

UNITED STATES PATENT OFFICE

2,622,022

METHOD FOR PRODUCING CAST IRON

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No Drawing. Application July 31, 1948,
Serial No. 41,906

8 Claims. (Cl. 75—130)

1

This invention relates to cast iron, and more particularly to a new cast iron, and the production thereof, which when cast produces finished cast iron or castings which are markedly different in characteristics from the cast irons as heretofore known such as so-called "gray iron," "malleable iron" and "white iron."

One of the principal objects of this invention is to provide a molten iron mix which in the molten state is such that the addition of small quantities of selected materials, as in the ladle before pouring into the mold, will produce this new iron of characteristics widely differing from the long and widely known gray irons, also from the white iron castings long produced to have such characteristics that upon heat treatment or annealing they will become the so-called malleable irons, and also from the malleableized irons which result from the annealing or heat treatment of white iron castings.

Another object of the invention is to produce such new iron, and castings of desired form, directly, as by the pouring into the mold with subsequent solidification on cooling, and without the necessity of the expensive annealing which is required to make white iron castings into the usual malleableized castings.

Still another object of the invention is to provide a method in the production of such molten iron mixes and the forming of castings thereof to produce the new iron product.

Other objects and advantages will be apparent from the appended description and the claims.

So-called gray iron, as castings of finished characteristics when removed from the mold, and malleable iron produced by making castings of a white iron mix and then subjecting the casting to the long and expensive annealing treatment have long been known in the iron foundry industry. It has also been long recognized that in the making of gray iron castings the constituents and the relative proportions thereof which are present in the molten iron mix (which may be controlled by determining the proportions which are admixed before melting to form the molten gray iron mix) must be such that when the molten gray iron is poured into the mold and is allowed to cool, most of the carbon which is present in the mix will separate so that in the finished casting it will be in flat or flake-like form, of varying dimensions. This flat or flake-like graphite carbon, produced by the presence of the constituents in such proportions that at least one of them has what is called a graphitizing effect to separate

2

most of the carbon as the flat or flake-like graphitic carbon, is universally recognized as being characteristic of so-called gray iron castings. Such a casting, in fracture, has an irregular surface which appears as of a definitely gray color, due in part at least to the effect of the flake graphite with respect to the reflected light, which is characteristic; hence its designation as "gray iron."

On the other hand, it is equally well recognized that for the production of "malleable" iron which has generally greater strength than gray iron and also is ductile and is capable of considerable elongation under tension or of bending, the castings must be produced from constituents which are such and the proportions of which are such, that when the molten iron mix is poured into the mold and allowed to cool the resulting casting will be free from the flake-like graphitic carbon described above in connection with gray iron. The presence of any appreciable quantity of flake-like graphitic carbon in the iron as cast will render a seemingly white iron casting useless for the production of malleable iron, as the graphitic carbon in malleable iron is that which is formed during the heat treatment from combined carbon, or iron carbides, and if graphitic carbon is in the casting as removed from the mold, in any appreciable quantity, the subsequent heat treatment or annealing will not change the inherent characteristics of the casting to give it those characteristics which are essential for so-called malleable iron. Such a casting, free from graphitic carbon as cast, in fracture appears white or a very silvery gray, and the appearance of the fracture of such a white iron casting is so markedly different from the appearance of the fracture of a gray iron casting, due to the differences in light reflection that the white or silvery gray appearance from such castings has led to the designation of "white iron." Such castings, are so extremely hard with respect to the usual machining operations, etc., that they are produced (except perhaps for some special end use) only because the inherent characteristics are such that upon the proper heat treatment or annealing the iron carbides break down and form free carbon; but in such circumstances the characteristics of the casting cause the resulting graphitic carbon to appear as so-called "nucleus." That is, the usual malleable annealing operation causes a breaking down of the iron carbides to form free carbon but not in the form of the flat or flake-like graphite which occurs in gray iron castings. Generally the car-

bon or graphite as separated from the carbides during anneal of a white iron casting appears as so-called "nodules" or "temper carbon," the carbon after such anneal being separated and distributed as generally spherical or nodular as observed under the microscope or in photomicrographs.

The present invention has to do with the production of a new form of iron in which the finished casting is made from an iron mix which would be generally close in constituents and proportions to the mixes which have long been used in the gray iron foundry industry. By the addition of small quantities of certain other constituents to the molten mix, an iron casting is produced which has free graphitic carbon appearing in the casting but such that there is substantially no flake-like graphitic carbon of typical gray iron described above formed while the casting is being made. The separated or graphitic carbon is in nodular form which in size and distribution and regularity of shape is comparable with the nodules of carbon in malleableized white iron.

This invention, therefore, has produced a new cast iron, which in its cast form and without any annealing or other treatment, has free, separated carbon but with the carbon in nodular form and as these nodules are small and discontinuous they interrupt the iron matrix which gives the real strength to the casting much less than is the case with ordinary gray cast iron with its flake-like graphitic carbon and therefore the castings as produced have much greater strength under the impact or shock test and also under the standard transverse test. The tensile strength of this new iron is much above that of ordinary gray iron castings and good grades of malleableized iron castings. As a fair comparison the tensile strength of this new iron is upward of 70,000 lbs. per square inch, and satisfactory castings have been produced with tensile strength of approximately 90,000 lbs. per square inch whereas the higher grade malleableized castings have tensile strength up to about 53,000-55,000 lbs. per square inch, and ordinary gray iron castings have tensile strengths varying widely from under 20,000 lbs. up to 45,000 lbs. per square inch. The iron, however, is not ductile or subject to elongation under tension as is the case with malleableized iron nor has it any substantial capacity for bending, which is true, of course, of malleable iron which can be given a considerable bend without fracture or breaking. In this so-called shock or impact test, a test bar of iron has one end held in a vise, or some other equivalent mechanism, and the other end is struck with a pendulum in a precision machine for such impact testing, in which a free swinging pendulum of given weight and length is elevated to a predetermined height and released. The impact measurement is determined by a scale calibrated to show the foot pounds of energy absorbed to break the test casting. This new iron has a shock or impact test which is far in excess of that of a comparable cross-section gray iron casting. The impact test on a comparable cross-section malleableized white iron casting may be of no import, because of the bending characteristics of malleable iron.

Thus an entirely new iron is made available in cast form, of these characteristics, which gives it great superiority over ordinary gray iron in the respects mentioned, in that it has a high shock or impact test and therefore can withstand shocks or blows in use which would be completely de-

structive of gray iron. It also has characteristics in certain respects which are superior to the malleableized white iron casting in that the greater tensile strength as stated above and the impact and transverse strength of the iron permits it to withstand shocks which might cause bending or distortion of a malleableized casting.

In the practicing of the invention it has been found that small proportions of magnesium, when introduced into a molten pig iron mix having constituents within the range of proportions set out below, will result in the production of castings, which when completed and taken from the mold, will have the nodular form of graphitic carbon and with the various characteristics above referred to. The character of magnesium is such, however, that it cannot safely be added as metallic magnesium to the molten iron mix as violent reactions will occur. In fact, in most forms of alloyed magnesium its reactivity is so great that it is too dangerous to use. However, if the magnesium is alloyed with copper, the resulting alloy can be safely used in the practicing of the present invention. The copper does not adversely affect the formation of the nodules of graphitic carbon which are produced by the action of the magnesium and it is comparatively cheap and therefore does not materially affect the cost of the casting.

Very satisfactory nodular graphite castings of the new iron have been produced using a copper magnesium alloy containing 90% of copper and 10% of magnesium. While such an alloy is still quite active in the molten iron due to the presence of magnesium, it can be readily prepared and safely used in the practicing of the invention. Copper magnesium alloys within the range of copper 90 to 95% and magnesium 5 to 10% have been found satisfactorily useable, such alloy being added originally in the range of about .1% to .2% of magnesium on the mix. Additional alloy may be added for longer pouring periods as set out below.

While magnesium as thus alloyed with copper gives highly satisfactory results, and magnesium seems to have a great activity or effect in causing the formation of the nodules of carbon, its great activity presents the problem of more careful handling than is the case when magnesium is alloyed with other materials hereinafter described. The use of an alloy consisting predominately of copper with relatively small quantities of magnesium and misch metal has been found thus far to give highly satisfactory results in operation, having in mind the various factors mentioned above. Such an alloy containing approximately 85% copper, 10% magnesium and 5% misch metal gives a new iron casting with the desirable characteristics referred to and with the nodules of graphitic carbon as formed in the iron while the casting is being produced in the mold being not only nodular but of a high degree of uniformity of dimensions of the nodules.

A copper, misch metal, magnesium alloy has been found satisfactorily useable within the ranges:

	Per cent
Copper	78-90
Magnesium	15-7
Misch metal	7-3

and satisfactory results have been secured with the addition of about 1% to 2% of such alloy, depending upon the responsiveness of the iron mix

to the new, nodular or spherical precipitation material.

While the magnesium reacts violently when it is introduced as such into molten iron, as stated above, nevertheless the magnesium can be readily and safely alloyed with copper and misch metal as the making of the alloy can be carried out in a closed crucible so that any violent reactions will be easily contained and furthermore the materials of the alloy can be added under any desired conditions as to relative quantities and rate to give the best alloying conditions.

The misch metal referred to is available commercially, the mixture being generally uniform and a byproduct of the production of thorium, and its commercial composition is approximately within the ranges set out below:

	Per cent
Cerium	45
Lanthanum	25
Neodymium and praeodymium	15
Samarium	10

An iron mix containing constituents within the following percentage ranges:

	Per cent
Carbon	3.0-4.3
Silicon	2.0-4.0
Manganese	0.4-2.0
Phosphorus	0.01-0.4
Sulphur	Less than 0.04

has been found to satisfactorily produce this new iron when the copper magnesium alloy or the copper magnesium misch metal alloy in the proportions set out above is added to the molten mix in the ladle before pouring.

It has also been found that when magnesium in some one of the alloy forms referred to, is added to the molten metal there is a comparatively short time interval during which sufficient of the magnesium or other alloy constituents such as misch metal will remain available in the molten metal to have the effect of controlling to cause the nodules of graphite carbon to be separated or precipitated in the cooling metal in the mold (or from the high temperature solid solution metal in the mold. Probably due to oxidation, or perhaps reaction of magnesium or the misch metal or both with some other materials present, the quantity introduced in the molten mix and effective to form the nodular graphitic carbon is decreased rather rapidly, the time varying inversely with respect to the temperature of the molten iron in the ladle. In practicable operations producing castings of this new iron, it has been found that the magnesium constituent of the magnesium, copper alloy and the magnesium and misch metal constituents of the copper, magnesium, misch metal alloy, in the small percentage ranges specified as effective to produce nodular graphitic carbon, will remain as such in sufficient quantity to produce the desired results for a period from about 7 to 13 minutes, after which time the production of the nodular graphitic carbon no longer occurs. If either of the above disclosed alloys is introduced into a ladle of molten iron which will be poured under such circumstances that the vitalizing reactions will not be terminated within the short period of pouring, the resulting castings will have the desired characteristics of this new iron.

It has been found, however, that if a longer period than the 7 to 13 minutes referred to is allowed to elapse before the molten iron is all poured into the mold and is in such condition of

cooling that the nodular graphite is not produced, the adding of small additional quantities of the magnesium, copper, or the copper, magnesium, misch metal alloy described will compensate for so much of the active material of the alloy as may have been lost through oxidizing, or the like, will restore the effectiveness of these materials to produce the new nodular graphite iron after the 7 to 13 minutes period stated. The disclosed alloys seem to have a stabilizing effect in the molten iron against graphitic precipitation. When the small amounts of such alloys as referred to above are introduced into the molten iron mix the molten iron should be poured within a period of from about 7 to 13 minutes and unless this is done, it is found that the amount of effective alloy material that is available to cause nodular carbon to appear is diminished so that the alloy is no longer effective to form nodular carbon as desired. If the amount of such alloys added to the molten mix is increased too much it not only has a stabilizing effect in the molten iron but also inhibits the breaking down of the carbides after the iron becomes solid which in turn may inhibit the formation of nodular carbon.

It has been found however that when additional amounts of these alloys are added into the ladle to prolong the pouring period, the inhibiting effects against the carbides breaking down in the solidified metal can be overcome provided a small percentage of an active graphitizing agent is added along with such alloys. For example satisfactory results have been secured where the amount of the alloy which is added is increased after this 7 to 13 minute period by the addition of about .5% on the mix, and at the same time 0.20% of a strong graphitizing agent such as calcium silicide was added, and under these conditions it was possible to increase the time of pouring and at the same time maintaining the stabilizing effect against graphitic precipitation and allowing the carbides to separate and form nodular carbon. Not only does the addition of the nodular forming metal or metals or alloys thereof build up the nodule forming characteristics to approximately the original effectiveness but when added along with a small percentage of the graphitizing agent the period during which this nodule forming graphitization will still take place is quite considerably increased, to as much as the 7 to 13 minutes of the original addition which in most cases will be ample for commercial foundry practices. To assure ample time for satisfactory operations over 20 to 26 minutes, however, it may be found desirable to add a second addition of about 0.5% of the alloy materials, and a second corresponding addition of about 0.2% of a strong graphitizing agent and a satisfactory casting of the nodular containing iron will thus be assured within the maximum time mentioned and without inhibiting the decomposition of the iron carbides.

While the process and product herein described constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to this precise process and product, and that changes may be made therein without departing from the scope of the invention which is defined in the appended claims.

What is claimed is:

1. The method of producing iron castings of the character described having in the as-cast state and without subsequent annealing free graphitic carbon therein present in nodular form and with substantially no precipitation of flake-

like graphitic carbon which comprises the steps of preparing a molten gray iron mix which on casting gives a gray cast iron and comprising about 3.0% to 4.3% carbon, about 2.0% to 4.0% silicon and less than 0.04% sulphur, adding to said mix before casting about 0.07% to 0.3% magnesium and about 0.014% to 0.063% cerium effective to control precipitation of graphitic carbon into said nodular form during graphite precipitation in said mix, and casting said mix while said added magnesium and cerium remain effective therein as the sole essential added materials to control said graphite precipitation into said nodular form.

2. An iron casting of the character described comprising a gray iron composition substantially free of flake-like graphitic carbon normally present in gray iron castings and having in the as-cast state graphitic carbon present substantially entirely in nodular form, said casting having been produced in accordance with the process of claim 1.

3. The method of producing iron castings of the character described having in the as-cast state and without subsequent annealing free graphitic carbon therein present in nodular form and with substantially no precipitation of flake-like graphitic carbon which comprises the steps of preparing a molten gray iron mix which on casting gives a gray cast iron and comprising about 3.0% to 4.3% carbon, about 2.0% to 4.0% silicon and less than 0.04% sulphur, adding to said mix before casting about 0.07% to 0.3% magnesium and about 0.03% to 0.14% misch metal effective to control precipitation of graphitic carbon into said nodular form during graphite precipitation in said mix, and casting said mix while said added magnesium and misch metal remain effective therein as the sole essential added materials to control said graphite precipitation into said nodular form.

4. The method according to claim 3 in which said magnesium and misch metal are added in the form of an alloy including copper as a carrier.

5. The method according to claim 3 in which said magnesium and misch metal are added in the form of an alloy comprising 7% to 15% magnesium, 3% to 7% misch metal and the balance copper as a carrier for said magnesium and misch metal.

6. The method of producing iron castings of the character described having in the as-cast state and without subsequent annealing free graphitic carbon therein present in nodular

form and with substantially no precipitation of flake-like graphitic carbon which comprises the steps of preparing a molten gray iron mix which on casting gives a gray cast iron and comprising about 3.0% to 4.3% carbon, 2.0% to 4.0% silicon and less than 0.04% sulphur, adding to said mix before pouring about 0.07% to 0.3% magnesium and about 0.014% to 0.063% cerium effective to control precipitation of graphitic carbon into said nodular form during graphite precipitation in said mix, and pouring said mix within about 7 to 13 minutes of said addition and while said added magnesium and cerium remain effective therein to control said graphite precipitation into said nodular form and concurrently inhibit flake graphite formation.

7. An iron casting of the character described comprising a gray iron composition substantially free of flake-like graphitic carbon normally present in gray iron castings and having in the as-cast state graphitic carbon present substantially entirely in nodular form, said casting having been produced in accordance with the process of claim 6.

8. The method according to claim 6 in which a second addition of magnesium and cerium is made to said mix before said pouring thereof is completed for extending the effectiveness of said added materials in said mix to control said graphite precipitation into said nodular form throughout the pouring period.

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