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PROCESS OF PREPARING IMPROVED CAST IRON ARTICLES

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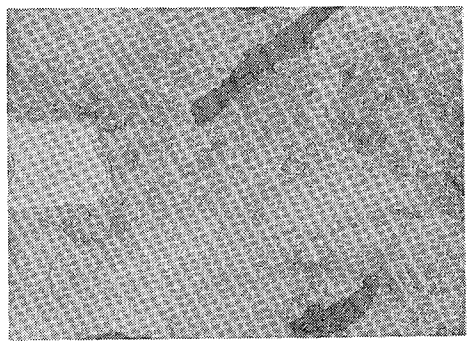


Fig. 1



Fig. 2

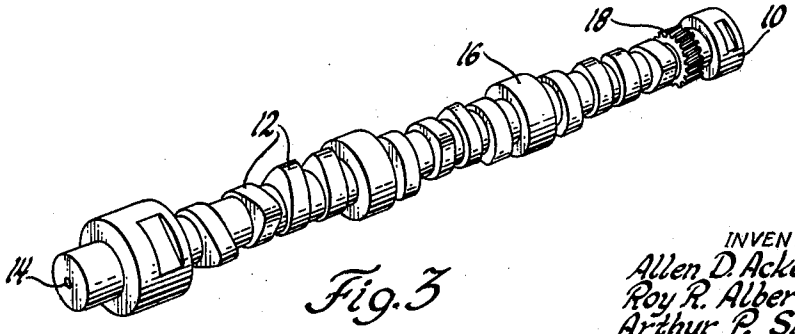


Fig. 3

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PROCESS OF PREPARING IMPROVED CAST IRON ARTICLES

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ABSTRACT OF THE DISCLOSURE

The machinability characteristics of a carbidic cast iron article containing at least 10% by weight primary complex iron carbides is substantially improved while maintaining the inherent excellent durability and fatigue resistant properties of the alloy by heating the cast article to an elevated temperature in the temperature range of 300 Fahrenheit degrees immediately below the lower critical temperature of the composition for a time sufficient to produce incipient spheroidization of pearlite and to lower matrix hardness below 30 Rockwell C and subsequently cooling the composition to about normal room temperature.

This invention relates to cast iron articles and more particularly to a process whereby excellent durability and good machinability are achieved simultaneously in a carbidic cast iron article requiring a wear resistant surface.

A specific example of an article to which this invention might be applied is cast gears. Another example is a camshaft. The surface of the camshaft lobes must be extremely hard and resistant to wear. The rest of the casting must be durable and machinable. Durability as used herein means resistance to wear, scuffing, spalling, pitting, fatigue and general deteriorization of the surface during service.

Previous to this invention improvement in the durability of a camshaft has been obtained only with a concurrent loss in machinability. This was because durability in a camshaft alloy was obtained by alloying gray cast iron with elements which promote the formation of complex iron carbides. These complex iron carbides in a matrix of fine lamellar pearlite significantly increased the durability of the camshaft but at the same time made the article very difficult to machine. It was believed that the only way that the article could be made more machinable was to reduce the content of the complex iron carbides and thus reduce durability simultaneously. The upper limit of how durable a camshaft could be made in the prior art was determined by whether the more durable camshaft could still be drilled, tapped, hobbed, milled, turned or ground at an economic rate without excessive tool wear or breakage.

Thus, it is an object of this invention to provide a durable and machinable carbidic iron casting.

Another object of this invention is to provide a method of producing a carbidic iron alloy article to obtain simultaneously properties of durability and machinability.

A more specific object of this invention is to provide a method of producing a carbidic iron alloy camshaft to obtain simultaneously excellent durability and good machinability characteristics.

These and other objects are accomplished by casting the article according to a standard technique known in the prior art, cooling, removing the mold, cleaning the casting, annealing at a temperature just below the austenite region until incipient spheroidization of the pearlite and until the matrix hardness is less than 30 Rockwell C, cooling, machining and surface hardening by heating

into the austenite region and quenching. The relative order of the machining and surface hardening steps is not critical but will depend upon the nature of the individual article.

In the figures:

FIGURE 1 is a photomicrograph depicting the microstructure of a typical carbidic cast iron alloy before the heat treatment of this invention.

FIGURE 2 is a photomicrograph depicting the microstructure of a typical carbidic iron alloy after the heat treatment of this invention.

The magnification in both the photomicrographs is 750×. In each case the specimens were etched with a 2% Nital solution.

FIGURE 3 is a camshaft.

Since the camshaft must be highly durable and must have a hard surface resistant to wear, gray iron alone is not a satisfactory material for the casting. Normally one or more carbide forming elements are added to the gray iron. These elements comprise chromium, vanadium, molybdenum, manganese, columbium, tungsten and zirconium. They are added in small quantities, each usually less than 2%, and promote formation of hard complex iron carbides.

An alloy of the above composition is cast into a camshaft according to a standard technique known in the prior art. Typically a shell mold may be used and two or more camshafts cast in each mold. After cooling the mold is removed and the castings are cleaned by sand blasting or other suitable means.

A camshaft casting containing one or more of the above mentioned alloying elements after cooling to about 100–200° F. will have a microstructure as depicted in FIGURE 1. This microstructure consists of flake graphite, pearlite, primary cementite and other metal carbides. In FIGURE 1 the large white areas indicate the complex iron carbides. The long narrow dark sections depict the flake graphite. The pearlite at this stage is in a fine lamellar state and appears as the gray mass throughout the photomicrograph in FIGURE 1. While the presence of pearlite, primary cementite and other carbides make a more durable casting, the combination of fine lamellar pearlite, primary cementite and other carbides makes subsequent machining difficult and expensive. However, surprisingly, it is unnecessary to reduce the content of these complex iron carbides and thus reduce durability in order to improve machinability. The durability can be maintained and the machinability improved by annealing the casting at temperatures below the lower temperature limit of the austenite region for camshaft alloys for times sufficient to produce incipient spheroidization of pearlite and lower matrix hardness below 30 Rockwell C.

The actual matrix hardness after annealing will depend upon the composition of the alloys. It has been found that most of the hardness values preferably fall in the range of 20–30 Rockwell C. However it is important only that the matrix hardness should be below 30 Rockwell C.

Temperatures should be as high as possible to allow rapid achievement of the incipient spheroidization of pearlite but not so high as to enter the austenite region and thus develop a hard martensite microstructure upon cooling. The pearlitic structure will tend to spheroidize at temperatures within 200–300° F. of the lower critical temperatures. However, when the annealing is conducted at the lower end of this range the process may be prohibitively slow. A preferred temperature is one which is sufficiently close to the austenite region to permit a rapid breaking up of the fine hard lamellar pearlite but not so rapid as to prevent good control of the process.

The rate of cooling of the casting from the annealing

temperature is dependent upon the size and shape of the article. Stresses caused by uneven cooling are undesirable. It may be necessary to cool large objects in the furnace. Objects of smaller cross section, such as camshafts, may preferably be air cooled.

The microstructure of the casting after the annealing treatment is shown in FIGURE 2. The flake graphite and the carbides are unchanged, but the fine hard lamellar pearlite structure has been broken up rendering machining significantly easier. It can be observed in FIGURE 2 that the alternate layers of cementite and ferrite which compose the pearlite, are now more discernable and that the cementite layer has started to contract.

After annealing and cooling the cast iron article may be machined and/or surface hardened depending upon the nature of the article and the economy of a particular production operation. The order in which these steps are performed may depend upon the nature of the article involved. By machining is meant drilling, tapping, hobbing, milling, turning or grinding. Any such machining is preferably done at an economic rate without excessive surface tool wear or breakage.

Surface hardening is typically accomplished by flame or induction heating to a temperature within the austenite region of the particular alloy and subsequently rapidly cooling to develop a hard martensite microstructure in the surface.

In the case of camshaft **10** as shown in FIGURE 3, this sequence of post-annealing operations is as follows:

Center holes **14** are located and drilled at either end of the camshaft **10** to facilitate the lobe hardening heat treatment. The surfaces of the lobes **12** are then heated by flame or by induction to a temperature in the austenite region of the particular alloy and subsequently cooled rapidly to develop a hard martensite microstructure in the surface. Other unhardened surfaces are then machined such as the journals **16** and the gear **18**. The lobe surfaces **12** are then finished by a grinding operation.

Specific cast iron compositions of this invention are secondary to microstructure and surface hardness obtainable by the post-annealing surface heat treatment. In a camshaft, the content of hard metallic carbides and the matrix hardness in the lodes are the factors to be controlled for good durability.

Metallic carbide content can be kept high by controlling the carbide forming element content (chromium, vanadium, molybdenum, manganese, columbium, tungsten and zirconium) and the chilling tendency of the mold. The proper economic balance between these factors that still produce a primary complex iron carbide content in excess of 10% by weight is the one to be used.

Thus, the subject invention includes the application of the above annealing heat treatment to a highly carbidic cast iron alloy article when it is desired to obtain a tough and durable article which can be economically machined and if necessary subjected to a surface hardening heat treatment.

An example of the proper combination of the composition factors and an illustration of a specific embodiment of the invention in the preparation of a camshaft is as follows. Reference may be made to the camshaft in FIGURE 3.

A cast iron alloy comprised of 3.25–3.50% carbon, 2.20–2.45% silicon, 0.60–0.80% manganese, 1.30–1.50% chromium, 0.40–0.60% molybdenum, 0.25–0.40% nickel, less than 0.15% sulphur, less than 0.20% phosphorus and the balance mostly iron was cast into a camshaft **10**. After shake out and cleaning the camshaft **10** was heated at temperatures of from about 1250° F. to about 1300° F. for about 3½ hours to produce incipient spheroidization of pearlite and lower matrix hardness below 30 Rockwell C. Of course, this temperature range is below the austenite region for this alloy.

Center holes **14** were drilled in the ends of the camshaft to facilitate the final lobe hardening heat treatment.

The camshaft **10** was then subjected to a post-annealing lobe hardening step. The lobe surfaces **12** were flame heated into the austenite region and then rapidly cooled to produce a hard martensite structure. Macro hardness produced by this surface hardening of the lobe should lie between 48 and 58 Rockwell C. This hardness is made more easily obtainable by the homogenizing effect of the pre-hardening anneal.

After the surface hardening operation various surfaces of the cam-shaft were machined as discussed in detail above.

While this invention has been described in terms of a certain preferred embodiment, it is to be understood that other applications will be apparent to those skilled in the art and are within the scope of this invention as defined by the following claims.

We claim:

1. A method of improving the durability and machinability characteristics of a carbidic cast iron article containing 10% by weight or more primary complex iron carbides which comprises annealing the cast iron casting at a suitable temperature in the temperature range of 300 Fahrenheit degrees immediately below the lower critical temperature of said carbidic cast iron for a time sufficient to produce incipient spheroidization of pearlite and to lower matrix hardness below 30 Rockwell C and subsequently cooling the casting to about normal room temperature whereby said casting may subsequently be machined at an economical rate and a surface of said article may more readily be hardened, said cast iron containing an element, which promotes the formation of hard complex iron carbides, taken from the group consisting of chromium, vanadium, molybdenum, columbium, manganese, tungsten and zirconium.

2. A method to improve the durability and machinability of a carbidic cast iron camshaft containing 10% or more by weight primary complex iron carbides which comprises casting the camshaft, cooling the camshaft casting and removing the mold, cleaning said casting, annealing said camshaft casting at a suitable temperature in the temperature range of 300 Fahrenheit degrees immediately below the lower critical temperature of said carbidic cast iron for a time sufficient to produce incipient spheroidization of pearlite and to lower matrix hardness below 30 Rockwell C, air cooling said camshaft, surface hardening the lobes of said camshaft by heating said lobe surfaces to a temperature within the austenite region and subsequently rapidly cooling to produce a hard martensite structure and machining predetermined surfaces of said camshaft other than said lobe surfaces, said camshaft alloy (having been inoculated with) containing a carbide forming element taken from the group consisting of chromium, vanadium, molybdenum, manganese, columbium, tungsten and zirconium.

3. A method to improve the durability and machinability of a cast iron camshaft which comprises casting the camshaft, cooling said camshaft casting and removing the mold, cleaning said casting, annealing said camshaft at a temperature from about 1250° F. to about 1300° F. for at least about 2½ hours to produce incipient spheroidization of pearlite and to lower matrix hardness below 30 Rockwell C, air cooling said camshaft, surface hardening the lobes of said camshaft by heating the lobe surfaces to a temperature within the austenite region and subsequently rapidly cooling to produce a hard martensite structure, and machining predetermined surfaces of said camshaft other than said lobe surfaces, said camshaft alloy comprised of 3.25–3.50% carbon, 2.20–2.45% silicon, 0.60–0.80% manganese, 1.30–1.50% chromium, 0.40–0.60% molybdenum, and the balance substantially all iron.

4. A method of improving the durability and machinability characteristics of a carbidic cast iron article containing 10% or more by weight primary complex iron carbides which comprises annealing the cast iron casting

at a suitable temperature in the temperature range of 300 Fahrenheit degrees immediately below the lower critical temperature of said carbidic cast iron for a time sufficient to produce incipient spheroidization of pearlite and to lower matrix hardness below 30 Rockwell C and subsequently cooling the casting to about normal room temperature whereby said casting may subsequently be machined at an economical rate and a surface of said article may more readily be hardened, said cast iron comprising by weight 3.25–3.50% carbon, 2.20–2.45% silicon, a carbide forming element taken from the group consisting of chromium, vanadium, molybdenum, manganese, columbium, tungsten and zirconium in an amount sufficient to produce said 10% or more by weight primary complex iron carbides and the balance substantially all iron.

5. A pearlitic carbidic cast iron article containing 10% or more by weight primary complex iron carbides wherein the pearlitic matrix is in the state of incipient spherodization having a hardness below 30 Rockwell C and wherein at least one surface layer of said article is martensitic and has a hardness greater than 48 Rockwell C.

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CHARLES N. LOVELL, *Primary Examiner.*

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,384,515 May 21, 1968

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It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 43, "lodes" should read -- lobes --. Column 4, line 51, cancel "(having been inoculated with)".

Signed and sealed this 16th day of September 1969.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents