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METHOD OF PRODUCING PEARLITIC CAST IRON

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Fig. 1.



Fig. 2.



Fig. 3.



Fig. 4.



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METHOD OF PRODUCING PEARLITIC CAST IRON

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This invention relates to the production of gray cast iron of essentially pearlitic structure and has for its object the production of castings of great strength, moderate Brinnell hardness, uniformity of structure, great resistance to frictional wear and abrasion and great stability of metallographic structural constituents at ordinary and elevated temperatures.

A normal good gray cast iron has the following chemical analysis:

Carbon	3.25% to 3.75%
Silicon	2.00% to 2.50%
Sulphur	.07 maximum
Phosphorus	.70 maximum
Manganese	50% to 90%
Balance iron except small percentages of impurities.	

When an iron of such an average analyses is in the molten condition, the entire carbon content is in solution in the iron. When the molten iron is cast into a sand mould and begins to solidify, a portion of the carbon present is precipitated from combination with, or solution in, the iron into the free or graphitic condition, the balance remaining in combination with the iron as carbide of iron.

If this molten iron be cast into a sand mould and allowed to cool normally in the sand with no artificial acceleration or retardation of the rate of cooling, it would have a graphitic or free carbon content of approximately 2.90%–3.40%.

Microscopic examination of the above mentioned iron would reveal a metallographic structure, in a suitably prepared and etched specimen, having essentially the characteristics as shown in Fig. 1 (approximate magnification 100). Examination of Fig. 1 shows the metal to have three structural constituents, the solid black, elongated, flakey areas, which are free or graphitic carbon, the hairlined or shaded, granular areas which are pearlite and the solid white, granular areas, which are ferrite. Pearlite is an intimate mechanical mixture of ferrite, or pure iron and cementite, the carbide of iron. The shaded areas of pearlite and the white areas of ferrite together constitute a matrix, in which the particles or flakes of graphitic carbon are imbedded in some cases crossing the grain boundaries of the pearlite and ferrite grains. From the above, it is at once apparent that such a gray cast iron as the above is in reality, steel of .35% carbon content, with particles of graphite imbedded in it.

Since graphite has practically no strength, the strength of a piece of cast iron must depend on

the matrix, which is steel; and must have properties commensurate with the general characteristics of steel, one of which is its dependence on the amount of carbon present for its strength. The combined carbon in the steel matrix of a piece of cast iron thus determines in a directly proportional manner the strength of that piece of cast iron. But since as above noted, graphite's strength is a negligible quantity, the graphite particles are detrimental to strength in direct proportion to their quantity, since they occupy space which, but for their presence, would be occupied by the stronger materials of the matrix; and they break into and disrupt the metallic continuity of the matrix. The strength of pearlite is ordinarily 125,000 pounds per square inch and the strength of ferrite is 55,000 pounds per square inch.

From the above well known facts, it is readily seen that for two pieces of iron of the same total carbon content, but with different combined carbon contents that iron with the larger combined carbon content will be decidedly the stronger. For the iron with the smaller combined carbon content will have the greater graphitic carbon content, and will have gained a greater percentage of weaker structural constituents (graphite and ferrite) by the loss of a part of the stronger constituent (pearlite).

It is broadly and generally known that if the combined carbon content of a cast iron be fixed at approximately .85%, a metal will result possessing very excellent characteristics of strength, good machinability, resilience and resistance to abrasive and frictional wear, but moderate Brinnell hardness. Such an iron will have a metallographic structure as shown in Fig. 2 (approximate magnification, 100). Referring to Fig. 2, it will be seen that there are but two structural constituents, a matrix of pearlite with finer and more evenly distributed graphite particles. Such an iron is called pearlitic and the pearlite matrix is called an eutectoid structure.

Pearlitic iron is generally considered ideal for castings which are applied to services in which they are subjected to heavy duty, impact, frictional and abrasive wear and particularly heat. An example of such service is the cylinder or cylinder liner of a locomotive or marine engine, particularly in those engines which employ superheated steam. But it is a well known fact that the precipitation of carbon from the combined to the graphitic condition does not necessarily cease in the ordinary iron or even pearlitic iron when the iron is cooled below the temperature at which

the primary precipitation of graphite occurs. If the temperature be raised to a high point though well below the melting point, for a short time, or to a much lower point, even below the critical temperature, of the iron, for an extended period of time, the solid iron carbide will decompose, forcing graphite into the precipitated free state, leaving the iron with which it was combined as ferrite. This increase in graphitic carbon content proceeds by increase in the size of the original graphite particles and by formation of new and additional particles; and it is attended by actual increase in cubical dimensions of the casting, which is due to a decrease in the density of carbon as it changes from a state of chemical combination with the iron to its free condition. In growing, we have found that cast iron is definitely and excessively weakened. By testing the transverse strength of two pieces of cast iron, poured from the same ladle full of metal, one of which was broken as cast, the other being subjected to an annealing temperature of 1450° F. for one hour before breaking, we have found that it is an ordinary expectation for cast iron to suffer the loss of half its strength by such subjection to heat. This is due to lack of stability of the combined carbon (iron carbide) of irons not provided with an effective stabilizing influence for its carbides.

We have discovered that chromium and molybdenum, due to their peculiar alloying effect, produce an iron having great strength, toughness, resilience and stability of structural constituents at elevated temperatures, together with tremendous resistance to wear at ordinary temperatures and at elevated temperatures. In our experiments, we have found that by the use of chromium, particularly in conjunction with molybdenum, which decidedly accentuates the effect of the chromium, we are able to produce a metal with great resistance to decomposition of its carbides. We have made transverse tests of pieces of our metal poured from the same heat with and without annealing by the same treatment as above described as applied to ordinary cast iron. These tests showed that our metal in no instance lost more than one tenth its strength, while as above described, ordinary iron with no agent present to stabilize the strengthening carbides, lost fully half its strength.

The fact that we utilize preferably an electric furnace for melting the material comprising the alloy permits the temperature and chemical analysis to be very accurately controlled, and also admits of the attaining of high melting and superheating temperatures, which are essential in producing a finely divided and nodular graphite in the finished product. The pouring temperatures may vary between 2500° F. and 3000° F., or these temperatures are reached and obtain sometime during the melting and refining process.

We have also found that there are certain advantages in making pearlitic iron in producing first a metal with a hypereutectoid structure, which has massive or free cementite as a structural constituent, which is decomposed and eliminated by thermal treatment of the casting after it is poured and allowed to cool to ordinary temperatures. This allows the use of wider ranges in the analyses of the metal, and eliminates the troublesome and costly methods of preheating moulds used by previous investigators. The thermal treatment referred to has another beneficial effect, which is the relief of the shrinkage strains in the casting and in consequence, warpage or

distortion of the casting during and after machining.

Thus it is an object of this invention to produce pearlitic cast iron wherein the iron during its process of manufacture is reduced to a molten condition and refined and superheated by the use of an electric furnace, or is reduced to a molten condition by the use of some other type of furnace such as a cupola, air furnace or open hearth furnace and subsequently superheated and refined by the employment of an electric furnace.

It is another object of this invention to produce a cast iron alloy containing chromium and molybdenum, and through the medium of high temperatures applied at some time during the period in which the alloy is in a molten condition, to produce in the subsequent cold iron an essentially pearlitic structure.

This application is a true division of our co-pending application, Serial No. 419,420 filed January 8, 1930 Patent Number 1,910,034 of May 23, 1933.

As an illustration of the new alloy composition, the following table sets forth the relative proportions and ingredients thereof:

	Per cent
Chromium.....	.10 to 2.00
Molybdenum.....	.01 to 2.00
Carbon.....	1.75 to 3.75
Silicon.....	.50 to 3.00
Manganese.....	.25 to 2.00

and iron approximately sufficient to make 100%, except for impurities such as phosphorus, sulphur and the like which are incidental to manufacture.

We have also secured satisfactory results from an alloy composed of the following ingredients in substantially the proportions given:

	Per cent
Chromium.....	.10 to 2.00
Nickel.....	.01 to 5.00
Molybdenum.....	.01 to 2.00
Carbon.....	1.75 to 3.75
Silicon.....	.50 to 3.00
Manganese.....	.25 to 2.00

The remainder being iron, except for impurities such as phosphorus, sulphur, etc., which are incidental to the manufacture.

Also the following ingredients in the proportions may be used:

	Per cent
Chromium.....	.10 to 2.00
Nickel.....	.01 to 5.00
Carbon.....	1.75 to 3.75
Silicon.....	.50 to 3.00
Manganese.....	.25 to 2.00
Iron approximately sufficient to make 100%.	

Another example consists in the use of the following:

	Per cent
Nickel.....	.01 to 5.00
Molybdenum.....	.01 to 2.00
Carbon.....	1.75 to 2.75
Silicon.....	.50 to 3.00
Manganese.....	.25 to 2.00
Iron approximately sufficient to make 100%.	

In the manufacture of this product, the iron may be melted in a fuel fired furnace or an electric furnace, and is subsequently alloyed, refined and superheated in an electric furnace to a temperature varying ordinarily between 2500° F. and 3000° F. This results in a metal whose final constituents are found to comprise a matrix of pearlite interspersed with finely divided even-

ly disseminated particles of graphite of nodular shape (see Fig. 4) and smaller size than those of ordinary gray (see Fig. 3) iron or even ordinary pearlitic iron. The molybdenum and chromium are provided in order to increase the stability of carbides at elevated temperatures, to raise the critical temperature at which carbide decomposition proceeds with rapidity thereby further increasing the stability of the carbides of the iron at any given temperature below said critical temperature and to strengthen and harden the matrix and increase the resistance of the metal to shock, impact, frictional and abrasive wear, fatigue and growth. For castings for special purposes, we have found the use of nickel in the percentages above specified is very advantageous due to its ability to strengthen the matrix in its pearlitic ferrite, and to add to the physical properties above described.

We prefer to use the electric furnace in melting the materials comprising this alloy for the reason that the temperature and chemical analysis may be very accurately controlled; but a cupola or other fuel fired furnace may be employed for the melting, and an electric furnace used subsequently for alloying, refining and superheating to the elevated temperatures which are essential in producing a finely divided and nodular graphite in the finished iron. As stated, these temperatures may vary from substantially 2500° F. to 3000° F., and are obtained at some time during the melting and refining process.

What is claimed is:

1. An alloy iron which has been superheated

in the molten condition at a temperature over 2550° F. containing .01% to 5.00% nickel, .01% to 2.00% molybdenum, 1.75% to 3.75% carbon, .50% to 3.00% silicon, .25% to 2.00% manganese, the remainder being iron except for impurities such as phosphorus, sulphur, etc., which are incidental to the manufacture, and having as its final constituents a matrix of essentially all pearlite interspersed with relatively finely divided particles of graphite.

2. The method of producing cast iron of pearlitic structure containing chromium, molybdenum and nickel by melting the iron in a cupola or other fuel fired furnace and alloying, refining and superheating in an electric furnace at a temperature over 2550° F.

3. An alloy iron which has been superheated in the molten condition at a temperature over 2550° F. and containing .10% to 2.00% chromium, .01% to 5.00% nickel, .10% to 2.00% molybdenum, 1.75% to 3.75% carbon, .50% to 3.00% silicon, .25% to 2.00% manganese, the remainder being iron except for impurities such as phosphorus, sulphur, etc., which are incidental to the manufacture, and having as its final constituents a matrix of essentially all pearlite interspersed with relatively finely divided particles of graphite, the chromium, nickel and molybdenum contents being sufficient to increase the stability of the carbide present at elevated temperatures.

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