Research and features of preliminary graphitizing processing of melt of iron with silicon carbide on the structure and properties of cast iron castings

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Abstract. The materials used for preliminary graphitizing treatment of cast iron melt (pre-modification), of which silicon carbide has the greatest technical and economic advantage, are considered. The features of the graphitizing effect of silicon carbide during the preparation of a gray cast iron melt on its structure and properties in standard cylindrical samples and clutch plate castings are analyzed. It is shown that its graphitizing effect on the cast iron melt begins to partially manifest itself already at the stage of introduction into the furnace and enhances the action of the main graphitizing modifier during subsequent ladle treatment as a result of a decrease in the content of interdendritic graphite in the microstructure.

1. Introduction

The problem of "necrosis" of the cast iron melt during the manufacture of castings often arises at industrial iron foundries. By "necrosis" is meant a significant deterioration in the susceptibility of the cast iron melt to graphitizing modification with a decrease in the number of nucleation centers of graphite inclusions (TCGI). "Necrosis" occurs due to its overexposure in the holding-furnace for more than 2 hours because of many organizational and technical problems [1-6].

In practice (when iron melting under the conditions of foundry of JSC AVTOVAZ), the consumption of the graphitizing modifier during ladle treatment of the melt from an induction crucible furnace (ICA) is 0.3%. The consumption is doubled during ladle treatment of the melt from an electric arc furnace (EAF). This difference is associated with the peculiarities of smelting processes in EAF (loops, gases in the metal, inhomogeneous overheating of the charge, reducing the amount of TCGI, etc.), which reduce the tendency of cast iron to modify and, as a consequence, cause the appearance of interdendritic graphite and carbides.

"Necrosis" is noticeably manifested in the one-stage graphitizing inoculation in the gray cast iron melt, therefore, the solution of this problem is extremely important and urgent, since it directly affects the quality of the resulting cast iron: casting defects (shrinkage and gas porosity, gas pockets), strength and structural indicators. An overexposed cast iron melt, modified according to any of the existing technologies, needs a "revitalization" operation. There are in-stream inoculation in the process of casting molds and in-stream inoculation during pouring from the holding-furnace into the casting ladle
[7]. The latter technology is more traditional and most widely used in most iron foundries. The main disadvantage of this technology is the withering of the effect of graphitizing modification in the process of casting molten cast iron into foundry molds. The problem is solved by treating the cast iron melt with pre-modifiers. Usually, a material based on FS65 Preseed® (Elkem, Norway) with additions of zirconium, aluminum and calcium is used. In the CIS countries, a material is used on the basis of FS45 Refloy® (NPP Tekhnologiya LLC, Russia), where magnesium, rare earth metals and fluorspar are introduced instead of zirconium [8,9].

However, the most economically and technically feasible is the use of metallurgical silicon carbide (SiC) to "revive" overexposed cast iron melt, in particular, the waste from the main production in the form of crushed and scrap carborundum stones, which is a secondary raw material with valuable metallurgical properties at a relatively low price [10].

The paper presents a study of the use of silicon carbide at the stage of finishing the cast iron melt in the duplex process during its overflow from the EAF to the holding-furnace (ICA).

2. Material and Methods

The study of the graphitizing ability of silicon carbide in the form of breakage and scrap of carborundum stones with a pure SiC content of 95% was carried out at the stage of finishing the cast iron melt in the duplex process during its overflow from the EAF to the holding-furnace (ICA). The execution time of each melting operation and the composition of the charge are given in table 1.

When overflowing, 50 kg of 95% silicon carbide was introduced into the gutter. There is a visual end of the process of its assimilation after overflow without an increase in slag formation. After that, the bath level of the cast iron melt was cleaned from slag and pieces of electrode breakage weighing 8-12 kg were introduced to reduce carbon waste and exclude the possibility of saturation of the surface layers of the metal with oxygen by creating a carbon film. The furnace and ladle chemical composition of cast iron is given in table 2.

To assess the microstructure of the smelted cast iron, a standard cylindrical sample Ø 25-30 mm was poured after finishing the cast iron melt on the trough during overflow from EAF to ICA with silicon carbide in an amount of 50 kg at 1500°C.

In order to create stable TCGI with the elimination of the time factor of the smelted metal being in the holding-furnace, the use of silicon carbide makes it possible to obtain a uniform distribution of lamellar graphite in the microstructure of cast iron with its deterioration with a decrease in the sample cross section.

After lowering the temperature of the cast iron melt in an induction furnace to 1470°C and finishing it with FS45 ferrosilicon to a silicon content of 1.85%, it was cast into ladles with microalloying with copper, tin and graphitizing treatment with 0.32% of the Barinoc®75 modifier (fr. 2-6 mm). The temperature of the cast iron melt in the ladle is 1410°C, the chill of the wedge sample is 1.8 mm. The chemical composition of cast iron in a ladle sample is given in table 2.

### Table 1. The execution time of each melting operation and the composition of the charge

| Operation, time               | Charge bucket, kg                                                                 |
|------------------------------|----------------------------------------------------------------------------------|
| Raw materials preparation, 30 min | Bucket I: return of own production 7500, low-alloy steel 9500, alloy steel 3000, pig iron (conversion) 2000, crushed graphite 500 |
| Bucket charging (I), 5 min    | Bucket II: return of own production 7500, low-alloy steel 9500, alloy steel 3000, pig iron (conversion) 2000, crushed graphite 500, ferrosilicon FS45 500 |
| Metal melting, 1 h            |                                                                                  |
| Bucket charging (II), 5 min   |                                                                                  |
| Metal melting, 1 h            |                                                                                  |
| Removing slag from EAF, 5 min |                                                                                  |
| Finishing of the chemical composition, 25 min |                                                                                  |
| Pouring into an induction 20-ton furnace, 10 min |                                                                                  |
| Total: iron smelting 5 h 40 min | Total: 45,500 excluding waste and error batch weighing                             |
Table 2. The chemical composition of cast iron in a ladle sample

| Sampling location | Chemical composition, % |
|-------------------|-------------------------|
|                   | C | Si | Mn | P  | S | Cr | Ni | Cu | Sn |
| EAF               | 3.28 | 1.57 | 0.31 | 0.026 | 0.025 | 0.065 | 0.027 | 0.15 | 0.016 |
| ICA               | 3.32 | 1.72 | 0.31 | 0.027 | 0.025 | 0.065 | 0.027 | 0.15 | 0.016 |
| Ladle             | 3.33 | 1.99 | 0.32 | 0.026 | 0.026 | 0.067 | 0.027 | 0.55 | 0.085 |

The measurement of mechanical properties (tensile strength of cast iron) was carried out in accordance with GOST 1497 on the sample with a diameter of 14 mm with an estimated length of 70 mm.

3. Results

The microstructure of cast iron (×100) along the edges (in the area of the ∅25 mm feeder, from the opposite edge ∅ 30 mm) and in the middle (∅ 30 mm) of a standard cylindrical sample is shown in figure 1.

![Microstructure of sections of a cylindrical sample (×100): a - Sample ∅25 mm (feeder zone) is characterized by a pearlite-cementite microstructure with interdendritic distribution of graphite types D, E; b - Sample ∅30 mm (middle) is characterized by a pearlite microstructure with a distribution of type A and D graphite. Ferrite up to 4% is present only between plates of type D interdendritic graphite; c - Sample ∅30 mm (edge) is characterized by a pearlite microstructure with a distribution of graphite of types A, D. Ferrite up to 4% is present both between plates of interdendritic graphite of type D and in zones with uniformly distributed graphite of type A.](image)

Thus, finishing of the cast iron melt over silicon (ladle modification and microalloying with copper and tin, carried out after processing the cast iron melt with silicon carbide on the trough during
overflow) allows providing a pearlitic metal base of cast iron and a uniform distribution of type A graphite in all sections of the cylindrical sample.

To assess the microstructure of cast iron in castings L 01202-0711-00 "Clutch disc", samples were cut along the "eye" from the side of the feeder and opposite it. Metallographic examination revealed the same content and distribution of ferrite in the area of the feeder and opposite it.

In the friction zone and the main section of the casting, graphitization is improved: the distribution of graphite is almost completely represented by type A, the content of types D, E is minimized (figure 2, 3). The rupture strength of cast iron in castings ranged from 260 to 290 MPa with a standard of at least 250 MPa.

**Figure 2.** Scheme of cutting out samples from casting L 01202-0711-00 "Clutch disc" to assess the microstructure and determine the ultimate tensile strength

**Figure 3.** Morphology of graphite and microstructure of gray iron in castings L 01202-0711-00 "Clutch disc" without pretreatment / with pretreatment of the melt with silicon carbide

**Conclusions**

Compared with the results obtained by the serial technology, additional processing of the cast iron melt with silicon carbide on the trough during its overflow from the arc furnace into the induction furnace made it possible to improve graphitization (the number of graphite inclusions): in thin sections
of the ear, the maximum content of interdendritic distributions of graphite types D, E decreased from 100% to 60%.

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