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MALLEABLE IRON WITH BORON AND
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5 Claims. (Cl. 75-123)

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This invention relates to the production of blackheart malleable iron, and, more specifically, it relates to a means for extending the range of usefulness of this material, making the resultant iron suitable for a greater range of thickness of section in malleable iron castings.

At the outset, it should be understood that in iron foundries the descriptive name "white iron" is common terminology for castings having a silvery fracture. In the manufacture of malleable iron product, white iron castings are first produced and subsequently said castings are made malleable by suitable heat treatment termed annealing. In order to secure good strength and toughness after annealing, it is essential that all of the carbon present in the white iron should be in the combined form. Free carbon present in the white iron is termed primary graphite, and it causes a fracture of the iron to appear mottled or gray, and is especially detrimental to the quality of malleable iron castings. The presence of primary graphite in the white fracture is governed not only by the composition of the iron but also by the thickness of the cast section of the castings ultimately formed. Heavy or thick section castings of desired carbon content particularly are difficult and critical to produce because the slow cooling during solidification of thick sections may result in precipitation of primary graphite in the cast material.

High carbon malleable iron is less suitable for heavy section castings than iron of lower carbon content. Of the elements other than carbon present in the iron and affecting its characteristics, and also limiting its use for thick sections, the element silicon is of primary importance. Silicon is termed a graphitizer; it tends to precipitate graphite in the as cast structure as the casting cools after pouring. Thus, an excess amount of silicon will cause the fracture of white iron castings to be either mottled or gray. Other elements recognized by the art as graphitizers, similar in effect to silicon, include aluminum, barium, calcium, copper, lithium, magnesium, nickel, potassium, sodium, titanium, and zirconium. On the other hand, elements which tend to whiten the fracture of malleable iron or stabilize the carbon in combined form are known to the art as carbide stabilizers and include the elements antimony, boron, cerium, chromium, manganese, molybdenum, selenium, sulfur, tellurium, bismuth, tungsten, and vanadium.

The art further teaches that the effects and functions of various graphitizers and carbide stabilizers may be quite different; thus, their use is

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limited to specific applications, and for this reason, they cannot be freely substituted one for the other as a simple matter of choice.

Most graphitizers tend to facilitate the annealing of white iron by accelerating the precipitation of graphite nodules termed "temper carbon" in the breakdown of carbides present, thus changing the fracture of the iron from white to dark gray or black. Silicon, for example, besides being a strong graphitizer of the white iron, also is a potent accelerator of graphitization during annealing. Temper carbon appears in the annealed iron in form of nodules in distinction to primary graphite, which is flaky. This difference in the shape of temper carbon and of primary graphite largely governs the physical properties of the iron.

Most whiteners of the cast structure (carbide stabilizers) tend to retard the precipitation of temper carbon in annealing. Some strong retarders of graphitization, for example, chromium, are carefully guarded against in the making of blackheart malleable products as their presence, even in small amounts, may prolong the time required for annealing of the iron and result in reduced machinability of the castings. Not all carbide stabilizers, however, act as retarders of graphitization in annealing. Boron, for example, although being a carbide stabilizer, nevertheless functions as an accelerator of graphitization in the annealing of malleable iron when present in minute amounts below about 0.1%.

The use of carbide stabilizers in minute amounts in the processing of blackheart malleable iron castings in order to alter the characteristics of the iron is known to the art. Minute amounts of tellurium, for example, act as a potent whiteners of the cast material. The retarding effect of tellurium in annealing can be overcome by additions of silicon and the coarse temper carbon distribution resulting from the presence of tellurium can be modified by additions of copper to the iron. Bismuth similarly is a strong whiteners of the iron in the as cast condition. The addition of silicon to bismuth treated iron also offsets the retarding effect of bismuth on graphitization in annealing.

The addition of tellurium together with silicon to iron of high carbon content or iron of critically balanced carbon-silicon ratio, however, has proved to be impractical in actual practice. On the basis of this finding, the use of tellurium together with boron was developed as covered by U. S. Patent Number 2,450,395, dated September

28, 1948, and the present invention may be considered an improvement over this patent.

The present invention relates to the use of a minute addition of boron together with bismuth to blackheart malleable iron, thus achieving characteristics and improvements as to usefulness and acquiring properties not heretofore known to the art. Bismuth, being a somewhat less potent carbide stabilizer than tellurium, when used together with boron produces effect of less critical proportions as compared to those obtained from the use of tellurium together with boron. Tellurium-boron treated iron, for example, is very susceptible to decarburization that often results from annealing malleable iron castings. Tellurium-boron treated iron for this reason cannot be annealed satisfactorily in decarburizing packing material because the effect of the decarburization is to form thick steely rims which make the iron non-machinable. Bismuth-treated iron exhibits similar characteristics although of somewhat less critical nature than tellurium; nevertheless, bismuth-treated iron cannot be satisfactorily annealed in decarburizing packing material as the decarburization produces steely rims which objectionably affect the machinability of the iron.

One of the more important objects of this invention is to overcome the foregoing undesirable characteristics developed in tellurium-boron and bismuth-treated iron when exposed to decarburizing conditions. It has been found that by adding minute amounts of boron together with bismuth to the iron, the undesirable effect from decarburization referred to is eliminated. Bismuth-boron treated malleable products thus can be annealed in decarburizing packing material resulting in greatly improved strength and ductility over those of iron annealed without packing, besides possessing more desirable machining properties. The following table shows, for example, comparative properties obtained on annealed test bars, the cupola malleable iron being annealed in oxidizing packing:

Bismuth Treated Bars				Bismuth-Boron Treated Bars			
Tensile Strength ¹	Yield Point ¹	Per Cent Elong. in 2"	Fracture	Tensile Strength ¹	Yield Point ¹	Per Cent Elong. in 2"	Fracture
51,800	40,200	7.0	Steely rim...	49,100	39,400	11.5	O. K.
54,000	40,200	7.0	-----do-----	49,800	38,800	12.5	Do.
51,400	41,200	6.5	-----do-----	50,400	41,000	12.0	Do.
51,400	41,400	6.0	-----do-----	50,200	39,500	13.0	Do.

¹ Lbs. per square inch.

Another object of the invention resulting from the use of boron is to offset the retarding effect of bismuth on graphitization in annealing, thus appreciably reducing the time otherwise required to complete the anneal.

The use of boron together with bismuth further extends its range of usefulness by making an iron suitable for castings having thicker sections than would be possible without the use of bismuth together with boron.

As stated, boron, like bismuth, is a carbide stabilizer. Thus property exhibited by boron is

extremely important, particularly in regard to its use in high carbon iron or iron of critically balanced carbon-silicon ratio. It has been found that the use of graphitizers, such as silicon together with bismuth in this type of iron is not practical, as the potent graphitizing action of silicon on the white iron tends to precipitate primary graphite, particularly in thick sections, thus rendering the material unsuitable for use in producing malleable iron castings.

Production test runs using silicon together with bismuth addition to high carbon white iron have proven that the silicon added for the purpose of accelerating the anneal renders the carbon-silicon ratio too critical in the white iron, thereby resulting in mottled or gray fracture castings, particularly where heavy sections are employed. Boron, in contrast to silicon, functions as a whitener of the as cast structure. Boron further acts as an accelerator in annealing, thus greatly reducing the amount of time required to complete the annealing operation. The use of boron together with bismuth in irons referred to thus assures improved quality control.

Another benefit resulting from the carbide stabilizing properties of boron is greater economy. Although they are comparatively expensive elements, both boron and bismuth are effective when present in very small amounts, thus appreciably lowering the production costs ordinarily resulting from the use of these additions. Small additions of these elements are less likely to affect the normal characteristics of the iron, and for this reason are deemed more desirable. The retarding effects on graphitization in annealing produced by large bismuth additions, for example, require an increase in the amount of boron added.

Large boron additions, particularly in high carbon irons, however, tend to cause precipitation of temper carbon in a dendritic arrangement detrimental to the mechanical properties

of the iron. The amount of bismuth added depends on the iron to be treated and the improvement to be accomplished, that is, for example, the thickness of the section which is to be cast. The addition of boron varies in proportion to the bismuth; as a rule, the boron addition is appreciably less than the amount of bismuth added. For general application, the boron addition is maintained roughly equal to about one-fifth of the amount of bismuth added.

The range of analysis (in per cent) of our overall improved malleable iron is:

Carbon	Silicon	Manganese	Bismuth	Boron
2.25 to 3.25	.60 to 1.60	.30 to .70	.002 to .025	.0005 to .01

while a typical working range analysis has been found to be (in per cent):

Carbon	Silicon	Manganese	Bismuth	Boron
2.25 to 3.25	.60 to 1.20	.30 to .70	.002 to .015	.001 to .005

In summary, our invention covers the addition of two carbide stabilizers to the iron and results in improvement in the properties of the annealed malleable iron product as described, one of the carbide stabilizers functioning as an accelerator of graphitization in the annealing process.

It should be understood that modifications or changes in the invention, however, may be made without departing from the principle or spirit of the invention as set forth in the appended claims.

We claim:

1. An annealable white iron casting comprising carbon approximately 2.25 to 3.25%, silicon .60 to 1.60%, manganese .30 to .70%, the remainder being substantially iron and small but effective amounts of the carbide forming elements bismuth and boron to prevent the formation of primary graphite during solidification, the boron accelerating the decomposition of iron carbide during annealing, thereby offsetting the retarding effect of bismuth in the graphitization of the malleable iron.

2. A white iron casting of relatively thick section substantially free from primary graphite and readily annealable to produce malleable iron containing approximately 2.25 to 3.25% carbon, .60 to 1.20% silicon, .30 to .70% manganese, and small but effective amounts of bismuth ranging up to .025% and up to .010% of boron to prevent the formation of primary graphite during solidification, the boron facilitating the decomposition of carbides during annealing, thereby offsetting the retarding effect of bismuth in the graphitization of the iron.

3. An annealable white iron casting of relatively heavy section and substantially free from primary graphite, containing at least 2.25% carbon, at least .60% silicon, at least .30% manganese, and small amounts of carbide forming elements bismuth and boron to prevent separation of free graphite during solidification, the said amounts being about .002 to .025% bismuth and .0005 to .005% boron, the relative amounts

of bismuth and boron being proportioned so that accelerating effect of boron in the decompo-

sition of carbides during annealing offsets the retarding effect of bismuth in the graphitization of malleable iron.

4. A white iron casting of relatively heavy section and substantially free from primary graphite composed of following essential components: carbon 2.25 to 3.25%, silicon .60 to 1.20%, manganese .30 to .70%, the remainder being substantially iron and small but effective amounts of bismuth from .002 to .025% and boron from .0005 to .005% of the mixture, the latter combined amounts being sufficient to obstruct the formation of carbon in the free form during solidification and being so proportioned that the accelerating effect of the boron in the decomposition of carbides offsets the retarding effect of bismuth in the annealing of the iron to produce malleable iron.

5. The process of making malleable cast iron articles of relatively heavy sections comprising casting a mixture containing about 2.25 to 3.25% carbon, .60 to 1.60% silicon, .30 to .70% manganese, and the balance being substantially iron in the presence of small but effective amounts of bismuth ranging from .002 to .025% and of boron from .0005 to .005% of the total, the said amounts being sufficient to prevent the formation of carbon in free form during solidification thereby to produce a white cast iron article, and then annealing the article under conditions to cause separation of substantially all of the carbon as temper carbon.

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The following references are of record in the file of this patent:

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