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GRAPHITIC STEEL

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7 Claims. (Cl. 148—2)

This invention relates to improvements in graphitic steels.

Graphitic steels as made heretofore in accordance with the invention of Patent No. 2,087,764, granted July 20, 1937, on an application filed by me, have proved themselves admirably adapted, unusually so in some instances, to various uses, and consequently not only have they been made and sold in large amounts, but also their uses have been progressively increasing. For the most part the graphitic steels used commercially have been of two types. One of these, a water hardening type, generally contains about 1.5 per cent of carbon and about 1 per cent of silicon; the other, which is hardened by oil quenching, is of similar composition but contains a small amount of molybdenum as taught in accordance with the disclosure of the aforesaid patent.

Despite the decidedly advantageous properties of such graphitic steels, extended experience in their use has shown that neither of the commercially used types, nor any other of the specific compositions described in my aforesaid patent, is adapted to uses involving operation at high pressures and under severe abrasive conditions such, for example as encountered in cold drawing dies, deep drawing dies, work blades of centerless grinders and the like. The previously used graphitic steels as ordinarily produced for other purposes are not adapted to these uses because they are deficient in wear resistance, and it has not been possible up to the time of this invention to adapt them for such purposes by any heat treatment.

It is among the objects of this invention to provide graphitic steel articles which are especially adapted for uses involving high pressure and severe abrasion, which may be made easily and readily, which combine the advantageous lubricating properties of ordinary graphitic steels as known heretofore with the ability to be hardened to provide higher wear resistance than heretofore possessed by graphitic steels.

In accordance with this invention graphitic steel articles are made from steels containing from about 1 to about 2 per cent of carbon, about 0.3 to 2.0 per cent of molybdenum, about 0.4 to 0.8 per cent of silicon, and about 2.0 to 6.0 per cent of tungsten. Within such ranges it is preferred for many purposes to form the articles from steels containing about 1.4 to 1.6 per cent of carbon, about 0.4 to 0.6 per cent of molybdenum, about 0.6 to 0.65 per cent of silicon, and about 2.6 to 3.0 per cent of tungsten. The remainder of the steels is iron together with impurities in the amounts customarily encountered in such steels, although there may be present other alloying elements provided they do not detrimentally affect the properties derivable through the practice of the invention, for which reason the remainder of the alloy may be said to be effectively iron inasmuch as such additional alloying elements do not alter the essential character of the products.

For the purposes of this invention the content of silicon in the steels is somewhat less than that of the graphitic steels made and used heretofore. In the articles provided by the invention it is desirable to have a certain amount of graphitic carbon present in the structure, to confer its lubricating properties, while having the remainder of the carbon present as carbides to provide the desired abrasion resistance. Hence the silicon is reduced in view of the graphitizing effect of molybdenum and tungsten so as to avoid graphitization to an undesirably great extent.

I have found that both molybdenum and tungsten are essential to the practice of the invention although it is sometimes considered in steel practice that these two elements are more or less interchangeable, due regard being had to proportions. Such equivalency or interchangeability is not present in the present invention. Molybdenum contributes to the ability to harden the products adequately at the surface, i. e., to achieve high hardness and shallow hardening. For this purpose it cannot be replaced by tungsten, thus, for the purposes of the invention tungsten cannot be eliminated by the use of larger amounts of molybdenum because when that substitution is made the desired wear resistance is not developed. On the other hand, molybdenum cannot be replaced by adjusting the amount of tungsten because, as experience has shown, when molybdenum is eliminated from the composition the desired hardening ability is not attained.

The steels are made in accordance with practice standard in the art for the production of graphitic steels. Preferably they are made in an electric furnace following standard killed steel practice, the molybdenum and tungsten being suitably introduced by furnace additions of ferro-molybdenum and ferro-tungsten.

It has been found that the best results are obtained by stripping the ingots from the molds only after the ingots have reached black heat, and then to permit the ingots to cool to atmospheric temperature before placing them in the soaking pits. Experience has shown that if the ingots are stripped at red heat, say at 1300 to

1400° F., and put directly into the soaking pits, graphitization may occur which will interfere with proper working of the ingot. Or, if the ingots are stripped black and placed in the soaking pits cracking may occur during the working. For this reason the ingots are stripped black, allowed to cool to atmospheric temperature, and then reheated, suitably by soaking at about 2000° F.

After reheating the ingots are worked hot, as by rolling or forging, suitably in the manner in which other graphitic steels are worked, care being taken that during the hot working the material does not cool below about 1600° F.

The shaped articles are then graphitized followed by hardening. To these ends they are first normalized by heating above the critical range, suitably at about 1700° F., to cause decomposition and diffusion of carbides, especially carbides segregated in the grain boundaries, after which they are cooled in accordance with ordinary normalizing practice. Thereafter the articles are reheated into or above the critical range, say at 1400° F., followed by cooling at a slow rate, advantageously about 40° F., per hour, to a temperature well below the critical range, suitably 900° F., after which they are removed from the furnace and allowed to air cool. In this manner, the carbides are partially decomposed with production of graphitic carbon and with spheroidization of residual carbides, the combination of which gives the properties desired together with uniform response to heat treatment.

A treatment as just described of steels made from the preferred composition stated above will contain from 0.3 to 0.5 per cent of graphitic carbon, with the remainder of the carbon in combined form. Such an amount of graphitic carbon provides surface lubricating qualities desirable in articles provided by the invention, while the spheroidized carbides provide, upon suitable heat treatment, high wear resistance. The combination of graphitic carbon and spheroidized carbides also causes the steels in this condition to be easily machinable. All of these properties are further enhanced by the fact that in steels made and treated in accordance with the invention, the graphitic carbon is much more finely dispersed than is the case with the previously used graphitic steels, and it is distributed highly uniformly throughout the entire structure.

After being graphitized the articles are machined or otherwise finished to shape and size, after which they are subjected to a hardening treatment in which they are heated above the critical range and quenched. Solid sections may, for example, be quenched into water or brine from about 1450° to 1500° F., the exact temperature and quenchant varying according to the section of the article and the particular surface hardness desired. Less uniform sections may be quenched in oil from about 1550° F. This heat treatment does not cause the graphitic carbon to return to the combined state, which is obviously advantageous. By heat treatment in this manner surface hardnesses as high as 69 to 70 Rockwell C may be obtained by water or brine quenching, while somewhat lower hardnesses, about 66 or 67 Rockwell C, result from quenching in oil.

The presence of extremely finely dispersed graphitic carbon and of carbides in the structure of articles produced in accordance with this invention contribute to provide, to repeat, properties which render the articles particularly adapted to the objects of the invention. Allied with this is fine grain structure which causes the articles to be of desirable impact strength. Experience has shown that articles made in accordance with the invention are highly resistant to scuffing and scoring, and provide better life than the materials heretofore used for these purposes.

According to the provisions of the patent statutes I have explained the principle and method of practicing my invention, and have described what I now consider to represent its best embodiment. However, I desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

I claim:

1. A hot worked and heat treated article of manufacture, the article being formed from steel containing about 1.0 to 2.0 per cent of carbon, about 0.3 to 2.0 per cent of molybdenum, about 0.4 to 0.8 per cent of silicon, about 2.0 to 6.0 per cent of tungsten, and the remainder effectively iron, the article being characterized by high surface hardness, by containing a substantial amount of its carbon content in the graphitic state in highly dispersed form uniformly distributed throughout the structure, by having spheroidized carbides uniformly distributed throughout the structure, and by high resistance to scuffing, scoring and wear.

2. A hot worked and heat treated article of manufacture, the article being formed from steel containing about 1.4 to 1.6 per cent of carbon, about 0.4 to 0.6 per cent of molybdenum, about 0.6 to 0.65 per cent of silicon, about 2.6 to 3.0 per cent of tungsten, and the remainder effectively iron, the article being characterized by high surface hardness, by containing a substantial amount of its carbon content in the graphitic state in highly dispersed form uniformly distributed throughout the structure, by having spheroidized carbides uniformly distributed throughout the structure, and by high resistance to scuffing, scoring and wear.

3. That method of making graphitic steel articles which comprises hot working an ingot of steel containing about 1.0 to 2.0 per cent of carbon, about 0.3 to 2.0 per cent of molybdenum, about 0.4 to 0.8 per cent of silicon, about 2.0 to 6.0 per cent of tungsten, and the remainder effectively iron, annealing the hot worked article by heating it above the critical, followed by cooling, to partially decompose carbides and produce a substantial amount of graphitic carbon finely dispersed throughout the structure, and then reheating the graphitized article to a temperature at least within the critical range to spheroidize residual cementite and thereafter cooling slowly to a temperature below the critical, and then heating the article to a temperature above the critical and quenching it to harden the article while retaining substantially all of the graphitic carbon in that form and thereby rendering the article highly resistant to scuffing, scoring and wear.

4. That method of making graphitic steel articles which comprises hot working an ingot of steel containing about 1.4 to 1.6 per cent of carbon, about 0.4 to 0.6 per cent of molybdenum, about 0.6 to 0.65 per cent of silicon, about 2.6 to 3.0 per cent of tungsten, and the remainder effectively iron, annealing the hot worked article

by heating it above the critical, followed by cooling, to partially decompose carbides and produce a substantial amount of graphitic carbon finely dispersed throughout the structure, and then reheating the graphitized article to a temperature at least within the critical range to spheroidize residual cementite and thereafter cooling slowly to a temperature below the critical, and then heating the article to a temperature above the critical and quenching it to harden the article while retaining substantially all of the graphitic carbon in that form and thereby rendering the article highly resistant to scuffing, scoring and wear.

5. That method of making graphitic steel articles which comprises hot working an ingot of steel containing about 1.0 to 2.0 per cent of carbon, about 0.3 to 2.0 per cent of molybdenum, about 0.4 to 0.8 per cent of silicon, about 2.0 to 6.0 per cent of tungsten, and the remainder effectively iron, annealing the hot worked article by heating it above the critical, followed by cooling, to partially decompose carbides and produce a substantial amount of graphitic carbon finely dispersed throughout the structure, and then reheating the graphitized article to a temperature at least within the critical range to spheroidize residual cementite and thereafter cooling slowly to a temperature below the critical, and then heating the article to a temperature above the critical and quenching it to harden the article while retaining substantially all of the graphitic carbon in that form and thereby rendering the article highly resistant to scuffing, scoring and wear.

6. In a method of making graphitic steel articles, the steps which comprise casting an ingot of steel containing about 1.0 to 2.0 per cent of carbon, about 0.3 to 2.0 per cent of molybdenum, about 0.4 to 0.8 per cent of silicon, about 2.0 to 6.0 per cent of tungsten, and the remainder effectively iron, stripping said ingot and cooling it to atmospheric temperature, then reheating said ingot above about 1600° F. and hot working it, annealing the hot worked article by heating it above the critical, followed by cooling, to partially decompose carbides and produce a substantial amount of graphitic carbon finely dispersed throughout the structure, and then reheating the graphitized article to a temperature at least within the critical range to spheroidize residual cementite and thereafter cooling slowly to a temperature below the critical, and then heating the article to a temperature above the critical and quenching it to harden the article while retaining substantially all of the graphitic carbon in that form and thereby rendering the article highly resistant to scuffing, scoring and wear.

7. That method of making graphitic steel articles which comprises hot working an ingot of steel containing about 1 to 2 per cent of carbon, about 0.3 to 2.0 per cent of molybdenum, about 0.4 to 0.8 per cent of silicon, about 2 to 6 per cent of tungsten, and the remainder effectively iron, heating the hot worked article to a temperature of at least about 1700° F. to decompose carbides and produce about 0.3 to 0.5 per cent of graphitic carbon distributed throughout the structure, and cooling to a temperature below the critical range, reheating the article to at least about 1400° F. to spheroidize residual cementite and then cooling slowly to about 900° F., then heating the spheroidized article to about 1450° to 1550° F. and thereafter quenching it, and thereby rendering the article of high surface hardness and of high resistance to wear, scuffing and scoring.

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