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PREPARATION OF IRON ALUMINUM ALLOYS

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This invention is in the field of ferrous metallurgy and is specifically directed to a process for the preparation of ductile iron aluminum alloys containing up to 18% aluminum.

Considerable scientific interest has been generated recently in iron aluminum alloys containing up to 18% aluminum, because of their excellent magnetic and electrical properties and resistance to heat and oxidation combined with their very acceptable tensile properties at elevated temperatures. These qualities are obtainable despite the complete absence of any of the so called critical or sensitive alloys. The commercial utilization of these iron aluminum alloys has been handicapped by the necessity of preparing them in vacuum equipment. While this type of vacuum apparatus is practical and feasible on a small scale, it is to be avoided on a large scale for reasons of economy.

This invention has been especially developed to enable iron aluminum alloys to be prepared in an air ambient and at ordinary atmospheric pressure without sacrifice of ductility.

We have discovered that iron aluminum alloys having commercially acceptable ductility may be prepared without resort to vacuum melting procedures provided that all ingredients of the alloy be rigidly deoxidized and maintained in this rigidly deoxidized condition until solidification has taken place. The exact procedure by which this deoxidation is consummated is immaterial, as long as there is finely produced a molten iron aluminum alloy containing a very low percentage of oxygen and this molten alloy is poured in a manner to retain this low oxygen content.

The requisite low oxygen content in the final alloy is best obtained by combining thoroughly deoxidized iron and similarly thoroughly deoxidized aluminum. These metals in their molten state are satisfactorily deoxidized by treating them with a metal having an affinity for oxygen greater than aluminum and preferably having an affinity for this element of the same order as calcium. By establishing in solution in the iron bath and the aluminum bath a small but significant residue of such an oxygen hungry metal, satisfactory deoxidization is assured. In this way the final alloy bath is prepared in which aluminum oxide is substantially absent.

In the preparation of this alloy, electrolytic iron is melted in a rammed magnesia crucible without the benefit of any slag covering. While not so limited, it is preferred that this melting be accomplished by use of high frequency currents. While the electrolytic iron is being melted, a bath of molten aluminum is prepared in an ordinary teapot graphite crucible. This aluminum is held at a temperature of about 1800° F.

After melting of the electrolytic iron is complete, a preliminary deoxidation is effected by the addition of 0.1% aluminum and 0.5% manganese, both being added as pure metals or as ferroalloys. A more drastic deoxidation of the molten iron is now required. This is accomplished by exposing the melt to metallic calcium. This

may best be done by wiring small cubes of metallic calcium to an iron rod and thrusting the iron rod into the melt. Calcium is preferred but for this purpose it may be replaced by an aluminum calcium alloy or by magnesium or any suitable combination of these elements. The violent ebullition of gas from the deoxidizing metal serves to purge and violently agitate the bath. By way of example, a total of 0.5% of calcium is added to the molten iron in two stages. The second of the two stages is carried out just before the mixing of the iron and aluminum so that a slight excess of calcium remains in the melt.

In a manner similar to that described for the iron the aluminum is now deoxidized using approximately 0.1% calcium, based upon the amount of the aluminum. This deoxidized aluminum is then further degassed by introducing chlorine into the melt through a refractory tube. This chlorination serves to eliminate any hydrogen which may have been generated by the reaction of the aluminum and the water vapor of the air. The reaction of the chlorine with the aluminum bath is exothermic and tends to raise the temperature of the bath. After the aluminum is completely degassed the oxidized dross is skimmed off, fluorspar is added to the iron bath after which the aluminum is slowly poured through the fluorspar slag into the iron. All fluorspar used in this process should be rigidly anhydrous to avoid reaction between the aluminum and water vapor.

Some oxidation of the aluminum during the pouring operation is inevitable. However, this aluminum oxide reacts with the fluorspar slag again exothermically and tends to heat the bath. Precautions should be taken to avoid any toxic effects from the aluminum fluoride which is generated at this point. It is important during and after the addition of the molten aluminum that the bath be vigorously agitated. Induction stirring per se has not been found inadequate for this purpose and resort has been had to vigorous mechanical stirring.

One minute prior to pouring the agitation is stopped and the power shut off. This permits the molten slag to stratify so that the bulk of the slag can be removed. Cast iron molds which have been given a wash of a chlorinated pitch or exposed to a carbon tetrachloride atmosphere are used to receive this metal. It is essential that the alloy be poured into the mold promptly to prevent harmful oxidation in the crucible. The metal is poured into these washed cast iron molds at about 2900° F. The hot topping procedure must take into account the very deep piping encountered in this type of alloy.

Promptly upon solidification the ingots are stripped from the molds and buried in a heat-insulating medium such as vermiculite or lime. This is necessary to prevent thermal cracking because of the poor thermal conductivity and high thermal coefficient of expression of iron aluminum alloys.

In rolling these iron aluminum ingots it is important that the maximum temperature of the ingots does not exceed 1800° F. to avoid excessive grain growth. A suitable practice is to charge the ingots into an electric furnace with the heating elements off and at a temperature of 1000° F. After the ingots have reached furnace temperature the furnace and ingots are quickly brought to 1800° F. and rolling started.

Caution must be exercised in the initial rolling passes to avoid cracking of the ingot. However, conventional rolling practices can be followed after the first few breakdown passes. For example, 2⅜ inch diameter ingot can be rolled to ⅞ inch square bar in two reheats and a total of six mill passes. The ⅞ inch square bar is subsequently rolled to ⅝ inch diameter rod from an initial temperature of 1400° F. and a total of four passes. Alloys cast and rolled in this manner are sound, ductile, and relatively free from surface defects.

In the table reproduced below is shown the comparison of metal produced according to the above outlined procedure and that produced by the most carefully executed vacuum melting process.

Percent Aluminum [1]	Percent Elongation in 1"	
	Vacuum Melts	Air Melts
8	38	38
10	25	25
12	9	9
14	8	5

[1] Actual composition.

The preceding described procedure for producing a deoxidized alloy is by no means intended to limit the breadth of this invention. It is obvious to those skilled in the art that the correct degree of deoxidation of the iron and of the aluminum and of the iron aluminum alloy can be attained in many ways other than the use of the specific deoxidants mentioned above. For example, if costs could be ignored magnesium alone will sufficiently deoxidize the iron without recourse to the use of manganese, silicon or calcium. Similarly other expedients may be used for controlling the cooling of the ingot to prevent cracking and it may be heated for rolling in any suitable manner as long as the temperature of 1800° F. is quickly attained and is not substantially exceeded.

For the guidance of those who care to pursue this matter further the following references are made of record.

1. E. R. Morgan, and V. F. Zackay, "Ductile Iron-Aluminum Alloys," Metal Progress, vol. 61, No. 10, 1955.

2. C. Sykes, and J. W. Bampfylde, "The Physical Properties of Iron-Aluminum Alloys," Jour. Iron and Steel Institute, 130, pp. 389–418, 1935.

3. J. F. Nachman, and W. J. Beuhler, "16 Percent Aluminum-Iron Alloy Cold-Rolled in the Order-Disorder Range," Jour. of Applied Physics, vol. 25, pp. 307–313, 1954.

4. D. C. Hilty, and W. Crafts, "The Solubility of Oxygen in Liquid Iron Containing Aluminum," Trans. AIME, vol. 188, p. 414, 1950.

We claim as our invention:

1. The process of producing a ductile iron aluminum alloy comprising producing a bath of molten iron containing a concentration of oxygen not substantially higher than that concentration which corresponds to the equilibrium between calcium and oxygen at the temperature of the molten iron, producing a substantially hydrogen free bath of molten aluminum containing a concentration of oxygen not substantially higher than that concentration which corresponds to the equilibrium between calcium and oxygen at the temperature of the molten aluminum, establishing on the molten iron bath a layer of fluoride containing anhydrous flux, adding the molten aluminum to the molten iron, intensively agitating the mix and promptly pouring the mixture into a mold.

2. The process of producing a ductile iron aluminum alloy comprising producing a bath of molten iron containing a concentration of oxygen not substantially higher than that concentration which corresponds to the equilibrium between calcium and oxygen at the temperature of the molten iron, producing a substantially hydrogen free bath of molten aluminum containing a concentration of oxygen not substantially higher than that concentration which corresponds to the equilibrium between calcium and oxygen at the temperature of molten aluminum, establishing on the molten iron bath a layer of fluoride containing anhydrous flux, adding the molten aluminum to the molten iron in an amount sufficient to produce a alloy containing six to eighteen percent aluminum, intensively agitating the mix and promptly pouring the mixture into a mold.

3. A ductile and workable alloy of iron and aluminum containing from six to eighteen percent aluminum and which is free from contamination by aluminum oxide, said alloy containing a small but significant residue of a metal having an affinity for oxygen at the melting point of the alloy much stronger than that of aluminum, said alloy having an oxygen content no higher than that which corresponds to the equilibrium between calcium and oxygen at the melting point of the alloy.

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