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METHOD OF HEAT-TREATING GRAY CAST IRON

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The present invention relates to the production of special hardened gray cast iron compositions and castings made thereof characterized by high hardness and by high resistance to the effects of corrosion, abrasion and wear.

It has now been discovered that a special alloy gray cast iron composition can be softened to a satisfactory hardness level for machining and is thereafter, in cooperation with a special thermal treatment, hardened to a high hardness level, e. g., about 450 Brinell or more.

It is an object of the present invention to provide alloy gray cast iron castings which can be machined and which thereafter can be hardened to a high hardness level.

Another object of the invention is to provide a hardened gray cast iron resistant to the corrosive effects of salty, acidic or basic environments.

The invention also contemplates providing a hardened gray cast iron resistant to the deleterious action of abrasives and resistant to metal-to-metal wear.

It is a further object of the invention to provide a special thermal hardening treatment cooperating with a special alloy gray cast iron composition to produce a high hardness level therein.

Broadly stated, the invention comprises a special hardened nickel-copper alloy gray cast iron characterized by a high hardness and a special process for the production of said hardened alloy gray cast iron. The special hardened alloy gray cast iron provided by the invention contains about 2.25% to about 3.25% total carbon, about 7% to about 10.5% nickel, about 3% to about 4.7% copper, about 1% to about 4% chromium, about 1.5% to about 3% silicon, about 0.3% to about 1% manganese, and the balance essentially iron, said balance being at least about 73% iron.

The special alloy cast iron composition provided by the invention is hardened to a high hardness level by a special treatment which comprises subjecting castings made of said cast iron to sub-zero temperatures, e. g., temperatures of about minus 70° F. to about minus 320° F. or lower, for relatively short periods of time, e. g., for periods of time sufficient to thoroughly cool said castings to the temperature of the treating medium.

In carrying the invention into practice, it is preferred to employ alloy cast iron compositions containing about 2.5% to about 3% total carbon, about 7.5% to about 9% nickel, about 3.5%

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to about 4% copper, about 2% to about 2.5% chromium, about 1.75% to about 2.25% silicon, up to about 0.8% manganese, and the balance essentially iron. The aforesaid preferred hardened alloy gray cast iron compositions are characterized by improved hardening in the sub-zero treatment and by improved corrosion resistance.

Castings containing less than about 12% copper plus nickel and/or more than about 2.5% chromium have been found frequently to be undesirably hard and/or to have a non-uniform hardness in the as-cast condition, with the result that such castings are machinable only with difficulty. It is desirable therefore, before machining such castings, to heat said castings to a temperature of about 1600° to about 1800° F., e. g., 1700° F., and to thereafter rapidly cool said castings, e. g., to oil quench said castings. The aforesaid rapid cooling or quenching is carried out at a rate of not less than about 325° F. per second (at 1300° F.) and the temperature of the castings is reduced below about 900° F. by means of the rapid cooling treatment. The quenching treatment is desirable to overcome the effect of possible production variables and to insure that the cast compositions provided by the process embodying the invention will have a uniform machinable hardness level within a range of about 160 to about 250 Brinell, e. g., a hardness level of about 225 Brinell. In those castings having a satisfactory machinable hardness in the as-cast condition, the aforesaid quenching treatment is not essential to insure hardening to a satisfactory hardness level upon the subsequent sub-zero treatment.

The special process contemplated by the invention thus provides alloy gray cast iron castings which may be thermally softened to a satisfactory machinable hardness level and which may be hardened after any required machining to a high hardness level. An expansion of about 0.004 inches per inch usually occurs during the thermal hardening treatment. As indicated hereinbefore, the special compositions contemplated by the invention cooperate with the special hardening treatment provided by the invention to produce gray cast iron castings having high hardness, e. g., castings having hardnesses of about 450 to about 575 Brinell are produced according to the invention. In general, it can be said that when the higher hardnesses are required, e. g., hardnesses of about 450 Brinell or more, the lower treating temperatures should be employed in the hardening operation.

The amounts of alloying elements in the cast iron compositions contemplated by the invention set forth hereinbefore are critical and the novel results provided by the invention are not achieved unless the aforesaid amounts of alloying elements are employed. Thus, when the carbon content is below about 2.25%, trouble is encountered by way of poor castability, poor machinability and poor metal-to-metal wear resistance. On the other hand, at carbon contents above about 3.25%, the high hardness values contemplated by the invention are not achieved. The total content of nickel plus copper in the special alloy cast iron provided by the invention is maintained within the range of about 10% to about 15% because when the total content of these two elements is substantially below about 10%, quenched castings are too hard to be machinable, and when the total content of these two elements is substantially above about 15%, the castings are not hardenable to a high level, e. g., a level of 450 Brinell or above. The chromium content in combination with the total content of nickel plus copper is also a critical factor as it has been found that with the total nickel plus copper contents set forth hereinbefore, castings containing less than about 1% chromium are not hardenable to a high hardness value and, on the other hand, castings containing more than about 4% chromium are not practically machinable, even after the rapid cooling treatment described hereinbefore. The preferred chromium content of about 2% to about 2.5% insures satisfactory machinable hardness at least after the aforesaid quenching operation and the development of high hardness in the subsequent sub-zero treatment. The silicon content in combination with the aforesaid nickel, copper and chromium contents is likewise critical as it has been found that when the silicon content is less than about 1.5% both the castability and the hardenability are impaired, whereas when the silicon content exceeds about 3% it is difficult to achieve the machinable hardnesses of less than about 250 Brinell in the as-cast and/or quenched conditions. The special alloy gray cast iron castings provided by the invention contain at least about 1% graphite up to about 2.6% graphite, e. g., the preferred compositions set forth hereinbefore will contain about 1.25% to about 2% graphite. For best response to the sub-zero hardening treatment, it is preferred to keep the manganese content low, e. g., below about 0.5%.

For the purpose of giving those skilled in the art a better appreciation of the advantages of the invention, the following illustrative examples are given:

Example 1

A gray cast iron casting containing about 2.6% total carbon, about 1.7% silicon, about 7.6% nickel, about 3.4% copper and about 2% chromium was produced. In the as-cast condition, this casting had a hardness of about 255 Brinell. The casting was heated to about 1700° F. and was quenched in oil. The hardness of the quenched casting was about 200 Brinell. The casting was then hardened by immersion in a bath having a temperature of about minus 70° F. After the hardening treatment, the casting had a hardness of 429 Brinell. After hardening at minus 320° F., another casing of the same composition and similarily oil-quenched developed a hardness of about 514 Brinell.

Example 2

A gray cast iron casting containing about 2.6% total carbon, about 1.7% silicon, about 9.3% nickel, about 4.1% copper and about 2% chromium was produced. In the as-cast condition, this casting had a hardness of about 165 Brinell. The casting was hardened by immersion in a bath of liquid nitrogen at a temperature of about minus 320° F. After the hardening treatment, the casting had a hardness of about 485 Brinell.

In addition to the alloying elements set forth hereinbefore, the alloy gray cast iron provided by the invention may also contain usual small amounts of incidental impurities and other elements found in gray cast iron and which do not materially affect the properties of the castings provided by the invention. Thus, the castings may contain up to about 0.14% sulfur, up to about 0.5% phosphorus, etc.

Castings contemplated by the invention may be produced by the usual methods and in the usual equipment employed in the production of high quality gray iron castings. Thus, the arc or induction electric furnaces, etc., have been employed successfully in the production of castings contemplated by the invention.

The special hardened alloy gray cast iron compositions provided by the invention having the high hardness described hereinbefore are characterized by a high combination of corrosion resistance, abrasion resistance, metal-to-metal wear resistance and heat resistance. Thus, the special cast iron has been found to be particularly resistant to the corrosive effect of salt water and to have a highly useful resistance to the corrosive effects of both acids and alkalies.

The high combination of corrosion resistance, abrasion resistance and metal-to-metal wear resistance which characterize the hardened alloy cast iron provided by the invention are particularly useful in pump parts and in other equipment handling sour crude oils containing sand or in handling salty crude oils containing sand. Parts for equipment used in handling acid or basic abrasive slurries, e. g., the corrosive slurries found in kraft paper mills, are also advantageously made from the new cast product provided by the invention. In addition, parts for equipment used in handling abrasive materials at elevated temperature are also made with great advantage from the new product.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention as those skilled in the art will understand. Such modifications and variations are considered to be within the purview and scope of the invention and of the appended claims.

I claim:

1. The improved process for producing a hard, wear-resistant, corrosion-resistant alloy gray cast iron casting which comprises subjecting an alloy gray cast iron casting containing about 2.5% to about 3% carbon, about 7.5% to about 9% nickel, about 3.5% to about 4% copper, about 2% to about 2.5% chromium, about 1.75% to 2.25% silicon, and the balance essentially iron to a thermal treatment comprising heating said casting to a temperature of about 1600° F. to about 1800° F., rapidly cooling said heated casting to a temperature below about 900° F. to soften said casting to a machinable hardness level of about 180 to about 250 Brinell, and there-

after subjecting said casting to a hardening treatment at a temperature below about minus 70° F. to harden said casting to a hardness of at least about 450 Brinell.

2. In the process for producing a hard, wear-resistant, corrosion-resistant alloy gray cast iron casting, the improvement which comprises thermally treating a gray cast iron casting containing about 2.25% to 3.25% carbon, about 7% to about 10.5% nickel, about 3% to about 4.7% copper, the sum of said nickel and said copper contents being about 10% to about 15%, about 1% to about 4% chromium, about 1.5% to about 3% silicon, up to about 1% manganese, and the balance essentially iron, at a temperature of about 1600° F. to about 1800° F., rapidly cooling said thermally-treated casting below about 900° F. to soften said casting to a low machinable

hardness level, and thereafter subjecting said softened casting to a temperature below about minus 70° F. to increase the hardness of said casting at least about 200 Brinell.

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