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Heine et al.

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[54] **NODULAR IRONS AND METHOD FOR CONTROLLING SAME**

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[58] **Field of Search** ....75/123 CB, 123, 130

[56] **References Cited**

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[57] **ABSTRACT**

Method for controlling number of nodules per unit volume in malleable and ductile irons by the incorporation of both titanium and tellurium as essential components in the range of 0.003 to 0.05 percent by weight titanium with the tellurium being present in the ratio of 1 part by weight tellurium to 10 to 50 parts by weight titanium. Titanium may be replaced in whole or in part with equivalent amounts of niobium, vanadium, or aluminum. Tellurium may be replaced in whole or in part with equivalent amounts of antimony or rare earth metals.

7 Claims, No Drawings

NODULAR IRONS AND METHOD FOR CONTROLLING SAME

This invention relates to the preparation of cast irons having improved graphitization characteristics and it relates more particularly to malleable and ductile or nodular cast irons in which the number of nodules or spheroid count is increased without formation of excessive carbide or deleterious graphite.

Since the first announcement of nodular cast iron as an industrial product in 1948, extensive researches and developments have been conducted to establish the principles which cause graphite to occur in spheroidal or flake-like shapes in cast irons, the effects thereof, and the means and methods by which such spheroidal or nodule forms of graphite can be controlled from the standpoint of their number and size for producing a desired cast iron product.

In our recent publication in Transactions Quarterly, Vol. 56, No. 1, published in March 1963 (pages 135–152), and entitled "The Solidification of Cast Iron with Spheroidal Graphite," which article is incorporated herein by reference, description is made of our studies on both hypo- and hyper-eutectic flake and spheroidal cast irons from the standpoint of temperature - time sequence of phases nucleated and growing in flake and spheroidal iron solidification, and the role of magnesium, which has become an accepted ingredient for influencing graphite spheroid or nodular formation in cast irons.

By way of generalization, in the production of commercially desirable malleable and ductile cast irons, it is sought to produce a cast iron having a high nodule count without introducing deleterious graphite or forming flake graphite mottling. As pointed out in U. S. Pat. No. 3,155,498, the formation of numerous large, free primary graphite flakes in grey iron castings interrupts the matrix in such a manner that any applied stresses are resisted by small areas of the matrix between the graphite flakes. These areas are usually of insufficient strength to resist large concentrations of stresses and are bridged quite readily by these stresses, thus rendering the castings brittle and susceptible to fracture by applied static or dynamic forces.

Conversion of the graphite to nodular or spheroidal free primary graphite in ductile or malleable irons tends to increase the strength and ductility of the castings. Under current commercial processing conditions, malleable irons normally develop 80–120 nodules during the malleabilizing — annealing process and a similar number of nodules are developed during normal processing and solidification of ductile iron.

In the manufacture of malleable cast iron, it is known that an increase in the number of nodules allows for annealing of the casting at lower temperature or in a shorter time and consequent decrease in casting warpage, all of which adds up to a greater economical benefit. To the present, such increase in the number of nodules has generally been achieved with corresponding increase in the formation of deleterious graphite and increase in primary graphite flake mottling, or in alignment of nodules and a decrease in strength.

In nodular iron, the number of spheroids or nodules controls the solidification process in that a fully nodularized structure will not be obtained if there is an insufficient number of nodules. Deleterious graphite, carbides and harmful segregation, all of which interfere with the quality of iron, occur when the nodule number is too low.

Thus it is an object of this invention to produce and to provide a method for producing malleable and nodular cast irons having increased spheroidal graphite or nodule count without corresponding increase in the formation of deleterious graphite or primary graphite flake mottling, or carbides in the case of ductile iron.

More specifically, it is an object of this invention to provide a means and method for controlling the number of sites of nucleation of graphite and the graphitization process in ductile and malleable irons.

The invention will be described with reference to iron melts having a nominal composition of 2.0 – 3.0 percent carbon and 1.30 – 2.30 percent by weight silicon together with normal amounts of manganese, phosphorus and sulphur in malleable cast iron and 1.5 – 3.5 percent silicon and 3.3 – 4.0 percent carbon and normal amounts of other elements, and additional amounts of magnesium to cause graphite spheroids to develop during the solidification process in ductile cast irons, as described in U. S. Pat. No. 2,675,308 and in our aforementioned article. It will be understood that the amount of carbon can vary quite widely in these high carbon irons, such as from a minimum of 2.0 percent to an upper range of 4.0 percent and that others of the ingredients including silicon, manganese, phosphorus and sulphur can vary within the amounts commercially employed in malleable cast iron and the additional magnesium in ductile cast iron.

It has been found that the number of nodules can be increased to a range above 80 and up to 1,000 and preferably to within the range of about 150 to 500 to produce a malleable iron which solidifies without undesirable primary flake graphite mottling while developing the desired number of nodules per square millimeter upon annealing, or to produce a ductile iron having the desired noduler count without the formation of deleterious graphite or excessive carbides when, in accordance with the practice of this invention, the iron is formulated to contain the combination of titanium in an amount within the range of 0.003 to 0.05 percent by weight and tellurium in the ratio of 1 part by weight tellurium to 10–50 parts by weight titanium, and preferably 0.005 to 0.05 percent by weight titanium with the same ratio of tellurium.

With malleable iron, the titanium can be introduced in the desired amounts, either as a part of the charge fed to the melting furnace or by addition to the iron after it has been reduced to the molten state. It can be added as elemental titanium but preferably as a master alloy of titanium or as titanium-bearing pig iron. The tellurium is added in the desired amounts to the molten iron after the titanium has been incorporated and preferably as the molten metal is being readied for tapping or pouring. The tellurium can also be added to the furnace charge either as elemental tellurium, or as a copper - tellurium alloy, or as a master alloy, or in other forms. Also, if desired, the titanium and tellurium may be added to the furnace charge as a master alloy of titanium and tellurium.

It would be the normal order, in practice, to add the titanium in the melting process and the tellurium in the tapping process.

The following example is given by way of illustration, but not by way of limitation, of the practice of this invention with malleable iron composition:

EXAMPLE 1

2.50 – 3.10 percent by weight carbon
1.35 – 2.35 percent by weight silicon
up to 0.65 percent by weight manganese
0.02 – 0.20 percent by weight sulphur
up to 0.1 percent by weight phosphorus
0.015 – 0.03 percent by weight titanium
0.0005 –0.002 percent by weight tellurium balance iron

The materials other than tellurium are reduced to molten state, usually at a temperature of 2,650° F. and above, and during the tapping, a master alloy of tellurium is introduced to incorporate the tellurium in an amount of 0.0005 percent by weight.

The amount of titanium and tellurium is balanced to yield a malleable iron that solidifies without the characteristic flake graphite mottling and to yield 200–400 nodules per sq.mm. upon annealing. The malleable iron can be annealed at a lower temperature within the range of 1,550° to 1,700° F.

With ductile iron, it is preferred to make use of magnesium to cause graphite spheroids to develop during the solidification process or during annealing. The titanium and tellurium components can be introduced in the same manner previously described with reference to malleable irons and in corresponding amounts, as illustrated by the following example:

EXAMPLE 2

2.50 – 4.00 percent by weight carbon
1.10 – 3.00 percent by weight silicon
up to 0.60 percent by weight manganese
less than 0.06 percent by weight sulphur
0.02 – 0.06 percent by weight magnesium
0.005 – 0.02 percent by weight titanium
0.0005–0.001 percent by weight tellurium balance iron

EXAMPLE 3

3.70 percent by weight carbon
2.40 percent by weight silicon
0.50 percent by weight manganese
0.02 percent by weight sulphur
0.05 percent by weight magnesium
0.015 percent by weight titanium
0.0005 percent by weight tellurium balance iron

The materials other than the titanium and tellurium are reduced to a molten state at a temperature of 2,600° F. or above. First a master alloy of titanium is added to introduce 0.0045 percent by weight titanium and then, as the molten metal is tapped, addition is made of a master alloy of tellurium to incorporate 0.00045 percent by weight tellurium.

The combination of titanium and tellurium, in the amounts described, is effective to develop 400–800 nodules without formation of deleterious graphite during solidification.

In the foregoing examples, the titanium can be replaced in whole or in part with equivalent amounts of niobium, vanadium, or aluminum, and the tellurium can be replaced in whole or in part with equivalent amounts of antimony or rare earth metals. While not equivalent to titanium and tellurium, such other metals are capable of controlling nodule nucleation and formation to yield malleable or ductile irons with the higher levels of nodule count and without mottling or formation of deleterious graphite.

It will be understood that changes may be made in the details of formulation and operation without departing from the spirit of the invention, especially as defined in the following claims.

We claim:

1. The method of controlling nodule formation in malleable or ductile irons comprising incorporating both titanium and tellurium as essential elements in the iron while in a molten state to provide an iron containing titanium within the range of 0.003 to 0.05 percent by weight and tellurium in the ratio of 1 part by weight tellurium to 10 to 50 parts by weight of titanium to produce a cast iron having a nodular count of more than 200 up to 1,000.

2. The method as claimed in claim **1** in which the titanium is present in an amount within the range of 0.005 to 0.05 percent by weight.

3. The method of controlling nodule formation in malleable and ductile irons comprising incorporating into the iron while in a molten state, a metal selected from the group consisting of niobium, vanadium and aluminum in an amount within the range of 0.003 to 0.05 percent by weight and another metal selected from the group consisting of antimony and rare earth metals in the ratio of 1 part by weight of said other metal to 10 to 50 parts by weight of the first metal.

4. A malleable cast iron containing the combination of titanium and tellurium with the titanium present in an amount within the range of 0.003 to 0.05 percent by weight and tellurium in the ratio of 1 part by weight tellurium to 10 to 50 parts by weight of titanium and in which the malleable cast iron has a nodule count of more than 200 up to 1,000 without flake graphite mottling.

5. A malleable cast iron as claimed in claim **4** in which the titanium is present in an amount within the range of 0.005 to 0.05 percent by weight and in which the number of nodules is within the range of 200 to 500.

6. Ductile cast iron containing the combination of titanium and tellurium with the titanium present in an amount within the range of 0.003 to 0.05 percent by weight and tellurium present in the ratio of 1 part by weight tellurium to 10 to 30 parts by weight titanium and in which the ductile iron has a nodule count within the range of 200 to 1,000 without deleterious graphite or excessive carbides being present.

7. Ductile cast iron as claimed in claim **6** in which the titanium is present in an amount within the range of 0.005 to 0.05 percent by weight and in which the number of nodules is within the range of 200 to 500.

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