MALLEABLE CAST IRON COMPOSITIONS

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This is a continuation-in-part of my co-pending application Serial No. 466,309, filed on November 2, 1954.

The present invention relates to cast iron compositions for the heat treating described in the U.S.A. patent applications Serial No. 335,579 of February 6, 1953, now U.S. Patent No. 2,901,386, dated August 25, 1959, and No. 336,187 of February 10, 1953, now U.S. Patent No. 2,901,384, dated August 25, 1959, to produce diffused nodular graphite cast iron of most greater than normal breaking strength of malleable iron and of such high strength that it is capable of replacing rolled steel in numerous applications.

The U.S.A. patent application Serial No. 335,579 is concerned by a process comprising the steps of subjecting the white cast iron after cooling to martensitic hardening of the casting by austenitization with heat at a temperature slightly above that at the end of the eutectoid transformation followed by progressive cooling including quenching in a medium maintained between 150 to 250°C, maintaining the casting in the medium for a period of time between 30 seconds and 6 minutes, and then cooling to room temperature to produce the martensitic transformation, nucleation tempering the thus-produced cast iron by heating at a temperature of 430 to 500°C for a prolonged period of time of 3 to 48 hours, further heating the thus treated iron at a temperature of about 900°C to effect graphitization of the iron, and cooling to room temperature.

In accordance with the U.S.A. patent application Serial No. 336,187, the iron is cast in the form of a white iron casting having a thickness up to 30 mm. and containing copper in a concentration of 0.7% to 3% and the thus-formed casting is then subjected to a specified sequence of steps which comprises subjecting the casting of the white cast iron thus obtained to hardening by austenitization with heat at a temperature above the temperature at the end of the eutectoid transformation, followed by step quenching, to a temperature below the M₁ whereby to form martensite, nucleation tempering at a temperature between 400 and 500°C for 24 to 100 hours to effect the formation of nuclei in the graphite, and subjecting the casting to graphitization of the primary cementite by maintaining the casting at a temperature of about 875°C to 900°C for a period of time sufficient for the total disappearance of the cementite.

In the cast iron composition mentioned in these patents and subjected to the above mentioned three-phase treatment, it becomes difficult to keep the structure completely white, i.e. free from graphite, when sand-moulding massive parts. This difficulty is increased by the presence of graphitizing elements such as copper. This can be remedied by limiting the carbon and increasing the manganese beyond the maximum proportions provided in malleable cast irons, owing to the new process of graphitization.

Moreover it has been found that the consecutive treatments of austenitization, followed by martensite hardening, nucleation tempering and graphitizing annealing in the manner described in said patent applications give rise to a number of nodules of graphite per unit of volume which is less in proportion as the solidification cooling is slower, that is to say as the casting thicknesses are more considerable and as the amount of heat removed by the mould is reduced, as is the case when dried core sand is substituted for wet green sand. Since the number of nuclei is reduced, there is a costly and notable increase in the time required for graphitization, the more so since the manganese content has also been increased.

It has been recognized that these disadvantages can be remedied by adding titanium and aluminum separately or simultaneously, but, in these cases, the nodules of graphite which appear in the annealing operation have a star-shaped form prejudicial to good mechanical properties.

It has now been shown according to the invention that zirconium, acting as spherical graphitizer, does not have these disadvantages and gives rise to nodules of annealing graphite which are of a very rounded, almost spherical shape, whilst remaining numerous and of small dimensions.

The invention relates therefore to a new high resistance cast iron composition for the three-phase treatment comprising preliminary hardening and nucleation tempering before graphitizing annealing as described in said applications and which is applicable to massive parts of up to 60 mm. in thickness or diameter, as is the case, more particularly, with cast crankshafts for internal combustion engines for automobile vehicles.

Thus, referring to said applications, this three-phase treatment comprises the steps of effecting martensitic hardening of the casting by austenitization with heat at a temperature slightly above that at the end of the eutectoid transformation followed by cooling to produce the martensitic transformation, tempering the thus-produced martensite by heating at a temperature of 400 to 500°C for a prolonged period of time up to about 100 hours, further heating the thus-treated iron at a higher temperature in the vicinity of 900°C to effect graphitization of the iron and cooling to room temperature.

According to one feature of the invention, the new composition is comprised within the following percentage limits:

<table>
<thead>
<tr>
<th>Element</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>1.6 to 2.6, preferably 2.10</td>
</tr>
<tr>
<td>Si</td>
<td>0.9 to 1.9, preferably 1.40</td>
</tr>
<tr>
<td>Mn</td>
<td>0.7 to 1.7, preferably 1.20</td>
</tr>
<tr>
<td>Cu</td>
<td>0.1 to 2.1, preferably 1.45</td>
</tr>
<tr>
<td>Zr</td>
<td>0.03 to 0.9, preferably 0.60</td>
</tr>
</tbody>
</table>

In addition it contains the customary impurities S, P, etc. in the usual concentrations, for examples: 0.04 sulphur and 0.03 phosphorus.

The invention also relates to compositions which, moreover, contain special elements such as Ni in order to improve the hardening capabilities or the structure, and therefore the mechanical properties, without changing the principle of the invention. It is to be noted that the more the castings are massive, the more important must be the amount of nickel which, however, must not exceed 3%.

The invention further relates to cast iron compositions wherein the manganese is partially replaced by an amount of at least one of the group of metals chromium, vanadium and molybdenum of equal content in order to make it easier to obtain a white casting structure, but sufficiently limited to allow graphitization by the aforesaid three-phase processes, the remaining manganese percentage being in all cases at least 0.35%.

When the manganese is partially replaced by an amount of only one of the groups of metals chromium, vanadium and molybdenum, the following percentages must be respected:

<table>
<thead>
<tr>
<th>Element</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cr</td>
<td>0.05 to 0.3</td>
</tr>
<tr>
<td>V</td>
<td>0.02 to 0.15</td>
</tr>
<tr>
<td>Mo</td>
<td>0.1 to 0.1</td>
</tr>
</tbody>
</table>

When the compositions comprise simultaneously the
above three elements, the total percentage of them must not exceed 1% for avoiding difficulties in graphitization, the sum of chromium and vanadium however rising not above 0.4%.

Cast irons made according to this invention have the following characteristics:

Number of very fine, uniformly distributed rounded, generally spherical graphite
2,000 to 10,000 per sq. mm.

Yield strength in kg./sq. mm. 60 to 85.
Tensile strength in kg./sq. mm. 70 to 90.
Elongation in percent 2 to 5.
Mesner's resilience in kg./sq. mm. 0.5 to 1.

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

Example 1

The following composition: C=2.07, Si=1.40, Mn=1.18, Cu=1.47, Zr=0.60, Ni=0.18, S=0.040, P=0.027, was cast in wedge moulds made from dry core sand according to the accompanying drawing, the dimensions being: d=50 mm., e=18, f=40, h=20, H=100, I=115.

When the casting is fractured, the structure is white to the heart and totally free from graphite. The casting treatment was as follows:

Heating at 820° C., for 30 minutes, 180° C. salt hardening, for 2 minutes, cooling in calm air;
Then re-heating to 450° C., 48 hours cooling in calm air;
Then re-heating to 930° C., 2 hours, cooling for 3 hours to 800° C., then drawing off and cooling in calm air.

The structure is graphitized in homogeneous manner throughout its entire section. The number of graphite nodules is approximately 4,500 per sq. mm. and the said nodules are of rounded shape proximating the spherical shape.

In order to improve tenacity, the complete graphitization treatment was followed by the following treatment for quality:

Re-heating to 840° C., 20 minutes oil hardening;
Re-heating to 680° C., 20 minutes oil hardening, to maintain the copper in super saturated;
Re-heating to 500° C., 2 hours, cooling in calm air, whereby to obtain a structural hardening by precipitation of copper.

The mechanical characteristics discovered in the wedge portion of the casting which was 17 x 20 mm. in section, are then:

Yield strength, kg./sq. mm., from 71 to 82, average 78;
Tensile strength, kg./sq. mm., from 77 to 87, average 83;
Elongation, percent, from 3 to 5, average 4;
Mesner's resilience in kg./sq. cm. from 0.6 to 0.9, average 0.8.

The endurance limit was determined by Moore sample rotary flexion and was found to be 36 g./sq. mm.

Example 2

Cranks of motor car engines with crankpins of a diameter of 55 mm. were cast in green sand moulds, the iron composition comprising: C=2%, Si=1.3%, Mn=1.2%, Ni=0.8%, Cu=1.3%, Zr=0.6%.

As cast, the iron had a white structure to the heart.

The treatment was as follows:

Heating at 820° C., for 30 minutes, 180° C. salt hardening, for 2 minutes, cooling in calm air;
Then re-heating at 450° C., for 24 hours, cooling in calm air;
The graphitization by re-heating at 950° C., for 4 hours, cooling in calm air.

The number of very fine, uniformly distributed rounded, generally spherical graphite nodules found to the heart was approximately 3,500 per sq. mm.

It is to be noted that the same composition, but without nickel, submitted to the same treatment, contained to the heart only less than 400 graphite nodules per sq. mm.

The following Example 3 shows the influence of chromium when it replaces partially manganese.

Example 3

The following two compositions: (a) C=2.2%, Si=1.5%, Mn=0.8%, Cu=1.3%, Ni=0.8%, Zr=0.10%;
(b) C=2.2%, Si=1.5%, Mn=0.5%, Cu=1.3%, Ni=0.8%, Zr=0.10%, Cr=0.15%, were cast in green sand moulds to produce cylindrical castings, the dimensions being:

Length=300 mm.
Diameter=40 mm.

The casting obtained with the first of the above mentioned compositions was not entirely white after pouring.

The presence of 0.15% chromium in the second composition permitted to obtain after casting an entirely white structure, this amount of chromium being insufficient for hindering graphitization in the conditions of treatment as described in the foregoing examples.

Without chromium, an identical result could only be obtained by increasing the amount of manganese from 0.8 to 1.7%.

The above indicated precise temperatures and times for the three-phase treatment and the treatment for quality are only those relating to examples, but it is evident that other temperatures and times of approximately the same values produce approximately the same mechanical characteristics as those above mentioned.

I claim:
A high strength malleable iron casting, white and free from graphite as cast, composed largely of iron and containing 1.6 to 2.6% carbon, 0.9 to 1.9% silicon, 0.35 to 1.7% manganese, 0.1 to 2.1% copper, 0.03 to 0.9% zirconium and a metal selected from the group consisting of chromium, vanadium and molybdolum, the quantity of chromium being 0.5 to 0.3%, the quantity of vanadium being 0.02 to 0.15%, and the quantity of molybdenum being 0.1 to 1%, the composition of the casting without said metal being such that it would form a grey structure as cast and at least one of said metals being present in an amount sufficient to obstruct formation of graphite during solidification of the casting, said casting containing 2,000 to 10,000 per sq. mm. of very fine, uniformly-distributed, generally-spherical graphite nodules, the composition of the casting without zirconium being such that the external area of the graphite nodules would, for a given volume, be greater than that of said generally-spherical graphite nodules, said casting having the following mechanical characteristics: an elastic limit in kg./mm.² of 60 to 85, a tensile strength in kg./mm.² of 70 to 90, an elongation of 3 to 5%, and a mesner's resilience in kg./cm.² of 0.5 to 1.

References Cited in the file of this patent

UNITED STATES PATENTS
2,077,117 Lavenstein ———————— April 13, 1937
2,185,894 Hultgren ———————— June 24, 1940
2,331,886 Boegehold ———————— Oct. 19, 1943
2,570,225 Boegehold ———————— Feb. 27, 1951
2,490,818 Kurniansky ———————— Dec. 13, 1949
2,651,570 Heine ———————— Sept. 8, 1953

OTHER REFERENCES