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CAST IRON

Harold W. G. Hignett, Edgbaston, Birmingham, England, assignor to The International Nickel Company, Inc., New York, N. Y., a corporation of Delaware

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The present invention relates to an improved process for producing gray cast iron; and more particularly, to an improved process for producing gray cast iron having improved properties and containing graphite in a compacted form; and to the product resulting from the improved process.

It has been discovered that the flake form of uncombined carbon normally occurring a gray cast iron, can be caused to appear in a more compacted form, including even a spheroidal form through the retention in a gray cast iron of very low amounts of magnesium.

It is an object of the present invention to provide an improved process for treating gray cast iron melts, particularly gray cast iron melts containing high sulfur contents, to produce improved gray cast iron containing graphite in a compacted form.

Another object of the invention is to provide an improved process for producing gray cast iron having improved properties, particularly improved strength and ductility, and containing very small amounts of retained magnesium.

The invention also contemplates providing a method for producing gray cast iron containing graphite substantially in a spheroidal form and containing very small amounts of retained magnesium.

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

Generally speaking, the present invention contemplates an improved process for producing gray cast iron alloys containing graphite in a compacted form which comprises treating a molten gray cast iron bath to reduce the sulfur content thereof from a relatively high level to a relatively low level, e. g., to a level of 0.02% or less sulfur and thereafter introducing into said bath magnesium to provide a retained magnesium content of at least 0.010% up to about 0.04%, and casting said desulfurized and magnesium-treated cast iron with sufficient graphitizing power to obtain gray iron castings.

The improved cast iron produced by the aforesaid process embodying the present invention comprises gray or graphitic cast iron containing 0.02% or less sulfur, e. g., 0.010% sulfur, and containing more than 0.010% and up to less than 0.04% retained magnesium. With retained magnesium contents of 0.010% to 0.02%, the improved cast irons provided by the invention contain graphite in a substantially compacted form as distinguished from the flake form of graphite found in ordinary gray cast irons of the same

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general analysis, or as distinguished from the "nodular" form of graphite found in American malleable iron. With retained magnesium contents over 0.02% and up to less than 0.4%, e. g., 0.025% or 0.030% magnesium, the compacted graphite form in the products produced in accordance with the invention is substantially spheroidal.

In carrying the invention into practice, it is preferred to establish a gray cast iron bath containing sulfur; to apply to this surface of said bath held in a ladle or other container at least one molten basic slag, e. g., a lime slag, etc., to reduce the sulfur content of said melt to a low sulfur level within the invention, e. g., to 0.010% sulfur; and to remove the slag from the bath before the introduction of magnesium into the melt to effect control of the graphite form in the resulting castings as provided by the invention. After the molten cast iron bath has been desulfurized from a relatively high sulfur level to a relatively low sulfur level through one or a succession of desulfurizing steps, sufficient magnesium is then introduced to provide the critical retained magnesium content and the melt is then preferably inoculated with the graphitizing inoculant such as ferro-silicon to insure that the metal will be graphitic when cast. The amount of silicon added as an inoculant is generally from 0.3% to 2.5%, preferably 0.4% to 1.2%. In a few cases where the graphitizing power of the melt is very high, inoculation may be dispensed with. For purposes of the invention lime slags are those containing 40% or 50% or more lime, and the balance essentially fluorspar or cryolite, etc. to insure fluidity, whereby a sulfur-avid slag is provided. Other basic ingredients, e. g., up to about 35% sodium silicate may be also included.

The desulfurizing action of the basic slag may be reinforced by other desulfurizing agents added to the melt covered with the basic slag. These agents include sodium carbonate, metallic calcium, metallic magnesium, metallic lithium, etc. The use of such agents, particularly calcium, in combination with the desulfurizing slag is a preferred embodiment of the invention and appears to produce products having superior properties at a given level of magnesium within the invention. It is to be understood that when magnesium is employed as a desulfurizing agent to reinforce the desulfurizing action of the basic slag, two additions of magnesium are made, the first addition to promote desulfurization, and the second addition to remain in the cast metal.

When calcium is employed as a desulfurizer as aforesaid, amounts of calcium of the order of about 0.2% have given satisfactory results although larger amounts, e. g., up to 0.5% or 1% calcium may be employed, particularly when high sulfur melts, e. g., melts containing more than 0.1% sulfur are being treated according to the invention. Calcium may be added to the melt in the form of calcium metal or as an alloy, e. g., as calcium silicide. When magnesium is employed for the purpose of producing desulfurization, an amount of magnesium approximately equal on a weight basis to the amount of sulfur to be removed should be incorporated in the molten bath. Magnesium may be added to the molten bath (either for desulfurization or for the purpose of introducing the required retained magnesium) in metallic form provided due caution is observed, but it is preferred to employ an alloy of magnesium with nickel, copper, an/or silicon.

In applying the desulfurizing basic slag to a molten gray cast iron bath in accordance with the invention, the bath is preferably well covered with the slag although the minimum amount of slag which successfully can be employed will depend on practical considerations.

Since North American cast irons normally contain about 0.03% to about 0.14% sulfur, relatively large amounts of sulfur will be removed from the molten cast iron bath in carrying out the process embodying the present invention. In general it can be said that at least about 0.02% sulfur is removed in desulfurizing cast iron melts according to the invention. Under certain conditions, particularly when the sulfur content of the iron bath being treated is high, e. g., 0.1% sulfur or more, it is preferred to successively reduce the sulfur content thereof from the relatively high level through an intermediate level to a relatively low level, e. g., 0.01% sulfur.

The cast iron baths to be treated according to the invention to produce castings containing compacted or spheroidal graphite in the as-cast condition are those compositions which when inoculated and cast produce gray cast iron. Gray cast irons produced according to the invention are eutectiferous alloys of iron and carbon usually containing substantial amounts of silicon. Gray cast iron baths employed in the process embodying the invention will contain about 1.7% to about 5% carbon, preferably about 2% to about 4.5% carbon, and about 0.5% to about 5.5% silicon, preferably about 0.8% to about 3.5% or about 5% silicon. The gray cast iron baths may be free from other alloying elements or may contain substantial amounts of alloying elements, as none of the common alloying elements in the usual amounts employed heretofore in gray cast iron with the possible exception of large amounts of copper have been found to interfere with obtaining the novel results provided by the process embodying the invention. Thus, the gray cast iron baths may contain the usual amounts of such alloying elements as manganese, nickel, molybdenum,chromium, etc. For example, the bath may contain about up to 5% nickel, up to about 2.5% manganese, up to about 1% chromium and up to about 2% copper. Other elements which are not usually found in cast iron and which are subversive are avoided or are present only in very small amounts because they interfere with the function of magnesium in controlling the graphite form in the final castings. These subversive elements include tin, lead, antimony, arsenic, selenium, tellurium, etc. Phosphorus may be present in amounts as high as 0.5% or more but the phosphorus content preferably should not exceed about 0.15%. The balance of the composition of the bath and the gray cast iron product will be essentially iron and iron generally constitutes at least about 85 or 87% of the total composition. The composition of the final castings will in general be the same as the composition of the bath after magnesium treatment and will fall within the ranges set forth hereinbefore, with the exception that the silicon content of the castings may be slightly higher than the bath since some silicon, e. g., about 0.5% silicon, is usually added before casting. The silicon content of the castings will be about 1% to about 6% silicon, preferably about 1.3% to about 4.5%. The castings produced in accordance with the process embodying the invention will contain less than about 1.2% combined carbon with the balance of the carbon content being uncombined or graphitic carbon.

For the purpose of giving those skilled in the art a better appreciation of the advantages of the invention, the following illustrative examples are given:

Example 1

Molten cast iron containing 3.6% carbon, 1.5% silicon, 0.6% manganese, 0.1% sulfur and 0.025% phosphorus was treated at 1400° C. by the application of a basic slag to the surface three times in succession, the slag consisting of 60% lime, 32% sodium silicate and 8% cryolite. The sulfur content of the molten metal was reduced to 0.004%. After desulfurization, the temperature was raised to 1450° C. and samples were tapped, additions of nickel-magnesium containing 8% magnesium being made to each sample in the ladle to provide a series of residual magnesium contents in the range of 0 to 0.04%. After the magnesium addition, each sample was inoculated with 0.5% silicon as ferro-silicon. Test bars were cast from each sample. It was found that when the amount of magnesium added was 0.02% the residual magnesium content in the iron as cast was 0.013% and the graphite was nearly all in a compacted form and the tensile strength was 25 tons per square inch (about 56,000 pounds per square inch). An addition of 0.03% magnesium gave a residual magnesium content of 0.020%, a structure in which most of the graphite was compacted and there were some spheroids, and a tensile strength of 30 tons per square inch (about 67,000 pounds per square inch). With an addition of 0.04% magnesium the residual magnesium content became 0.028% and the compacted graphite wholly spheroidal. The tensile strength was then 40 tons per square inch (about 89,000 pounds per square inch). The term "tons" means long tons.

Example 2

The procedure was exactly the same as in Example 1 except that during the desulfurization metallic calcium in an amount equal to 0.2% of the weight of the molten metal was added and the sulfur content was reduced to 0.002%. It was found that the graphite was nearly all in a compacted form when 0.02% magnesium was added to give a residual magnesium content of 0.010% and the tensile strength of the iron was then 25 tons per square inch (about 56,000 pounds per square inch). An addition of 0.03% magnesium gave a residual magnesium content of 0.02% and a mixture compacted graphite structure containing spheroidal graphite, the tensile strength be-

ing 33 tons per square inch (about 74,000 pounds per square inch). An addition of 0.04% magnesium gave a residual magnesium content of 0.026% with all the graphite in the spheroidal form, the tensile strength of the iron being 42 tons per square inch (about 94,000 pounds per square inch). The retained magnesium values in the foregoing two examples were obtained by a spectrographic method.

Example 3

A gray cast iron melt was desulfurized to a sulfur content of 0.01% by means of a basic slag containing 66% calcium oxide, 25% sodium silicate and 9% cryolite and by means of an addition of 0.2 calcium under said slag. After desulfurization, magnesium was introduced into the melt, the melt was inoculated and 1.2-inch diameter bars were cast. The castings contained 3.2% carbon, 1.33% silicon, 0.6% manganese, 0.01% sulfur and 0.018% magnesium, with the balance essentially iron. The microstructure of the castings comprised substantialy compacted graphite particles with a few spheroids. The magnesium-containing castings had a transverse strength in the as-cast condition of 9,000 pounds whereas the transverse strength of the base iron was only 3,880 pounds under the same test conditions. The magnesium in the foregoing example was determined by a chemical wet method.

Magnesium alloys which have been found to be particularly suitable for the purpose of treating gray cast iron melts in accordance with the process embodying the present invention are those alloys based on nickel and/or silicon. An example of a suitable alloy is one containing about 10% to about 20% magnesium, about 1.3% to about 2.5% carbon, balance essentially nickel. Alloys containing magnesium and silicon such as iron-magnesium-silicon and nickel-magnesium-silicon alloys possess the advantage that, under proper conditions, the magnesium introduction and silicon inoculation can be accomplished simultaneously through the use thereof in the process embodying the invention.

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.

I claim:

1. The process for producing improved graphite structures in magnesium-containing gray cast iron which comprises establishing a molten iron bath having such a composition as to be a gray cast iron when inoculated and cast, conditioning the molten iron of said bath by adding to said iron under a basic slag at least about 0.2% calcium, separating said slag and the thus-conditioned molten iron from each other, thereafter introducing magnesium into said conditioned molten iron and retaining about 0.01% to about 0.04% magnesium in said molten iron, and casting said molten iron in an inoculated condition to obtain a gray iron casting containing about 0.01% to about 0.04% retained magnesium and having an improved graphite structure for the amount of magnesium retained in the casting.

2. The process for producing improved graphite structures in magnesium-containing gray cast iron which comprises establishing a molten iron bath containing a relatively high value of sulfur of at least about 0.08% and having such a composition as to be a gray cast iron when inoculated and cast, conditioning the molten iron of said bath by adding to said iron under a basic slag calcium in an amount approximately equal on a weight basis to the amount of sulfur in excess of 0.02%, separating said slag and the thus-conditioned molten iron from each other, thereafter introducing magnesium into said conditioned molten iron to retain about 0.01% to about 0.04% magnesium in said molten iron, and casting the magnesium-containing molten iron in an inoculated condition to obtain a gray iron casting containing about 0.01% to about 0.04% retained magnesium and having an improved compacted graphite structure for the amount of magnesium retained in the casting.

3. The process for producing improved graphite structures in magnesium-containing gray cast iron which comprises establishing a molten iron bath having such a composition as to be a gray cast iron when inoculated and cast, adding calcium to the molten iron of said bath under a basic slag to provide conditioned molten iron containing not more than about 0.02% sulfur, separating said slag and the thus-conditioned molten iron from each other, thereafter introducing magnesium into said conditioned molten iron to retain about 0.01% to about 0.04% magnesium in said molten iron, and casting the molten magnesium-containing iron in an inoculated condition to obtain a gray iron casting containing about 0.01% to about 0.04% retained magnesium and having an improved compacted graphite structure for the amount of magnesium retained in the casting.

HAROLD W. G. HIGNETT.

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