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FERROUS METAL AND METHOD OF MAKING SAME

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Fig. 1

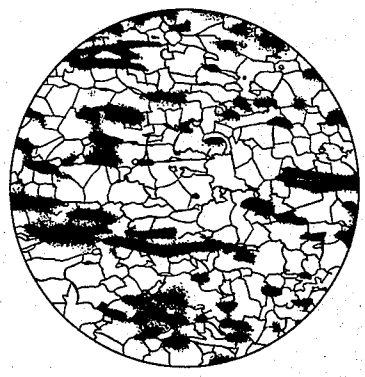
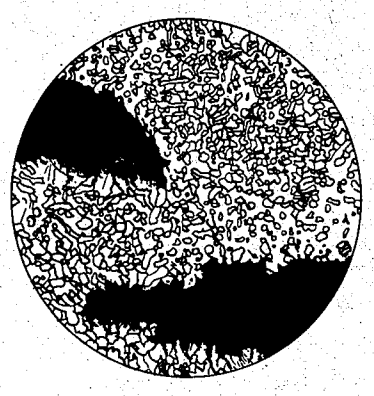


Fig. 2

Fig. 3

Fig. 4



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FERROUS METAL AND METHOD OF MAKING SAME

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Continuation of application Serial No. 658,764, February 27, 1933. This application April 20, 1936, Serial No. 75,508

10 Claims. (Cl. 148—21.8)

This invention relates to the manufacture of rolled products of graphitic iron and we have successfully made rolled sheets, plates and bars of such metal by the methods herein set forth. By the term graphitic iron we mean iron containing any form of precipitated free carbon.

Broadly speaking, the invention contemplates products consisting of rolled graphitic iron wherein the graphite is distributed in the matrix in the form of elongated or fibrous clusters arranged in approximate parallelism.

The products are novel and commercially useful materials having among other properties advantageous corrosion resistant qualities. These products may be used for many purposes for which steel sheets, plates and bars are ordinarily used and are preferable to steel for some purposes.

The present invention also contemplates a novel method wherein white cast iron is subjected to a heat treatment and subsequently rolled into the desired shape at elevated temperatures. The rolled metal may then be subjected to further heat treatment to impart thereto desirable characteristics.

In the drawing:

Figure 1 is a showing of the structure of the metal parallel to the direction of rolling and perpendicular to the rolled surface magnified 125 diameters showing the elongated shape of the graphite;

Fig. 2 is a showing at about 500 diameters of the structure of one form of the product, showing the ferrite matrix resulting from one form of subsequent heat treatment;

Fig. 3 is a showing at about 500 diameters of the structure of a second form of the product, showing the sorbite matrix resulting from a second form of subsequent heat treatment, and

Fig. 4 is a showing at about 500 diameters of a third form of the product showing the spheroidized cementite in a ferrite matrix resulting from a third form of subsequent heat treatment.

The first step in the method consists in the production of suitable ingots of white cast iron. The ingots may have any convenient size or shape and may be formed by pouring into metal molds, green or dry sand molds, or core sand, or any other molds customary in foundry practice. The analysis of this iron will depend largely upon the subsequent treatment adopted and upon the ultimate product desired. The ingots will contain a certain proportion of massive cementite (iron carbide) which, under heat treatment, can be decomposed with a resultant precipitation of graphite in the metal. Unless otherwise expressly stated, the term "cementite" as used throughout the specification and the appended claims is intended to mean iron carbide as a distinct crystalline constituent formed upon solidification of the metal and not cementite formed at temperatures below this point. It is our belief that those skilled in the art will be able to select the permissible analyses in the light of the disclosure hereinafter made, and when considered with the specific examples given. When the proper white iron ingots have been prepared, as will presently be described and illustrated, they are subjected to a heat treatment to facilitate the deformation operations and to prepare the metal for subsequent heat treatment. This initial heat treatment may take any of three forms which are, in general, treatments for the purpose of decomposing the massive cementite and precipitating graphite as so called "temper carbon" in the metal.

In the first and preferred form, the ingots are heated up to above the graphitizing temperature. With iron of an analysis ordinarily capable of solidification as white iron and capable of graphitization without unusual difficulty, this temperature will lie above about 1350° F., and for the best form of graphite should be kept below 1750° F., though it will be understood that, with some metal of special analysis, graphitization might be brought about outside of this temperature range, as is commonly known by people handling such materials. The metal is held within this graphitizing range until decomposition of the major part of the cementite has occurred. The remaining cementite, if any, should not be present in sufficient quantity to cause difficulty during rolling. The metal is then further heated to a rolling temperature above the critical temperature, that is, within the range at which the metal is austenitic and preferably in the region of 1800° F. to 2100° F. at which temperature the metal is rolled, as hereinafter described, to produce the desired shape.

By critical temperature we mean the temperature separating the ferritic or pearlitic and austenitic phases, that is, where ferrite or pearlite changes to austenite and above which the metal will always be austenitic. This temperature may be between 1350° F. and 1500° F. depending upon various factors, principally the composition of the metal. This temperature is apparently the same as that at which temper carbon can be redissolved

in ferrite and above which combined carbon is always present in the matrix, at least in so far as normal compositions of metal are concerned. We have found that the metal is most plastic in the austenitic range and particularly at temperatures of 1800° F. or higher.

In the second form of heat treatment, the ingots are heated to the graphitizing range as in the first form and held until the major part of the cementite has been decomposed. The ingots are then allowed to cool either through a controlled cycle to produce a completely malleableized metal or without control, in which case there may or may not be residue combined carbon, and at some subsequent time the ingots are reheated to the rolling temperature and rolled as in the first form. It will be seen that this form differs from the first form in that the ingots are allowed to cool after heat treatment and before rolling. The practical results of these two forms will usually be substantially the same with the exception that the first form is more economical in cases where it is possible to have continuous operation so that the ingots may be rolled immediately after heat treatment.

A third form of heat treatment consists in heating up the ingots directly to the rolling temperature, that is, to a temperature above the critical temperature, that is, within the austenitic range at which the massive cementite breaks down and preferably to about 1800° to 2100° F., and holding them at this temperature until the major part of the cementite has been decomposed and then rolling the ingots. The length of time the ingots need to be held at this temperature to accomplish the decomposition of the cementite will vary widely, say, from twenty minutes to twenty-four hours, depending upon conditions such as temperature, composition and size of the ingot, all of which will be understood by those skilled in the art.

The preliminary heat treating step confers upon the metal superior rolling characteristics and permits a reduction in rolling time by increasing the amount of reduction possible at each pass through the rolls because of the greater plasticity of the heat treated metal. Furthermore, because of this increased plasticity the metal can be rolled with a given reduction until it has cooled to a lower temperature than would otherwise be the case and this permits it to be passed through the rolls a greater number of times before reheating will be required, as subsequently described, thus reducing the amount of reheating. The preliminary heat treatment also, because of the plasticity imparted to the metal, permits the rolling of more difficult shapes.

In the last above mentioned form of heat treatment the graphite is in a more dispersed form than results from the previous two forms of heat treatment and the metal heat treated in this manner will not normally permit as great a degree of deformation during each pass through the rolls. This is doubtless because of the fact that the graphite is not present in the most compact form. However, in general, the last form of heat treatment normally gives fairly satisfactory rolling characteristics and for many types of work will be found to be the most economical method.

Our experience teaches us that in general the rolling can best be carried out at temperatures above the critical temperature, that is, within the austenitic range and preferably between about 1800° F., and the temperature at which a liquid phase begins to appear in the metal, the metal being more easily deformed above 1800° F. and having the best microstructure above the critical. In general, it seems that the best rolling temperature is the highest temperature attainable without the presence of a liquid phase. However, the temperature of the metal falls as the rolling operations proceed, and the rolling becomes more difficult as the metal passes much below 1800° F. and approaches the critical temperature. One advantage of our method lies in the fact that because of prior heat treatment, the metal retains a high degree of its plasticity over a wider temperature range and may be passed and repassed through the rolls until a somewhat lower temperature is reached without changing the degree of reduction.

A feature of the invention lies in the manner of rolling. Any conventional rolling mechanism may be employed but it will be found that as rolling proceeds the operation becomes increasingly difficult. This we have found to be due to the rapid drop in temperature of the iron and the rapid decrease in plasticity with change in temperature, and we have discovered that if the metal is reheated one or more times during the rolling, the desired reduction in section may be speedily accomplished with a maximum degree of reduction. It is, therefore, advisable to locate the heating furnace in such proximity to the rolling mechanism as to prevent excessive loss in temperature of the metal between the heating furnace and the rolls.

We have also discovered that where the product is to be used for corrosion resistance purposes valuable improvement in such characteristics is imparted by rolling the metal in directions at right angles to each other. In this method the graphite is rolled or elongated in two directions so that each cluster is spread out into a disc-like form. As the metal is reduced in section, these discs tend to overlap so that upon corrosion of the metal surface a greater proportion of the surface area is covered by graphite. It is our belief that this increase in the proportion of the metal surface covered by graphite upon corrosion of the surface metal accounts for the improved corrosion resistance properties of metal rolled in this manner.

Another feature of our invention lies in the treatment of the metal subsequent to the rolling step designed to render it utilizable commercially. This phase of the invention contemplates a metal in which the cementite is substantially completely decomposed as it comes from the rolls or hot deformation operations, as will be the case with metal which has been heat treated in the manner previously described. The subsequent heat treatment contemplates various forms adapted to produce a metal of commercially usable characteristics and involves the heat treatment of the metal as it comes from the rolling operations, the type of heat treatment depending upon the analysis of the metal and the microstructure desired. Thus, in order to produce a product of predetermined physical characteristics, we control both the analysis of the metal and the heat treatment imparted to the metal subsequent to the rolling operations, this heat treatment resulting in the production of uniform products from rolled materials which would otherwise have uncertain and erratic structures. The subsequent heat treatment thus serves two purposes, that of bringing the parts of each rolled form and also the various rolled

forms to uniformity and that of imparting desired structural characteristics to the material.

In one form of this subsequent heat treatment, we take a rolled metal having an analysis which would normally be suitable for the production of malleable iron. For most commercial purposes, this rolled metal will best be prepared in the manner previously set forth from ingots of white iron capable of being graphitized and having a carbon content preferably not less than about 1.5%, a percentage of carbon plus a percentage of silicon content greater than about 2.9%, and a manganese content which is twice the percentage of sulphur plus .10% to .30%. It is known by those familiar with the art that the silicon can be replaced in equivalent proportions by other graphitizing agents. We heat this rolled metal to a temperature above the critical temperature, that is, the lowest temperature at which austinite is formed, and cool it very slowly through the critical temperature until the combined carbon has been completely precipitated, or else heat to a temperature within the critical range or to just below the critical temperature and hold at that temperature until the combined carbon has been decomposed to form graphite, in either case producing a material having the graphite in an elongated form dispersed in a matrix of ferrite. The critical range may be defined as the temperature range between the critical temperatures of the stable and meta-stable iron-carbon diagrams, respectively. This range is variously estimated as being from 10 to 15 Fahrenheit degrees.

We have successfully executed the following procedure which is given by way of example illustrative of the first form of subsequent heat treatment. An ingot was prepared of white iron of the following analysis: Carbon 2.4%; silicon .90%; manganese .25%; sulphur .070%; phosphorus .16%. This ingot was preheated to 1700° F., and held at this temperature for twenty-four hours. It was then further heated to 1950° F., and rolled using a reduction of approximately 20% for each pass through the rolls. When the temperature of the metal dropped below 1800° F., it was reheated to 1950° F., and rolling continued until the desired size and thickness of sheet or bar was obtained, reheating as frequently as necessary to keep the material above about 1800° F. After rolling was completed, the material was placed in a heat treating furnace before excessive loss of temperature had occurred and was held at about 1350° F., for twenty hours. The final product consisted of a rolled graphitic iron wherein the graphite or temper carbon was in an elongated form in a matrix of ferrite. The micrograph shown in Fig. 2 illustrates the material obtained.

A second form of subsequent heat treatment involves heat treatment of a rolled metal wherein the metal has a carbon content preferably not less than about 1.5%; a percentage of carbon plus a percentage of silicon content greater than about 2.9%; and a manganese content which is twice the percentage of sulphur plus .10% to .80%, preferably twice the percentage of sulphur plus .30% to .80%. Higher manganese can be used but there appears to be no advantage in doing so. This metal after rolling is heated to above the critical temperature, but not more than about 200° F., thereabove, and is then cooled through this temperature at a speed such as to retain the combined carbon in the matrix in the form of pearlite or sorbite.

The following example outlines a method involving the second form of subsequent heat treatment. A white iron ingot was made of the following analysis: Carbon 2.40%; silicon .90%; manganese .80%; sulphur .07%; and phosphorus .16%. The ingots were preheated to 1700° F., and held at this temperature for twenty-four hours. The temperature was then raised to 1950° F., and the metal rolled as described in the first example. After leaving the rolls, the metal was brought to a temperature of about 1500° F., and then cooled rapidly through the critical temperature to room temperature. Cooling in the open air usually provides a satisfactory rate of cooling. The resultant material showed a pearlitic matrix containing elongated clusters of graphite or temper carbon. Fig. 3 illustrates the structure obtained as a result of this procedure.

A third form of subsequent heat treatment deals with a rolled metal of an analysis wherein the carbon is not less than about 1.5%, the percentage of carbon plus the percentage of silicon is greater than about 2.9% and the manganese content is about twice the percentage of sulphur plus .10% to .80%, preferably twice the percentage of sulphur plus .30% to .80%. In this form, the rolled metal is heated to above the critical temperature but not more than about 200° F., thereabove, and is then cooled through the critical temperature at a speed such as to retain the combined carbon in the matrix in the form of pearlite or sorbite, and is then held at or reheated to the spheroidizing range (about 1200° to 1300° F.) for a sufficient time to spheroidize the pearlite or sorbite to the desired degree.

We have successfully used the following method which is given as a concrete example of a procedure utilizing the third form of subsequent heat treatment. A white iron ingot of the composition set forth under the second example was made and heated to 1700° F., where it was held for twenty-four hours. The metal was then brought to a temperature of 1950° F., and rolled in the manner set forth in the first example. After the rolling operation was complete, the material was cooled at the rate of about 600° per hour through the critical temperature (in this case about 1375° F.) and then held at a temperature of about 1275° F., for twenty-four hours, whereupon it was cooled to room temperature. This metal had a matrix of finely spheroidized cementite, uniformly distributed through ferrite crystals, and elongated clusters of graphite were embedded in this matrix. Fig. 4 illustrates the structure thus obtained.

It will be seen that in our process we use as a starting point white iron. This enables us to control the structure of the metal throughout the various subsequent operations to produce the proper microstructure at the proper time. Thus, by starting with white iron, we are enabled to so heat treat the metal prior to the rolling operations for the best economy and so as to obtain a most favorable rolling structure of the metal, that is, the structure in which the metal is the most plastic and in which the precipitated carbon is most favorable to such operations. Likewise, through these steps, the metal emerges from the rolling operations in a structural condition most favorable to subsequent heat treatment and to the production of a desired product.

During the rolling operations, the metal cools to various indefinite and variable temperatures and is in many instances reheated and again cools during the additional rolling. Further-

more, the various ingots will require different amounts of rolling and reach the desired reductions when at different temperatures. Various parts of the same piece of metal may be subjected to different conditions so that there may be a variation in the structure of each piece. As a result of all of these variables, the physical properties of the material or different pieces of the material as it emerges from the rolling operation may not be uniform; nevertheless, where there are no special requirements in the rolled metal the subsequent heat treatment may in many instances be dispensed with and the metal used directly as it comes from the rolls. In order to overcome this lack of uniformity, we may subject the metal after rolling to a heat treatment for the purpose of imparting uniform characteristics to the product. As another phase of the invention, we regulate the analysis of the white iron and subject the rolled material to certain heat treatments after rolling, thereby producing uniform products of definite yet variable physical properties. The heat treatment prior to the rolling not only facilitates the rolling operations and makes it commercially feasible to roll such metal, but prepares the iron for the subsequent heat treatment.

New and novel products result from the method above disclosed. These are briefly of four types. In each type the graphite and other inclusions are in the form of elongated or flattened deposits in substantially parallel relationship, such as clearly shown in Figure 1. One type of product consists of the metal as rolled without subsequent heat treatment, in a second form the matrix consists of ferrite as illustrated in Fig. 2, in a third form the matrix is pearlite or sorbite as illustrated in Fig. 3, and in a fourth form the matrix is of spheroidized cementite uniformly distributed through ferrite crystals as shown in Fig. 4.

Cast iron and metals containing graphite have long been well known for their corrosion resistance properties, particularly corrosion due to atmospheric exposure and underground services. For this use the metals must in many cases be thin in section. In the past, metals for this purpose have been non-ferrous metals or steel alloys which contain substantial quantities of other metals, such as chromium, copper, nickel, etc. These alloys are relatively expensive. The difficulty has been that while iron containing graphite has in the past been available in the form of individually cast plates, there is a limitation to the minimum section which can be cast of graphite bearing iron. That is, in the past there has been no method of making graphite bearing iron in sheets of sufficient size and thinness of section to permit the general use of such metals for corrosion resistance purposes or for other purposes to which such metal in the sheet form might be adapted. Our method completely obviates this difficulty and permits the rolling of such metal in very thin section and in relatively large sheets The method brings about the production of sheets of graphite bearing metal with almost the same facility with which steel sheets are made, thus opening up a large variety of new materials for the sheet metal industry. The method also permits the production of graphite bearing metal in shapes and sizes which have heretofore not been obtainable.

A number of uses for the metals made in accordance with our method might be listed. The metal made in accordance with the first example is valuable for use in fabrications where drawing and forming operations are necessary. The metal made in accordance with the second example will be of particular value where wear resistance and corrosion resistance are important, such, for example, as in the manufacture of elevator buckets. Metal made in accordance with the third example possesses corrosion resistance as well as high strength and ductility, and is of particular value in the manufacture of such materials as ship plates, coal hoppers, tanks, and the like.

We have dealt throughout this specification with the composition of the metal as this is concerned with certain well known constituents. It will be understood, however, that numerous other elements may be present in the metal or may be added thereto which will, or may, effect the method or the product, some beneficially and some otherwise.

This is a continuation of copending application of Duncan P. Forbes and Erwin J. Mohr, Serial No. 658,764, filed February 27, 1933.

While we have thus described and illustrated specific embodiments of our invention, we are aware that numerous alterations and changes may be made without departing from the spirit of the invention and the scope of the appended claims, in which—

What is claimed is:

1. The method of making rolled sheets, bars or other shapes of graphitic iron, comprising holding graphitizable white iron ingots at a graphitizing temperature until the major part of the massive cementite has been decomposed, and thereafter rolling the ingots at a temperature at which the metal is austenitic.

2. The method of making rolled sheets, bars or other shapes of graphitic iron which includes the steps of heat treating the iron to decompose the massive cementite, rolling the iron to the desired shape at a temperature at which the metal is austenitic, and heat treating the rolled iron in a manner dependent upon the chemical composition of the metal to produce any of a plurality of uniform predetermined microstructures of the metal.

3. The method of making rolled sheets, bars or other shapes of graphitic iron, comprising bringing graphitizable white iron to a rolling temperature above that separating the pearlite and austenite phases, holding said iron at the rolling temperature until the massive cementite has been largely decomposed whereby to facilitate the rolling of the metal, rolling said metal substantially at said rolling temperature, and subsequently heat treating the rolled metal to impart uniform properties thereto.

4. The method of making rolled sheets, plates or bars of graphitic iron, comprising heating a wholly or partially graphitized white iron of an analysis within the following limits—carbon not less than about 1.5%, percentage of carbon plus percentage of silicon greater than about 2.9%, manganese equal to twice the percentage of sulphur plus about .10% to .30%, to a rolling temperature above that separating the pearlite and austenite phases, rolling said iron substantially at said temperature, and thereafter holding the rolled metal at a temperature below the stable critical temperature until the combined carbon has been substantially completely precipitated as graphite.

5. The method of making rolled sheets, plates or bars of graphitic iron, comprising heating a

wholly or partially graphitized white iron of an analysis within the following limits—carbon not less than 1.5%, percentage of carbon plus percentage of silicon greater than 2.9%, manganese equal to twice the percentage of sulphur plus .10% to .80%, to a rolling temperature at which the metal is austenitic, rolling said iron, and cooling said iron from a point slightly above the critical range at a speed such as to retain the combined carbon in the matrix in the form of pearlite.

6. The method of making rolled sheets, plates or bars of graphitic iron, comprising heating a wholly or partially graphitized white iron of an analysis within the following limits—carbon not less than 1.5%, percentage of carbon plus percentage of silicon greater than 2.9%, manganese equal to twice the percentage of sulphur plus .10% to .80%, to the rolling temperature, rolling said iron, cooling the iron from a point slightly above the critical range through the critical range at a speed such as to retain the combined carbon in the matrix in the form of pearlite and then holding the metal at a spheroidizing temperature to spheroidize the pearlite.

7. The method of making rolled sheets, plates or bars of graphitic iron which consists in producing ingots of white cast iron, heating said ingots to substantially decompose the cementite, causing said ingots to be brought to a high temperature above 1800° F., but below the melting point of the metal, and reducing said ingots to rolled forms of a desired size by rolling the ingots first while at substantially said high temperature and then successively while the ingots are at a temperature above about 1800° F., reheating of the ingots between successive rolling operations being resorted to if necessary to maintain the ingots at a temperature above about 1800° F., until so reduced.

8. The making of rolled sheets, plates or bars by producing ingots of white cast iron, heat treating the ingots to substantially decompose the cementite, and reducing said ingots to the desired form by rolling, the ingots being maintained at a temperature above about 1800° F., during the rolling.

9. A metal product comprising rolled graphitic iron having a matrix of pearlite containing substantially uniformly distorted elongated deposits of free graphite uniformly distributed therein in approximately parallel relation.

10. A metal product comprising rolled graphitic iron having a matrix of spheroidized cementite uniformly distributed through ferrite crystals and containing uniformly distributed elongated deposits of free graphite arranged in approximately parallel relation.

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