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PROCESS FOR MAKING NODULAR IRON

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ABSTRACT OF THE DISCLOSURE

A method is disclosed for treating molten cast iron with magnesium to manufacture nodular iron. In a preferred embodiment magnesium particles and scrap cast iron or steel particles are mixed together and briquetted, magnesium making up 5% to 30% by weight of the briquettes. A suitable number of these briquettes are immersed in molten cast iron to obtain a retained magnesium content therein of about 0.035% to 0.07% by weight.

This invention relates to the manufacture of nodular iron and more particularly to a new method and form of adding magnesium to molten cast iron to produce castings in which the uncombined carbon is in a substantially spheroidal form.

Several years ago, Millis, Gagnebin, and Pilling (U.S. 2,485,760) discovered that cast iron could be consistently and reproducibly manufactured into a casting in which the uncombined carbon was present in spherical rather than flake form. In accordance with their method (U.S. 2,749,-238), this advantageous graphite structure is obtained by introducing magnesium into a heat of molten cast iron in an amount suitable to provide about 0.035% to about 0.5% by weight retained magnesium in castings poured from the heat. This small amount of magnesium retained in the casting is sufficient under proper conditions to effect the occurrence of uncombined carbon in a spheroidal form in the as-cast condition. In the years succeeding their discovery, the means by which magnesium is incorporated into molten cast iron has proven to be one of the more troublesome steps of the process. Magnesium has a boiling point which is substantially lower than the normal pouring point of any commonly used cast iron composition. Moreover, magnesium does not dissolve in iron in appreciable amounts. As a result, the direct addition of pure magnesium to molten iron normally culminates in a violent oxidation of the magnesium before it can be incorporated into the iron alloy resulting in the loss of the magnesium and frequently the loss of some of the molten cast iron. Consequently, magnesium has been alloyed with such materials as nickel, copper, and/or silicon, prior to contact with the hot cast iron, as a more suitable means of placing the magnesium in the molten ferrous solution. In this regard, the prior art has also taught that magnesium may be incorporated with other materials such as graphite or calcium to reduce the violence of the reaction of magnesium in the molten iron. However, since magnesium is insoluble in iron, the prior art has never considered mixing magnesium with iron particles in the manufacture of nodular iron. Possibly this is is because it is not apparent that iron would effectively cooperate with magnesium in a mechanical mixture of the two materials, once the mechanical mixture was submerged in a greater mass of molten iron, to cause a high proportion of the magnesium to be retained in the melt in a useful form.

The prior art alloys and mixtures in which magnesium has been incorporated before immersion in molten iron in the production of nodular iron are not a completely

satisfactory solution to this problem. Nickel and copper are critical elements which under certain economical and political conditions are not available in adequate supply. Moreover, in most gray iron alloy compositions the presence of these elements is not required nor particularly desired. Since the acceptable composition limits of magnesium in alloys with copper and nickel is rather low, usually on the order of 15–20% or less, the employment of substantial amounts of magnesium requires that large amounts of these critical elements be added to the molten cast iron. Although calcium and graphite are not critical elements, it is noted that their addition to cast iron normally is not required nor desired in the manufacture of nodular iron. The same observation may be made with respect to silicon. As a matter of fact, when magnesium is alloyed with ferrosilicon for addition to molten cast iron, precautions usually must be taken to reduce the silicon content of the original cast iron melt to permit the later addition.

Therefore, it is an object of our invention to provide a magnesium addition agent in a form suitable for the production of nodular iron, which agent consists essentially of magnesium and scrap iron.

It is a further object of our invention to provide a method of adding magnesium safely and efficiently to a molten cast iron in which method no diluting elements other than those normally present in cast iron or steel are added which increase the cost of the nodular iron or which require that special precautions be taken to achieve the desired final composition of the nodular iron.

These and other objects of our invention are accomplished by first uniformly mixing magnesium particles with a greater weight of iron or scrap ferrous alloy particles. The scrap ferrous alloy particles are of a composition which is representative of steel or cast iron. The only further restriction is that they be clean and dry and otherwise suitable for remelting and use in the manufacture of cast iron or steel. The particles may be in the form of borings, chips, turnings, or the like. The mixture of magnesium and steel particles is then compacted in the form of a brick or briquette, which briquette is immersed by any of a number of suitable techniques described below directly in molten cast iron held in a suitable ladle. The mechanical mixture comprising the briquette contains no extraneous expensive or critical elements, but only those which would normally be included in cast iron or steel. Of course, magnesium is also present because it is required in the production of nodular iron. The quantity of briquettes which is added to the melt is determined from the size and chemical analysis of the cast iron melt. In this determination it must be expected that some magnesium will be lost by vaporization and oxidation. Some will react with sulfur or other elements present which have a great affinity for magnesium. Nothwithstanding these losses, a small but effective amount of magnesium, usually about 0.035% up to about 0.4% by weight, and preferably about 0.035% to 0.07% by weight, must be retained in the melt to cause all uncombined carbon to be present in a compacted spherical form in the cast product. When magnesium is added in accordance with our method, it may be expected that the recovery of magnesium in useful form will be at least about 40% of that added to the melt, not including the magnesium that is consumed by sulfur or other elements which form stable compounds with magnesium. Finally after the magnesium treatment it may be necessary to inoculate the treated melt with a small amount of ferrosilicon (0.05% to 1.2%) as is presently done in the manufacture of nodular iron to promote graphite formation.

These and other objects will become more apparent

in view of a detailed description of the invention which follows.

A few examples will better illustrate the invention by serving as the basis for further discussion. In the following examples the briguettes were prepared by mixing six parts by weight of cleaned and dried cast iron borings with one part by weight of 40 mesh magnesium spheres. The mixture was compacted into seven pound briquettes. Three approximately seven pound briquettes were used in each of the following examples.

EXAMPLE I

A 1700 pound melt of cast iron composition was prepared in a ladle suitable for treatment with magnesium. The melt comprised by weight: 3.57% carbon, 2.00% silicon, 0.48% manganese, 0.11% chromium, 0.065% phosphorus, and 0.088% sulfur. Three, seven pound megnesium-containing briquettes were plunged into the molten melt using an immersion bell in which the alloy briquettes were placed and thrust into the bottom portion of the ladle. The immersion bell is a device which is commercially available for submerging and maintaining relatively low density solids beneath the surface of a liquid, and its use is well known in the art of nodular iron manufacture. The molten iron was treated at a temperature of 2685° F., the reaction being completed in 95 seconds. A portion of the cast iron was then transferred to a pouring ladle in which it was inoculated with a small amount of ferrosilicon (the amount of silicon added being about 0.75% of the weight of the cast iron melt) and cast into an ingot mold. Specimens of the cast ferrous alloy were examined under the microscope. All of the graphite was found to be nodular in form. The matrix microstructure was 80% pearlite and 20% ferrite. The magnesium content was determined to be 0.040% which represented a recovery of the magnesium charged of 45%. Magnesium recovery was calculated from the following standard relationship.

$$\text{Percent Mg. recovery} = \frac{\text{Percent retained Mg.}}{\text{Percent Mg. added-Percent S in original Iron}} \times 100$$

The ultimate strength of the cast material was 84,500 p.s.i.; the yield strength was 51,700 p.s.i.; the reduction in area of a tensile specimen was 9.7% and the elongation in two inches was 11.7% contrary to the teachings of the prior art, the reaction of the iron alloy-magnesium mixture with the molten iron was readily controllable even on the large production scale quantity used and the recovery of magnesium, it will be noted, was particularly favorable being much higher than those typically obtained using prior art magnesium alloys.

EXAMPLE II

Three, seven pound briquettes each comprising of six parts cast iron borings and one part pure magnesium, were added to a 1600 pound cast iron melt. The melt originally comprised by weight: 3.61% carbon, 2.03% silicon, 0.48% manganese, 0.09% chromium, 0.025% phosphorus, and 0.089% sulfur. The briquettes were plunged into the bath at a temperature of 2645° F. and the reaction was completed in about 105 seconds. The treated melt was transferred from the plunging ladle to a pouring ladle in which it was inoculated with ferrosilicon as is well known in the art. The treated and inoculated melt was then cast into ingots. The castings contained 0.058% magnesium by weight. The magnesium recovery was thus determined to be 54.8%. The ultimate strength of the nodular cast iron was 91,700 p.s.i. and the yield strength was 53,000 p.s.i. while the reduction in area was 6.6% and the elongation in two inches was 8.6%. All of the uncombined carbon was found to be in nodular form and the matrix microstructure was 100% pearlite.

EXAMPLE III

Twenty and one-half pounds of the above-described magnesium-scrap iron briquettes were plunged into 1600 pounds of molten cast iron in a suitable plunging ladle. The composition of the melt before treatment comprised by weight: 3.65% carbon, 2.01% silicon, 0.46% manganese, 0.09% chromium, 0.04% phosphorus, and 0.095% sulfur. The magnesium addition was performed at a temperature of 2675° F. and required 88 seconds. A portion of the treated molten iron was immediately transferred to a smaller pouring ladle and inoculated with ferrosilicon. The treated and inoculated melt was then cast into ingots. The magnesium content of the casting was 0.045% by weight which represents a recovery of 49%. The uncombined carbon in the cast material was entirely in the nodular form and the matrix microstructure consisted of 80% pearlite and 20% ferrite. The ultimate strength of the cast material was 79,400 p.s.i. and the yield strength 49,100 p.s.i. The reduction in area in tensile test specimens was 13.8% and the elongation in two inches was 14%.

EXAMPLE IV

Twenty-one pounds of the above-defined briquettes were plunged into an 1800 pound cast iron alloy melt in a plunging ladle. The composition of the melt comprised by weight: 3.50% carbon, 2.04% silicon, 0.51% manganese, 0.10% chromium, 0.06% phosphorus, and 0.095% sulfur. The temperature of the plunging treatment was 2650° F. and 100 seconds were required for the treatment. The treated melt was transferred to a pouring ladle in which it was inoculated with ferrosilicon. The treated and inoculated melt was then cast. All of the uncombined carbon in the casting was found to be in nodular form and the matrix microstructure of the casting was comprised of 80% pearlite and 20% ferrite. The magnesium content of the cast material was 0.046% by weight representing a recovery of magnesium of 64%. The ultimate strength of cast material was 125,000 p.s.i., the yield strength was 69,700 p.s.i., the reduction in area of the tensile specimen was 35% and the elongation in two inches was 4.7%.

EXAMPLE V

Twenty-one pounds of the above-defined briquettes were added to a melt of 1500 pounds of cast iron in a plunging ladle. The cast iron melt originally comprised by weight: 3.69% carbon, 2.10% silicon, 0.48% manganese, 0.08 %chromium, 0.04% phosphorus, and 0.115% sulfur. The temperature of the treatment was 2720° F. and 90 seconds were required. The treated melt was transferred from the plunging ladle to a suitable pouring ladle in which it was inoculated with ferrosilicon. Subsequently, the magnesium-treated and silicon-inoculated melt was cast. The casting contained 0.038% by weight magnesium. The magnesium recovery was 45%. All of the uncombined carbon in the cast material was observed to be in the nodular form and the matrix consisted of about 90% pearlite and 10% ferrite. The ultimate strength of the cast material was determined to be 107,390 p.s.i. and the yield strength was 68,500 p.s.i. The reduction in area was 4% and elongation in two inches was 3.9%.

In accordance with our invention, a briquetted mechanical mixture of scrap ferrous particles and pure magnesium particles may be used to treat any suitable cast iron heat which now may be treated with magnesium incorporated in prior art alloys and mixtures. Our briquettes may also be used to treat melts which contain relatively high amounts of sulfur, in excess of 0.02% by weight, because the addition of greater amounts of magnesium does not increase the amount of undesired and unneeded elements. Of course, it is less expensive to treat cast iron in which the sulfur content has previously been reduced below about 0.02% by weight because less magnesium is consumed. Moreover, one skilled in the art will recog-

nize that the magnesium recovery is advantageously high when using briquetted magnesium and scrap iron which permits the more economical treatment of the alloy.

The briquettes used in accordance with our invention may be compressed using any suitable extruding or compacing equipment. Briquetting equipment is commonly found in cast iron foundries to prepare briquettes of scrap iron or steel for charging to a cupola or any other melting furnace. If such briquetting equipment is available, normally no other special machinery is required. Iron borings or turnings preferably should be cleaned and dried before compacting with magnesium. Commercially available pure magnesium is used in accordance with our invention preferably having a particle size in the range of 4–60 mesh. Particle sizes slightly outside this range are suitable but if the particles of magnesium are much finer than 60 mesh they are more susceptible to oxidation. It is also preferred, if possible, that the scrap iron particles and magnesium particles be roughly the same size so that a more uniform mixture may be attained and maintained prior to and during compaction of the briquettes. Since only a mechanical mixture is prepared and briquetted it may be accomplished at or about room temperature and a melt of magnesium is not required as in other alloying operations in the prior art. Because the magnesium is not melted there is much less tendency of oxidation and loss. Exactly the same magnesium content can be achieved in the briquettes from one prepared lot to another. For this reason control of the magnesium addition is much more readily attained in accordance with our invention. However, we have found that in employing briquettes comprising the mechanical mixture of magnesium and scrap iron, it is preferable that they not be exposed to an oxidizing environment for more than about three days before they are used to treat molten cast iron.

The optimum size and weight of the briquettes is determined in view of the size of the cast iron heat which is to be treated and by the method in which the briquettes are to be added. For example, in the relatively large melts described in the above illustrations, a five to ten pound briquette is suitable. If the briquettes are to be submerged in the melt using an inverted cup or bell, the size and shape of the briquettes will in most instances be limited by the capacity of the plunging device.

The composition of the briquettes in accordance with this invention suitably consists essentially at 5–30% magnesium and the balance scrap iron. Lower percentages of magnesium could be used but this is usually economically unjustified because too many briquettes are required to do the job. Magnesium concentrations in excess of 30% by weight in a mechanical mixture tend to oxidize too rapidly upon standing and are not suitable in accordance with our invention. Preferably the briquette consists of 10–20% by weight magnesium and the balance scrap iron.

Various known means have been devised for immersing magnesium-containing alloys and mixtures, such as our briquettes, in the cast iron melt. Three such means are widely used; the pressure ladle method, the plunging method using an immersing refractory basket (described above), and the ladle addition method. These methods are described in detail in the Metals Handbook, 8th ed., vol. 1, at pages 391 and 392. Any of these and other methods may be employed to immerse the magnesium-scrap iron briquettes in the molten cast iron.

It is also known, as indicated generally above, that the magnesium-treated cast iron melt may require inoculation with a graphite promoter in order that nodular iron be obtained. This is because magnesium strongly promotes the formation of cementite. If sufficient carbon in the cast iron is to be present in uncombined form, a graphite promoter, such as silicon, is commonly required. Inoculants and inoculation techniques suitable for use in combination with our method are described in the Metals Handbook, supra, at page 392.

Thus, while the prior art has, since the discovery of nodular iron, taught the use of extraneous alloying or diluting elements as a means of introducing magnesium into the molten cast iron, we have discovered a new process and form of adding magnesium which is economical and safe to use. No element not commonly found in cast iron is added and no special provision need be made to control the silicon content beyond those now required in connection with the inoculation step. Moreover, a particularly advantageous and unusually high recovery of magnesium is obtainable by means of our process which further reduces cost in comparison with prior art techniques. Because large amounts of silicon, nickel, copper, or other extraneous alloys are not added with the magnesium, the silicon content of the initial molten cast iron to be treated need not be reduced to an extremely low level. Because of the affinity of magnesium for sulfur, the magnesium itself, if desired, may be used to control the sulfur content. Thus, our method and process may be used with both a high or low sulfur content cast iron composition.

While our method is described in terms of certain specific embodiments it should be realized that the scope thereof should be limited only by the following claims.

We claim:

1. A method of treating molten cast iron compositions for the manufacture of nodular iron comprising the steps of forming a briquette consisting essentially by weight of 5% to 30% magnesium particles and the balance iron based particles, said iron based particles being of a composition selected from the group consisting of iron, cast iron and steel, and immersing a sufficient quantity of said briquettes in molten cast iron to obtain a retained magnesium content in the cast iron of about 0.035% to 0.07% by weight effective to produce the uncombined carbon in spheroidal form, said briquettes not having been exposed to an oxidizing environment for more than about three days prior to said immersion step.

2. A method as in claim 1 wherein said magnesium particles are of 4 to 60 mesh size.

3. A method of treating molten cast iron compositions for the manufacture of nodular iron comprising the steps of preparing a substantially uniform mixture consisting essentially by weight of 5% to 30% magnesium particles of 4 to 60 mesh size and the balance scrap ferrous alloy particles of a composition selected from the group consisting of cast iron and steel, said ferrous alloy being of a quality and composition ordinarily suitable for remelt in the production of cast iron or steel, compressing said mixture into a briquette whereby a dense mechanically bonded alloy of said iron and said magnesium is formed, and immersing a sufficient quantity of said briquettes in said molten cast iron to obtain a retained magnesium content in the cast iron of about 0.035% to about 0.07% by weight effective to produce the uncombined carbon in spheroidal form, said briquettes not having been exposed to an oxidizing environment for more than about three days prior to said immersion step.

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