAKING ALUMINUM ALLOYS

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This invention relates to methods for the preparation of aluminum alloys.

Considerable difficulty has been experienced in the past in the making of aluminum alloys because of the marked tendency for the aluminum to combine with oxygen. As a result a portion of the aluminum is frequently lost and does not enter into the alloy composition, and the resulting alloy has a composition which is materially different from the one it was intended to obtain. In addition to the uncertainty of obtaining an alloy of the desired composition, the oxidation of aluminum during the preparation of the alloy results in the formation of considerable aluminum oxide which is, to a considerable extent, retained in the finished alloy where it exerts a detrimental influence upon its properties.

An object of this invention is to provide a method for the making of aluminum alloys which results in a high recovery of the aluminum used in the preparation of the alloy, and which makes possible the consistent production of aluminum alloys of high quality and of a composition close to that which it is desired to obtain.

While the invention is applicable to the production of many different kinds of aluminum alloys, it will be specifically illustrated, for convenience in description, in connection with the preparation of iron-chromium-aluminum alloys and particularly alloys of this kind such as those which are described in the co-pending application of S. L. Hoyt and R. S. Archer, Serial No. 715,158, issued to U. S. Letters Patent No. 1,995,923 on March 26,1935. Such alloys contain some 37% chromium and 7% aluminum, the balance being substantially all iron.

The crucible used in the preparation of aluminum alloys should be one which is substantially free from oxides which are reducible by aluminum. Otherwise oxides of the crucible may be reduced by the aluminum in the alloy, and certain constituents of the crucible may then enter into the alloy where they exert a detrimental effect upon its properties. Crucibles of magnesia or of magnesia plus alumina have been found to be satisfactory and can be made as required or purchased from the makers of crucibles.

Various methods of heating may be used but it is preferred to melt in a high frequency induction furnace because of the excellent control of temperature which it provides and also because of the stirring it produces in the bath, thus insuring that an alloy of homogeneous composition is obtained.

In the production of iron-chromium-aluminum alloys, the required amount of iron or of a mild steel low in impurities which are detrimental to the quality of the desired alloy, is charged into the crucible and is then melted. No slag covering over the charge is necessary at this stage. If the desired alloy contains a greater percentage of manganese than is furnished by the iron or steel used in making the alloy, the amount of ferro-manganese necessary to make up the deficit is melted along with the charge of iron or steel. For the purpose of computing the amount of the manganese or ferro-manganese addition required to make up this deficit, it can be safely assumed that the recovery of iron and manganese is one hundred percent.

After the melting is completed the molten bath is deoxidized. Calcium has been found to be highly suitable as a deoxidizer but other suitable deoxidizers can be used, provided they act so vigorously as to leave behind substantially no oxygen combined in the form of oxides which would later be reduced by aluminum. The substantially complete deoxidation of the bath before any aluminum is added is of importance in the production of a clean alloy. If the bath contains a substantial amount of iron or chromium oxide or other oxide reducible by aluminum, these oxides are reduced upon the addition of aluminum and result in the formation of alumina inclusions which tend to remain in the bath rather than separate from it. This results in the production of an alloy contaminated by the presence of alumina inclusions. By deoxidizing the path before any aluminum is added, and by doing this with a deoxidizer which is not aluminum but which has so great an affinity for oxygen as to leave substantially no oxygen present in the bath in a form which can combine with the aluminum later added as a constituent of the alloy, the formation of any substantial amount of alumina is avoided and a clean alloy is obtained. When calcium is used as a deoxidizer it is desirable to employ a small excess over the amount which is actually required to combine with the oxygen present in the bath. A deficiency of deoxidizer results in incomplete cleaning of the bath, while an excess of such a deoxidizer as calcium does no harm. As the boiling point of metallic calcium is below the melting point of iron, it is probable that any excess of calcium is vaporized out of the bath.

After the deoxidation of the molten iron, the

required amount of chromium to make up the desired percentage of chromium in the finished alloy is added, preferably in the form of ferrochromium. The necessary weight of the chromium addition can be readily calculated from the composition of the alloy which it is desired to produce, on the basis that the iron and chromium used are completely recovered in the alloy. After the chromium addition in melted down, the bath is again treated with calcium in order to provide a bath which will be substantially free from oxygen when the aluminum is added.

The bath is then covered with a suitable slag. The slag should be free from boron or its compounds, or of substances such as metallic oxides which are reducible by aluminum and upon reduction throw into the bath metals or metalloids or other constituents which are not desired in the alloy.

Excellent results have been secured with a slag consisting of approximately equal parts of alumina and lime. It has been found desirable to preheat the mixture of lime and alumina used to make the slag, to a temperature of about 1500° or 1600° F. before it is placed on the bath. It is not necessary that the mixture be used immediately after it is heated but it should not be allowed to stand for more than a short time before use. In some cases in which this precaution has been omitted, the ingots cast from the alloy have contained blowholes. Blowhole formation is greatly reduced or entirely eliminated by the preliminary heating of the slag forming ingredients.

The bath is held molten under the slag until the slag becomes fluid and picks up the calcium oxide resulting from the deoxidation of the metal with calcium, or other oxides which may be present as a result of deoxidation with other deoxidizers if such are used, or iron or chromium oxides if such be present and have not been reduced because of the use of a deficiency of deoxidizer, or have escaped reduction for any other reason. A deoxidizer is then added to the slag to deoxidize it and to return to the molten metal bath any iron or chromium which it may have contained in the form of oxides. Aluminum chips placed on the slag have been found to be convenient and effective for deoxidizing the slag. While aluminum is not desired as a deoxidizer to be added to the molten metal bath because of the formation of alumina inclusions and their retention in the alloy, the use of aluminum as a slag deoxidizer is free from objection since any alumina which may be formed is formed in the slag and not in the metal bath. In some cases a small amount of metallic magnesium is used along with the aluminum chips to assist in starting the reaction. With small melts the reduction of the slag is usually completed in some twenty minutes.

The slag is then removed from the bath, a further small quantity of calcium is added, and the required quantity of aluminum is added. The weight of the aluminum addition is calculated from the desired alloy composition on the basis that the aluminum recovery is 95% to 97%, the recoveries of iron and chromium being taken at 100% as previously specified.

The most satisfactory results in adding the aluminum have been obtained by weighing out the required quantity in the form of a long aluminum wire or rod and pushing this into the bath as rapidly as it melts away, the end of the aluminum rod being wired to an iron rod so that the last bit of aluminum may also be fed into the bath in this way and melted beneath the surface. The rod of aluminum should be of such size that it does not appreciably chill the bath, and should be fed in at a sufficiently rapid rate so that the melting of the aluminum rod takes place entirely below the surface of the molten bath and not above it. Too slow a feeding of the rod results in melting the rod above the surface of the bath and the formation of a layer of molten aluminum which is exposed to rapid oxidation. Too rapid a rate of feed may result in the breaking off of portions of the rod by contact with the bottom of the crucible. Pieces of solid aluminum broken off in this way rise to the surface of the bath because of their low density and there melt with the same disadvantages that attend too slow a rate of feed. In preparing about thirty pound melts of iron-chromium-aluminum alloys containing about 37% chromium and 7% aluminum, a ¼" aluminum rod has been found to be a convenient size and is fed in as fast as it melts. When the aluminum rod is fed into the bath by hand the end of the rod can be felt to bear against the bottom of the crucible and forms a guide for the rate of feeding.

By adding aluminum in this way, a thin skin of tough oxide is formed over the surface of the bath and protects it from oxidation; the bath is not unduly chilled by the aluminum addition; and a consistent and high recovery of aluminum is obtained. In view of the consistent and high recovery of aluminum, it is much easier to produce an alloy of predetermined composition than with previous methods of adding aluminum which gave larger and less certain losses of aluminum and made the production of aluminum alloys of predetermined composition more largely a matter of chance and good fortune than of certainty.

After the aluminum addition, slag is again placed over the bath. The second slag may consist wholly of lime in which case it does not melt but remains in a somewhat pasty condition, or it may be similar to the first slag and consist of lime and alumina. It has been found that boron is an undesirable constituent in both the first and second slags, and that fluorspar is undesirable in the second. When fluorspar is present in the second slag sudden flashes of light appear at intervals and the alloy produced is not as satisfactory for use in resistance elements as if no fluorspar is used. The use of fluorspar in the first slag has no such disadvantages, but as the complete removal of the first slag is somewhat difficult, its use in the first slag frequently results in carrying some over into the second slag where it is undesirable. For this reason it is ordinarily preferable to omit fluorspar from the first slag as well as from the second.

The melt is held under the second slag for some ten minutes before pouring. If further additions of minor alloying constituents still remain to be made, this may conveniently be done at this time by adding them through the slag. The slag is then removed and the melt is poured.

In preparing iron-chromium-aluminum alloys which are to be used for heating elements or for other purposes which require resistance to oxidation at elevated temperatures, it is desirable that the melt be poured at a temperature which is as low as possible. For an alloy containing iron with some 37% chromium and 7% aluminum, a pouring temperature of about 2900° F. (apparent temperature as measured by an opti-

cal pyrometer sighted upon the molten metal and not corrected for emissivity) is found to be suitable and is about as low as it is practicable to use. The use of a high pouring temperature appears to cause a segregation of alloy constituents which exerts a detrimental effect upon the oxidation resistance of the alloy at elevated temperatures.

While the method of this invention has been specifically illustrated in connection with the preparation of iron-chromium-aluminum alloys it is to be understood that it is also applicable to other aluminum alloys and is not restricted to those which contain iron or chromium or both.

We claim:

1. The method of making an aluminum alloy which comprises preparing a molten metal bath of alloy constituents other than aluminum, deoxidizing said bath by the addition of a deoxidizer other than aluminum but of such efficacy as to leave in the molten metal bath substantially no oxygen combined in the form of oxides of such nature as to be reducible by aluminum, covering said molten metal bath with a slag which is substantially free from compounds of boron and oxides of such nature as to be reducible by aluminum, holding the molten metal bath under the slag to permit the slag to absorb oxides present in the molten metal bath, deoxidizing said slag by the addition of a deoxidizer, removing said slag, adding aluminum to the molten metal bath, covering the molten metal bath with a slag substantially free from fluorspar and boron compounds and oxides reducible by aluminum, holding the molten metal bath under said slag and then pouring said alloy.

2. The method of making iron-chromium-aluminum alloys which comprises melting iron, to form a bath of molten iron, deoxidizing said bath of molten iron by the addition of a deoxidizer other than aluminum but of such efficiency as to leave substantially no oxygen in the molten bath in such form as will result in the formation of aluminum oxide upon the addition of aluminum, adding chromium to said bath of molten iron to form a bath of molten iron and chromium, adding to said molten metal bath a further quantity of said deoxidizer, treating said molten metal bath with a slag which is free from compounds of boron and oxides reducible by aluminum, deoxidizing said slag by the addition of aluminum, removing said slag, adding aluminum to said molten bath of iron and chromium, treating the molten metal bath with a slag which is free from fluorspar, compounds of boron and oxides reducible by aluminum, and pouring the molten alloy.

3. The method of making an iron-chromium-aluminum alloy which comprises melting iron in a high frequency induction furnace to form a bath of molten iron, deoxidizing the molten iron by the addition of calcium, adding chromium and heating to form a molten metal bath of iron and chromium, treating the molten metal bath with a slag composed essentially of lime and alumina, deoxidizing the slag by the addition of aluminum chips, removing the slag from the molten metal bath, adding a further quantity of calcium to the molten metal bath, adding aluminum to the molten metal bath, and thereafter treating the molten metal bath of iron, chromium, and aluminum with a slag containing substantially no other substances than those found in the group consisting of lime and alumina.

4. The method of making an iron-chromium-aluminum alloy which comprises melting iron in a high frequency induction furnace to form a bath of molten iron, deoxidizing the molten iron by the addition of calcium, adding chromium and heating to form a molten metal bath of iron and chromium, treating the molten metal bath with a slag composed essentially of lime and alumina, deoxidizing the slag by the addition of aluminum chips, removing the slag from the molten metal bath, adding a further quantity of calcium to the molten metal bath, feeding an elongated body of aluminum into the metal bath at such a rate that fusion of the aluminum occurs below the surface of the bath, and thereafter treating the molten metal bath of iron, chromium, and aluminum with a slag containing substantially no other substances than those found in the group consisting of lime and alumina.

5. The method of making iron-chromium-aluminum alloys which comprises melting iron, to form a bath of molten iron, deoxidizing said bath, adding chromium to said bath of molten iron, adding to said molten bath a deoxidizer other than aluminum but of such efficiency as to leave substantially no oxygen in the molten bath in such form as will result in the formation of aluminum oxide upon the addition of aluminum, treating said molten metal bath with a slag which is free from compounds of boron and oxides reducible by aluminum, deoxidizing said slag by the addition of aluminum, removing said slag, adding aluminum to said molten bath of iron and chromium, treating the molten metal bath with a slag which is free from fluorspar, compounds of boron and oxides reducible by aluminum, and pouring the molten alloy.

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