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PROCESS FOR HARDENING ALLOY GRAY CAST IRON

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The present invention relates to a process for hardening special alloy cast iron compositions to impart thereto high hardness and high resistance to effects of corrosion, abrasion and wear.

In my copending application, Serial No. 109,075, filed August 6, 1949 now Patent No. 2,530,545, I disclosed a special alloy cast iron composition and a hardening heat treatment for this composition and in another copending application, Serial No. 109,613, filed August 10, 1949 now Patent No. 2,567,791, I disclosed a different method for hardening alloy cast irons of substantially the same composition by means of a treatment at sub-zero temperatures.

I have now discovered another special process for thermally hardening certain alloy cast irons within the compositional ranges disclosed in my previous applications.

It is an object of the present invention to provide a special thermal hardening treatment cooperating with a special alloy cast iron composition to produce a high hardness level in castings made of the special composition.

It is a further object of the invention to provide a special heat treating process whereby alloy gray cast irons of special composition may be softened to desired low hardnesses for machining purposes and may thereafter be hardened to high hardnesses on the order of 400 Brinell or more.

The present invention comprises subjecting special nickel-copper alloy cast iron castings containing about 2.25% to about 3.25% total carbon, about 7% to about 9% nickel, about 3% to about 4.5% copper, with the sum of the nickel and copper contents being about 10% to about 12%, about 1% to about 4% chromium, about 1.5% to about 3% silicon, up to about 1.2% manganese, e. g., about 0.3% to about 0.8% or 1% manganese, with the balance of the composition being essentially iron and constituting at least about 73% of the total composition, to a heat treatment which comprises heating the castings at a temperature of about 1600° F. to about 1800° F., e. g., about 1700° F., for sufficient time to at least insure substantially uniform temperature throughout the casting, and thereafter slowly cooling the castings, as by furnace cooling, at a rate not exceeding about 100° F. per hour, e. g., at a cooling rate of about 50° F. per hour, down to a temperature of about 900° F. The aforementioned heat treatment when applied to alloy gray cast irons having a composition within the foregoing narrow range will provide a hardness in the heat-treated castings of about 450 Brinell or

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more, e. g., 514 Brinell. Preferably, the slow cooling at the controlled rate defined hereinbefore is conducted down to a temperature of about 400° F. The slow cooling rate, such as a furnace cooling rate, employed in hardening the special alloy cast irons in accordance with the present invention is measured as the average cooling rate on cooling from about 1600° or 1800° F. down to about 900° F.

The cooling rate set forth hereinbefore has been found to be critical and, when it is attempted to harden alloy cast irons within the scope of the invention using more rapid cooling rates than those disclosed hereinbefore, hardnesses on the order of 450 Brinell or more are not obtained. Castings within the foregoing narrow range of composition 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. When it is desired to machine such castings before hardening, the castings may be softened to a hardness value at which they are readily machinable by heating the castings to a temperature within the range of about 1600° F. to about 1800° F., e. g., 1700° F., and thereafter rapidly cooling the hot castings at a rate not substantially slower than that obtained through oil quenching the hot castings. The temperature of the castings is reduced below about 900° F. but not substantially below atmospheric temperatures by means of the rapid cooling or quenching treatment. The rapid cooling treatment or quenching can be carried out with little danger of cracking the castings and is desirable to overcome the effect of possible production variables and to insure that the cast compositions within the invention will have a uniform machinable hardness level, e. g., a hardness of about 180 to 250 Brinell. In those gray cast iron castings having a satisfactory machinable hardness in the as-cast condition, the aforesaid quenching or rapid cooling treatment may not be required prior to machining and hardening.

In applications where hardnesses on the order of about 400 Brinell or more are satisfactory, the hardening process described hereinbefore may be applied to castings containing about 7% to about 10% nickel together with about 3% to about 4.5% copper with the sum of the nickel and copper contents being in the range of about 10% to about 14%, and the carbon, chromium, silicon and manganese contents being those defined hereinbefore. Castings having compositions within the latter-mentioned ranges but outside the narrower ranges set forth hereinbefore may also be hardened to hardnesses on the order of about 450 Brinell or more by the process comprising heating to within the range of about 1600° F. to 1800° F. for at least a sufficient time to thoroughly heat the castings and thereafter slowly cooling the castings to about 900° F. at a slower rate not exceeding about 25° F. per hour. For practical reasons, the slow cooling rates usually will not be less than about 10° F. per hour. Of course, these slower cooling rates can also be employed for treating compositions within the narrower ranges set forth hereinbefore but are not necessary to obtain the desired hardening in the narrower compositional range.

The length of time for which the castings are held within the range of about 1600° F. to 1800° F. before the hardening slow cooling operation and/or before the softening rapid cooling operation contemplated by the invention should be at least sufficiently long to heat the castings throughout the section thereof. This is usually obtained by holding at temperature for one hour per inch of casting section thickness, but the duration of heating can be longer, for example, to modify the microstructure and/or properties.

The amounts of alloying elements in the cast iron compositions set forth hereinbefore are critical and are required to achieve the novel results provided by the present invention. 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%, it is not practically possible to obtain high hardnesses on the order of about 400 Brinell or about 450 Brinell or more in accordance with the invention. The total content of nickel plus copper in the special alloy cast iron treated in accordance with the invention should be at least about 10% since it has been found that when the total content of these two elements is substantially below about 10%, quenched castings remain too hard to be machinable. On the other hand, when the total content of these two elements substantially exceeds about 14%, the castings are not thermally hardenable to a high level above about 400 Brinell. The chromium content in combination with the total content of nickel plus copper is also a critical factor as it has been found that castings containing less than about 1% chromium are not hardenable to hardnesses above about 400 Brinell and, on the other hand, castings containing more than about 4% chromium are not practically machinable even after the rapid cooling or quenching treatment described hereinbefore. The silicon content in combination with the nickel, copper and chromium contents is likewise critical for purposes of the present invention since when the silicon content is less than about 1.5%, both the castability and the hardenability are impaired while when the silicon content exceeds about 3%, it is difficult to achieve low machinable hardnesses in the as-cast and/or quenched conditions. For best response to the hardening treatment provided by the invention, the manganese content preferably is kept low, e. g., not more than about 0.5%. The special alloy cast irons which have been treated in accordance with the invention will contain graphite in amounts usually between about 1% and about 2.6%.

In addition to the alloying elements set forth hereinbefore, alloy cast irons treated in accordance with the present invention may also contain the 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. Thus, the castings may contain up to about 0.14% sulphur, up to about 0.5% phosphorus, etc.

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 2.8% total carbon, about 1.6% silicon, about 1.1% manganese, about 7.4% nickel, about 3.3% copper and about 2.8% chromium was produced. This gray cast iron casting had a hardness of about 285 Brinell in the as-cast condition. The casting was heated to about 1700° F. and quenched in oil to produce a machinable casting. The hardness of the casting in the quenched condition was about 250 Brinell. The casting was then heated to about 1700° F. for a sufficient length of time to thoroughly heat the casting and was slowly cooled from this temperature to below 900° F. at an average rate of about 50° F. per hour. The thus-treated casting had a hardness of about 540 Brinell.

Example 2

A gray cast iron casting containing about 2.6% total carbon, about 1.7% silicon, about 1.1% manganese, about 6.8% nickel, about 3.1% copper and about 2.1% chromium was produced. In the as-cast condition, this gray cast iron casting had a hardness of about 316 Brinell. The casting was heated to about 1700° F. and quenched in oil to produce a machinable casting. The hardness of the quenched casting was about 226 Brinell. The casting was then heated to about 1700° F. for a sufficient length of time to thoroughly heat the casting and was slowly cooled from this temperature to below 900° F. at an average rate of about 50° F. per hour. After the aforesaid heat treatment, the casting had a hardness of about 511 Brinell.

From the foregoing description, it may be seen that the special process contemplated by the present invention provides a means whereby alloy cast iron castings of special composition may be thermally softened to a satisfactory machinable hardness level and may thereafter be hardened after any required machining to a high hardness level on the order of about 400 or 450 Brinell or higher.

An outstanding practical advantage afforded by the process embodying the present invention is that the process can be carried out with a minimum of supervision since it is only necessary that a furnace having the desired cooling characteristics be heated under supervision for a sufficient length of time to insure that the castings therein will be heated to a temperature within the range of 1600° to 1800° F. and will be heated throughout. Thereafter, the heat supply to the furnace may be cut off and the castings allowed to cool in the furnace unattended. In this manner, castings produced in accordance with the invention can be hardened while the remainder of the foundry is not operating as, for example, over the weekend, etc.

Alloy gray cast iron castings which may be hardened in accordance with the present invention may be produced by the usual methods and with 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. Likewise, the cupola furnace may be employed in cases where the volume of production warrants. The foregoing examples of methods and equipment which can be employed in producing the castings are given merely as illustrations and are not to be construed as excluding the applicability of the invention to alloy cast iron castings produced by other methods and/or in other equipment.

Hardened alloy gray cast iron castings provided by the process embodying the invention are characterized by a high combination of corrosion resistance, abrasion resistance, metal-to-metal wear resistance and heat resistance. Thus, parts of the special alloy gray cast iron hardened in accordance with the present invention have been found particularly useful in applications where the corrosive effect of salt water, acids or alkalis is encountered and where sandy or abrasive materials must be handled. Thus, alloy gray cast iron castings produced in accordance with the invention are particularly useful in pump parts and in equipment for handling sour crude oils containing sand or salty crude oils containing sand. Likewise, parts for equipment used in handling acid or basic abrasive slurries, e. g., the corrosive slurries found in kraft paper mills, and parts for equipment used in handling abrasive materials at elevated temperatures may also be produced in accordance with the invention.

This application is a continuation-in-part of my copending U. S. application Serial No. 109,075, filed August 6, 1949 now Patent No. 2,530,545.

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 readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claims.

I claim:

1. The process for producing a hardened alloy cast iron casting which comprises heating within the range of about 1600° F. to about 1800° F. a casting comprised of an alloy gray cast iron containing about 2.25% to about 3.25% total carbon, about 7% to 9% nickel, about 3% to about 4.5% copper, the sum of the nickel and copper contents being about 10% to 12%, about 1% to 4% chromium, about 1.5% to 3% silicon, about 0.3% to 1% manganese and the balance essentially iron, and thereafter slowly cooling said casting from within said temperature range to below about 900° F. at an average rate not exceeding about 50° F. per hour to impart to said casting a hardness of at least about 450 Brinell.

2. The process for producing a hardened alloy cast iron casting which comprises heating within the range of about 1600° F. to about 1800° F. a casting comprised of an alloy gray cast iron containing about 2.25% to about 3.25% total carbon, about 7% to 9% nickel, about 3% to about 4.5% copper, the sum of the nickel and copper contents being about 10% to 12%, about 1% to 4% chromium, about 1.5% to 3% silicon, about 0.3% to 1% manganese and the balance essentially iron, and thereafter slowly cooling said casting from within said temperature range to below about 900° F. at an average rate not exceeding about 100° F. per hour to impart to said casting a hardness of at least about 450 Brinell.

3. The process for producing a hardened alloy cast iron casting which comprises heating within the range of about 1600° F. to about 1800° F. a casting comprised of an alloy gray cast iron containing about 2.25% to 3.25% total carbon, about 7% to 10% nickel, about 3% to 4.5% copper, the sum of the nickel and copper contents being about 10% to 14%, about 1% to 4% chromium, about 1.5% to 3% silicon, about 0.3% to 1% manganese and the balance essentially iron, and thereafter slowly cooling said casting from within said temperature range to below about 900° F. at an average rate not exceeding about 25° F. per hour to impart to said casting a hardness of at least about 450 Brinell.

4. The process for producing a hardened alloy cast iron casting which comprises heating within the range of about 1600° F. to about 1800° F. a casting comprised of an alloy cast iron containing about 2.25% to 3.25% total carbon, about 7% to 10% nickel, about 3% to 4.5% copper, the sum of the nickel and copper contents being about 10% to 14%, about 1% to 4% chromium, about 1.5% to 3% silicon, up to about 1.2% manganese and the balance essentially iron, and thereafter slowly cooling said casting from within said temperature range to below about 900° F. at an average rate not exceeding about 100° F. per hour to impart to said casting a hardness of at least about 400 Brinell.

5. The process for producing a hardened alloy cast iron casting which comprises heating within the range of about 1600° F. to about 1800° F. a casting comprised of an alloy cast iron containing about 2.25% to 3.25% total carbon, about 7% to about 9% nickel, about 3% to 4.5% copper, the sum of the nickel and copper contents being about 10% to 12%, about 1% to 4% chromium, about 1.5% to 3% silicon, about 0.3% to 1% manganese and the balance essentially iron, rapidly cooling said casting from within said temperature range to below about 900° F. at a cooling rate not substantially slower than oil quenching to provide a soft and machinable casting, thereafter reheating the thus-treated casting to a temperature within the range of about 1600° F. to about 1800° F., and furnace cooling said casting from said temperature range to a temperature below about 900° F. at an average rate not exceeding about 100° F. per hour to harden said casting to a hardness of at least about 450 Brinell.

6. The process for producing a hardened alloy cast iron casting which comprises heating within the range of about 1600° F. to about 1800° F. a casting comprised of an alloy cast iron containing about 2.25% to 3.25% total carbon, about 7% to about 10% nickel, about 3% to 4.5% copper, the sum of the nickel and copper contents being about 10% to 14%, about 1% to 4% chromium, about 1.5% to 3% silicon, about 0.3% to 1% manganese and the balance essentially iron, rapidly cooling said casting from within said temperature range to below about 900° F. at a cooling rate not substantially slower than oil quenching to provide a soft and machinable casting, thereafter reheat-

ing the thus-treated casting within the range of about 1600° F. to about 1800° F., and slowly cooling said casting from within said temperature range to below about 900° F. at an average rate not exceeding about 100° F. per hour to harden said casting to a hardness of at least about 400 Brinell.

FREDERICK GEORGE SEFING.

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