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Technology for producing cast iron castings with compact graphite by top filling

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Abstract. The technology of ladle modification "top filling" has been tested and introduced to produce castings of parts from low grades of high-strength cast iron, in particular ChVG40, VCh50. The technology allows us to consistently achieve a degree of graphite spheroidization of at least 80%. For each of the mastered castings of the parts "Reduction gear axle casing", "Front idler hub" and "Exhaust manifold", the consumption of a spheroidizing modifier and a graphitizing modifier was selected. In the chemical composition of the castings, to obtain a predominantly ferrite-pearlite structure, the manganese content was adjusted from 0.4...0.5% to 0.3...0.4%.

1 Introduction

The purpose of the work is to test and develop new promising technologies and materials to reduce costs and improve the quality of cast iron in castings in the production of automotive castings from high-strength cast iron.

Considering the fairly wide range of grades of high-strength cast iron used for the manufacture of castings for car parts, a step-by-step approach to their development is the most justified and rational [1-4]. In particular, castings from low grades of high-strength cast iron (ChVG40, VCh50), having less stringent requirements for microstructure and properties (the predominance of the ferrite component of the structure and SSG ≥ 80% [5-7]), can be obtained in a somewhat simplified manner both in terms of labor intensity, and the complexity of the equipment and technology used.

The most widespread and well-proven in practice "sandwich" process in an open ladle can be used to modify high-strength cast iron only in ladles with a height to average diameter ratio of 2...2.5:1 [8,9]. Pouring ladles with a metal capacity of 1.2 tons used in iron foundries have a height to average diameter ratio of 1.4:1 [10,11]. In practice, the fundamental impossibility of stable modification of high-strength cast iron using the "sandwich" process in open serial pouring ladles with a wide variety of designs and

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locations of the reaction pocket for accommodating the modifier has been repeatedly confirmed [12,13]. Thus, with the existing characteristic ratio in the ladle of 1.4:1, the stability of the technological process of modifying high-strength cast iron can be ensured only by transforming it into the "ladle with lid" process. The use of this technology can be justified when producing castings from medium grades of high-strength cast iron, for example, Gh56-40-05, Gh65-48-05. When making castings from high-strength cast iron, a technology that is somewhat more simplified in relation to the "sandwich" process - "top filling" (Fig. 1) [14,15] can also be used.

2 Methodology and description of technology

The objects of study were castings of parts made of high-strength cast iron of the brands VCh40 - "Exhaust manifold" and VCh50 - "Front idler hub" and "Reduction gear axle casing".

Using the "top filling" technology, a modifier of the FSMg type (Lamet®5836) is placed on the bottom of the ladle on the opposite side from its toe. It is introduced through a special filling pipe (Fig. 1, a) or placed in a plastic bag in a ladle previously rotated by 45° (Fig. 1, b).

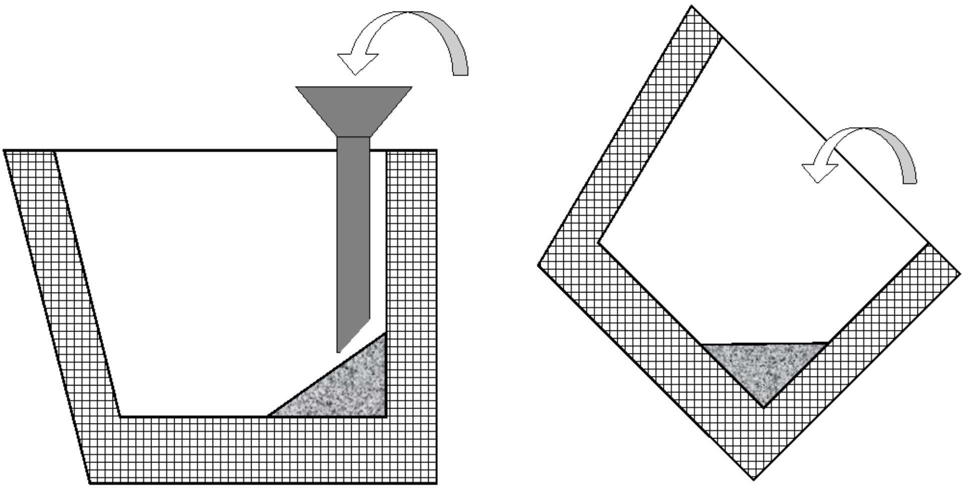

Fig. 1. Options for filling "light" magnesium-containing master alloy when modifying high-frequency materials using the "top filling" method

When filling the ladle with metal, the melt stream is supplied closer to the toe of the ladle to avoid erosion and premature reaction of the modifier with the molten cast iron. The metal stream from the holding furnace must be supplied continuously, and the force of its pressure must be determined based on the following considerations.

Based on Reynolds' law:

$$Re = \vartheta \cdot D_{eq} / \nu \qquad (1)$$

where Re is the Reynolds number; ϑ – average fluid flow velocity, m/s; Deq is equivalent pipeline diameter, m; ν is kinematic viscosity of the liquid at operating temperature, m^2/s, The time for filling the ladle with liquid cast iron can be estimated from the expression:

$$t_k = {V_k \cdot D_{eq}^n}\Big/{S_{ci} \cdot v_{ci} \cdot \mathrm{Re}} \qquad (2)$$

where t_k is the time of filling the ladle with molten cast iron, s; V_k is ladle volume, m^3; D_{eq}^n is equivalent diameter of the furnace nose, m; ν_h – kinematic viscosity of cast iron melt at pouring temperature, m^2/s; S_{ci} is the live cross-section of the cast iron flow, m^2; Re is the Reynolds number.

When filling a ladle with a "light" spheroidizer in accordance with the "top filling" technology, it is necessary that the mode of movement of the cast iron melt from the holding furnace into the ladle is unsteady, that is, Re ≈ 3000...6000. In contrast to the "top filling" technology, the "sandwich process" technology has significantly less sensitivity to the mode of movement of the melt in the ladle. As a result, there are no strict restrictions on the Reynolds number, since the modifier is covered with a coating material.

In the turbulent mode of movement of the cast iron melt from the furnace to the ladle (that is, with a strong jet, Re > 6000), due to the rapid filling of the ladle, a splash of metal occurs and particles of unreacted modifier are released. All this worsens the environmental situation and imposes restrictions on working with this technology in an open ladle.

In the laminar mode of movement of the cast iron melt from the furnace to the ladle (that is, with a weak jet, Re < 3000), due to the slow filling of the ladle, most of the modifier floats to the mirror and reacts with air oxygen, which leads to accelerated fading of the modifying effect due to premature magnesium waste.

Therefore, the ladle filling time is inversely proportional to the Reynolds number and should be within the recommended range. It is accepted that the metal consumption of the ladle is 0.17 m3, the equivalent diameter of the furnace nose is 0.367 m, the open flow cross-section is assumed to be 2/3 of the cross-section of the furnace nose - 0.0176 m2 and the kinematic viscosity of the cast iron melt is 2·10-5 m2/s there are known and constant quantities. By substituting the range of Reynolds numbers 3000...6000 into the formula, you can determine the optimal range of time for filling the ladle with the best absorption of magnesium from the modifier: t = 30...60 s.

Considering that, due to the absence of a coating material, the modifier begins to immediately react with the cast iron melt, its weight should be slightly increased compared to the weight recommended for the "sandwich" process.

During the first casting of each part, one casting from the last mold of each ladle was provided for control as the most indicative. During subsequent castings, from one to several castings were selected for control in random order according to the established procedure. Secondary modification in the pouring bowl of the mold is a piece of FS75l3.

In the process of testing this technology, five float castings were carried out for the "Exhaust manifold" parts made of cast iron of the ChVG40 grade, four for the parts "Front idler hub" and six parts for the "Reduction gear axle casing" parts from cast iron of the VCh50 grade.

Ladle modification when receiving parts:

- "Exhaust manifold": Lamet®5836 – 8 kg.
- "Front idler hub":
  1. Lamet®5836 - 15 kg, FS75l6 - 4 kg.
  2. Lamet®5836 - 16 kg, FS75l6 - 4 kg.
  3. Lamet®5836 - 16 kg, FS75l6 - 4 kg.
  4. Lamet®5836 - 16 kg, FS75l6 - 5 kg.
- "Reduction gear axle casing":
  1. Lamet®5836 – 16.5 kg, FS75l6 – 2 kg.
  2. Lamet®5836 - 16.5 kg, FS75l6 - 2 kg.

3. Lamet®5836 - 17 kg, FS75l6 - 3 kg.
4. Lamet®5836 - 17 kg, FS75l6 - 3 kg.
5. Lamet®5836 - 17 kg, FS75l6 - 3 kg.
6. Lamet®5836 – 17 kg, FS75l6 – 3 kg (manganese in the oven – 0.36%).

3 Result and Discussion

Furnace and ladle chemical analysis of cast iron in castings is presented in Table 1. The microstructure and Brinell hardness of the studied casting samples are given in Table 2.

Table 1. Furnace and ladle chemical composition of cast iron in castings. %wt.

Sampling location	C	Si	Mn	P	S	Cr	Ni	Cu	Sn	Mg
"Exhaust manifold"										
Furnace	3.63-3.80	1.91-1.97	0.43-0.50	0.017-0.020	0.007-0.010	0.058-0.064	0.22-0.31	0.22-0.44	0.016-0.023	–
Ladle	3.50-3.75	2.12-2.27	0.43-0.50	0.016-0.019	0.005-0.009	0.057-0.065		0.21-0.45	0.015-0.026	0.019-0.040
	"Front idler hub"									
Furnace	3.63-3.68	1.90-1.95	0.41-0.44	0.017-0.018	0.005-0.009	0.050-0.068	0.20-0.28	0.21-0.27	0.013-0.020	–
Ladle	3.50-3.64	2.62-2.84	0.42-0.44	0.016-0.023		0.051-0.068	0.20-0.29	0.20-0.30	0.014-0.021	0.044-0.070
	"Reduction gear axle casing"									
Furnace	3.67-3.74	1.90-2.02	0.36-0.48	0.015-0.022	0.006-0.009	0.053-0.063	0.18-0.31	0.16-0.23	0.014-0.026	–
Ladle	3.47-3.70	2.60-2.81		0.013-0.023	0.005-0.009	0.052-0.065	0.17-0.32	0.14-0.25		0.050-0.069

Table 2. Microstructure and Brinell hardness of cast iron in castings.

Casting	Microstructure	$HB_{5/750/10}$
"Exhaust manifold"	Vermicular graphite VGf2, VGf3 – 20-60%; spherical ShGf4, ShGf5 – 40-80%. Metal base – P 30-60%	187-239
According to normative documentation	Vermicular graphite VGf2, VGf3; spherical ShGf4, ShGf5 without specifying the proportion of spherical inclusions. The metal base is ferrite-pearlite, cementite no more than 5%.	180-250
"Front idler hub"	SSG - 80-90%; metal base – F 50-90%	170-229
According to normative documentation	Nodular graphite, SSG – not less than 80%; metal base – ferrite-pearlite, cementite up to 5%	170-210 (after annealing)
"Reduction gear axle casing"	SSG - 80-90%; metal base – F 50-80%	179-217
According to normative documentation	Nodular graphite, SSG – not less than 80%; metal base – ferrite-pearlite, cementite up to 5%	170-220

Thus, the structure and properties of the experimental castings meet all the requirements of the RD. In the process of testing the technology, the most stable results were obtained with the following ladle flow rates of modifying materials:

”Exhaust manifold”: Lamet®5836 – 8 kg;

”Front idler hub”: Lamet®5836 – 16 kg, FS75l6 – 5 kg;

"Reduction gear axle casing": Lamet®5836 - 17 kg, FS75l6 - 3 kg.

Data on ladle consumption of modifying materials were included in the technological instructions "For the production of high-strength cast iron with nodular graphite."

The manganese content in cast iron was reduced from 0.4...0.5% to 0.3...0.4% in order to avoid the high hardness of the "Front idler hub" and "Reduction gear axle casing" castings.

The results of the work carried out to test and implement the "top filling" technology in an open ladle with a ratio of height to average diameter of 1.4:1 confirmed the possibility of using a "light" alloy of the FSMg type in the production of castings of parts from low grades of high-strength cast iron - up to HF50 inclusive. Scientifically based recommendations have been developed for the mode of movement of molten cast iron from the furnace to the ladle when working using the "top filling" technology and, based on this, the optimal time for filling the ladle with molten cast iron, from the point of view of the efficiency of the modifier, has been established t = 30...60 s.

4 Conclusion

A technology has been developed and implemented for producing castings from low-grade ductile iron (VCh40, VCh50) - "top filling". It has been established that this technology makes it possible to ensure stable quality of cast iron in castings with a degree of graphite spheroidization of at least 80%. Scientifically based recommendations have been developed for the mode of movement of molten cast iron from the furnace to the ladle. The optimal time for filling a serial pouring ladle with molten cast iron, from the point of view of the efficiency of the modifier, has been established as t = 30...60 s. The consumption of a "light" ligature of the FSMg type has been selected to ensure the required quality of modification: for the VCh40 brand - 0.67% (8 kg per metal capacity of the ladle 1200 kg), for the VCh50 brand - 1.33-1.42% (15-16 kg per ladle with a metal capacity of 1200 kg).

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