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ALLOYING METHOD

Pierre P. Turillon, Ramsey, and Patrick J. Hanley, Westwood, N.J., assignors to The International Nickel Company, Inc., New York, N.Y., a corporation of Delaware

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ABSTRACT OF THE DISCLOSURE

The invention is directed to a method for producing nickel-magnesium-silicon alloys wherein production of magnesium oxide vapor is prevented comprising preparing a melt of nickel containing about 26% to about 45% silicon, reducing the temperature of the bath so as not to exceed 1950° F., covering the surface of the bath with a fluid slag and plunging magnesium through the slag cover into the bath. Desirably, the casting produced from the bath is slowly cooled at a rate not exceeding about 350° F. per hour so as to produce an ingot having substantial toughness and substantial freedom from the production of fines when crushed.

Nickel-magnesium-silicon alloys are useful for the purpose of introducing magnesium into ductile iron. The alloys are described in U.S. Pat. No. 2,563,859. In the preparation of the alloys, the commercial practice which has been developed involved charging a furnace such as an induction furnace or an electric furnace with nickel, a small amount of carbon to quiet the melt, iron and silicon, melting down as rapidly as possible and charging further nickel and silicon to keep the crucible full. The bath was then heated to about 2300° F. and held until complete melting had been obtained. The hot nickel-iron-silicon melt was then poured rapidly into a ladle containing magnesium in ingot form and a small amount of cryolite. The alloyed melt in the ladle was then mixed for a short time with an argon lance and poured into a pan mold. The completed cake was then cooled, removed from the mold, and crushed. This practice had been adopted since it had been found there was a danger of explosion in the furnace when it was attempted to melt nickel and magnesium together. The practice which had been developed resulted in a vaporization of a large quantity of magnesium with generation of magnesium oxide fumes in quantities sufficient to cause an air pollution problem.

In view of the difficulties which had been encountered, it was highly desirable to provide a new method for preparing nickel-magnesium-silicon alloys which would avoid generation of magnesium oxide fumes and prevent the air pollution problem.

It is an object of the present invention to provide a method for melting nickel - magnesium - silicon alloys wherein generation of magnesium vapor and magnesium oxide fumes is prevented.

Other objects and advantages of the invention will become apparent from the following description.

Generally speaking, the present invention comprises a method for preparing nickel-silicon-magnesium alloys without the production of appreciable amounts of magnesium vapor or magnesium oxide vapor and with high recovery of magnesium which comprises preparing a melt of nickel containing about 26% to about 45% silicon, preferably about 28% to about 42% silicon, and up to about 12% iron, covering the melt surface with a fluid slag of a readily fusible material such as sodium chloride or cryolite (Na_3AlF_6), adjusting the melt temperature so as not to exceed 1950° F., e.g., about 1750° F. to about 1850° F., and then introducing magnesium through the slag cover into the molten bath by positive means. When the foregoing operations are carried out vaporization of magnesium is prevented and recovery of introduced magnesium is high, approaching or reaching a magnesium recovery of 100% in most cases. It is to be appreciated that while the boiling point of pure magnesium is given as 1117° C. (2043° F.), molten magnesium exerts an appreciable vapor pressure at temperatures well below the boiling point when melts containing appreciable proportions, e.g., 10% or more, of magnesium are exposed to the atmosphere.

It is to be appreciated that silicon reduces the melting point of nickel and nickel melts containing about 28% to about 42% silicon will have a melting point not higher than about 1000° C. (1832° F.). Introduction of magnesium into the nickel-silicon melt will lower the melting point even further, e.g., down to about 1600° F.

In preparing the melt, the nickel may be melted first, e.g., in an induction furnace, and the silicon may be added as pure silicon or as a ferrosilicon alloy containing up to about 25% iron. Reduced power should be employed since the addition of silicon to nickel is exothermic.

Preferably, alternate layers of nickel and silicon or ferrosilicon alloys are charged into the furnace, e.g., an induction furnace, so that faster melting can be obtained.

It is important to control the temperature of the melt accurately. Thus, magnesium can be introduced into the nickel-silicon melt at temperatures as low as 1750° F. and even up to temperatures as high as 1950° F. However, at temperatures in excess of 2000° F., objectionable amounts of smoke are generated and the potential for creating combustible magnesium vapor is undesirably increased. A desirable bath temperature is in the range of about 1800° F. to about 1850° F. It is also very important that a slag cover be maintained completely over the melt surface while magnesium is being introduced. It is also important that the slag cover should be liquid at all times. It is to be appreciated that reactions between magnesium oxide and the slag can cause the slag to become crusty in which case the potential for creation of magnesium vapor beneath the slag with possibly explosive results exists. Satisfactory dry slag materials having a melting point not exceeding about 1800° F. include sodium chloride, cryolite (Na_3AlF_6), soda-lime glass, calcium chloride, magnesium chloride and lithium fluoride. The slag preferably is liquid at temperatures above 1650° F. The slag cover need not exceed about ½ inch in thickness, provided always that sufficient slag material is added to the bath surface to completely cover the surface while magnesium is being introduced into the bath. The slag material preferably is chosen to be nonfuming at the melt temperatures involved.

It is also important that the magnesium be plunged into the molten nickel-silicon alloy through the slag cover. Thus, merely dropping chunks of magnesium on top of the melt is not only unsatisfactory but may be dangerous since the formation of a slag crust is thereby promoted. Pure magnesium can be introduced in the form of a rod or a chunk plunged vertically down into the melt. Mechanical means may be employed for this purpose. The melt is cast into ingot molds at a melt temperature in the range of 1750° F. to 1950° F., e.g., 1850° F. It is found that when the melt is cast into a cast iron mold, even one preheated to a temperature on the order of about 200° F., a casting is produced which is extremely brittle and which produces a large amount of fines during crushing. This brittleness can be considerably reduced by slowly cooling, i.e., at a rate not exceeding about 350° F. per hour and preferably not exceeding about 100° F. per hour, the cast metal from the casting temperature down to a temperature of about 1400° F. or lower, e.g., 900° F. The metal thus produced is substantially less brittle and produces a much lesser amount of fines upon crushing. The desired effect can be produced by preheating the mold to about 1600° F. prior to pouring and burying the filled mold in an insulating material such as vermiculite. Satisfactory results are obtained by cooling the cast ingot slowly for about 2 hours after which the ingot may be rapidly cooled to room temperature.

Nickel-silicon-magnesium alloys produced in accordance with the invention contain about 25% to about 40% silicon, about 12% to about 20% magnesium, up to about 12% iron and the balance essentially nickel. Preferably, the alloys contain about 25% to about 30% silicon, about 17% to about 20% magnesium, up to about 12% iron, and the balance essentially nickel. Small amounts, e.g., up to about 5%, of calcium, yttrium, lanthanum, cerium or other rare earth metal can be introduced into the alloy if desired.

In order to give those skilled in the art a better understanding of the invention and a better appreciation of the advantages of the invention, the following illustrative examples are given:

EXAMPLE I

A charge consisting of about 3,750 parts of nickel with 4 parts of carbon for deoxidation was melted in an air induction furnace. When the nickel was melted, the temperature was adjusted to about 2700° F., the power was turned down and 2,738 parts of a ferrosilicon alloy containing about 85% silicon were slowly added. During the addition, the temperature of the bath was slowly reduced to about 1800° F. The temperature of the bath was then adjusted to about 1850° F., the bath surface was covered by a layer of fluid sodium chloride slag about ½ inch thick, and magnesium chunks comprising about 1,222 parts by weight of the bath were then plunged into the melt. Almost no smoke evolved from the melt.

EXAMPLE II

A charge comprising 3,750 parts by weight of nickel, about 4 parts by weight of carbon, and about 2,738 parts of a ferrosilicon alloy containing 85% silicon was melted in an air induction furnace. The temperature of the melt was adjusted to about 1825° F. About 200 parts by weight of pure, dry sodium chloride were added to the melt surface where it immediately liquefied. A rod of pure magnesium about one inch in diameter comprising 1,392 parts by weight of the melt driven by a screw-drive mechanism was plunged into the melt at a rate of about 3 inches per minute without the production of any magnesium oxide smoke.

EXAMPLE III

A melt was prepared in accordance with the procedure described in Example II. Four 1¼ inch diameter molds were prepared, two of which were made of cast iron and

the other two of which were made of graphite. One of the cast iron molds and one of the graphite molds were preheated in a gas furnace to 1600° F. The preheated molds were filled with the nickel-magnesium-silicon alloy and placed back in the furnace at 1600° F. and were then furnace cooled at a rate not exceeding 100° F. per hour down to 1400° F. The two remaining molds were also filled with the nickel-magnesium-silicon alloy to form ingots which were cooled rapidly therein. It was observed that the two furnace cooled ingots could be dropped on a concrete floor from a height of 24 inches without breaking whereas the chill-cast ingots shattered when dropped from a height of only 6 inches. In addition, it was observed that the furnace cooled ingots had a coarse grainy structure whereas the chill-cast ingots had a smooth lustrous fracture surface.

EXAMPLE IV

A melt was prepared as described in Example III and a portion was poured into a 1¼ inch diameter graphite mold, preheated to 1600° F. The mold was immediately surrounded by vermiculite and slowly cooled for 2 hours to a temperature of about 900° F. The mold was then removed from the vermiculite. The ingot was stripped and rapidly cooled to room temperature. The resulting ingot could be dropped from a height of 24 inches without breaking. When dropped from a height of 6 feet, it broke in two pieces revealing a coarse grainy structure. The material from this example and the slowly cooled material from the previous example could be crushed with the production of only a minor proportion of fines whereas the rapidly cooled material of the previous example provided a large amount of fines when crushed.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claims.

We claim:

1. In the production of nickel-magnesium-silicon alloys, the improvement for obtaining high magnesium recovery and for avoidance of magnesium oxide fuming which comprises establishing a melt containing, by weight, about 26% to about 45% silicon, up to about 12% iron and the balance essentially nickel, reducing the temperature of the bath so as not to exceed about 1950° F., covering the surface of the bath with a fluid slag and plunging solid magnesium through the slag cover into the bath to introduce about 12% to about 20% of magnesium by weight therein, and thereafter casting said bath.

2. The process according to claim 1 wherein the bath contains about 28% to about 42% silicon.

3. The process according to claim 1 wherein the slag material is a metal halide having a melting point not exceeding about 1800° F.

4. The process according to claim 1 wherein the slag material is selected from the group consisting of sodium chloride, cryolite, soda-lime glass, calcium chloride, magnesium chloride and lithium fluoride.

5. The process according to claim 1 wherein magnesium in an elongated shape is introduced through the slag cover into the bath at a steady rate.

6. The process according to claim 1 wherein the cast alloy is cooled at a rate not exceeding about 350° F. per hour over the temperature range from the casting temperature to a temperature not exceeding about 1400° F. to produce an ingot characterized by substantial toughness and substantial freedom from the production of fines on crushing.

7. The process according to claim 6 wherein the cooling rate does not exceed about 100° F.

8. The process according to claim 1 wherein an alloy containing about 25% to about 40% silicon, about 12% to about 20% magnesium, up to about 12% iron and the balance essentially nickel is produced.

9. The process according to claim 8 wherein the alloy produced contains about 25% to about 30% silicon and about 17% to about 20% magnesium.

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L. DEWAYNE RUTLEDGE, Primary Examiner

E. L. WEISE, Assistant Examiner

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