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ISSN 0543-5846
METABK 60(1-2) 97-100 (2021)
UDC – UDK 669..14:669.163-678.674:620.18:66.093-621.6.02=111

LOST PATTERN COMPLEX COMPOSITION EFFECT ON STEEL CASTING STRUCTURE AND PROPERTIES

Received – Primljeno: 2020-08-26
Accepted – Prihvaćeno: 2020-10-25
Preliminary Note – Prethodno priopćenje

One of the ways to produce high-quality castings at relatively inexpensive costs is lost foam casting. However, the existing problem of surface carburization due to the burnout of the polystyrene pattern and general contamination of the near-surface layer is one of the factors that hinder the widespread use of this casting method. In order to minimize carburization, it is proposed to use a complex pattern composition. The results of studying the effect of the pattern complex composition and the technological parameters of manufacturing the "Through Cover" casting for the ingot purity and structure are presented.

Keywords: steel, foundry polystyrene, casting microstructure, water vapor, solid residue.

INTRODUCTION

Recently, new requirements have been imposed on the quality of castings: decreasing the cost of consumables, increasing the quality of castings, and decreasing the cost of finished products. These requirements are met by the technology of manufacturing castings by the lost foam casting method, where polystyrene is used as the material for the patterns [1-4]. Lost foam casting is used at a number of machine-building enterprises of the Republic of Kazakhstan, in particular, it is introduced at the Parkhomenko KMZ LLP (Karaganda). Producing high quality castings is ensured by using the pattern material with a good degree of gasification and, at the same time, with a low cost. Studying the effect of the lost pattern composition on the structure and properties of steel castings were carried out both in the laboratory conditions and directly in production practice in order to determine the optimal composition of the pattern for manufacturing steel castings for cast parts of equipment for the mining industry of the Republic of Kazakhstan.

One of the disadvantages of lost foam casting is carburization of the casting surface layer, as well as the problem of ingot contamination. To minimize this phenomenon, it is recommended to use low-density polystyrene foam, to optimize the pouring rate, to use apertures, non-stick coatings with high gas permeability [5-8].

RESEARCH METHODOLOGY

It used the "Through cover" casting as an object of research. Such parts of different standard sizes are used in many units and structures, for example, in the hydraulic power cylinder or for support units on rolling bearings.

It is known that interaction of the lost pattern with molten metal produces the following combustion products: the water vapor, the liquid phase, the solid residue and gas that contains the elements of hydrogen, hydrocarbon, carbon monoxide, and carbon. The content of the solid phase relative to the gaseous phase increases with increasing the temperature and at steel pouring temperatures exceeds 75 %. Carbon and soot form the solid phase that contributes to carburization of the casting both on the surface and in the bulk of the ingot as a whole.

In the foundry of the Parkhomenko KMZ LLP (Karaganda) there were carried out studies to select the parameters for manufacturing castings with a complex composition of the lost pattern that was made using cast polystyrene and granules of secondary construction polystyrene foam. Previously, studies were carried out to optimize the composition of the pattern [9-10]. The composition is shown in Table 1.

Processing polystyrene granules is an important part of the technological process and includes the following operations: classification of particle size distribution, foaming the granules, drying and their activation. The size of polystyrene granules is determined by the pattern wall thickness, since the foamed granules must fill

Table 1 **Lost pattern composition**

No	Polystyrene	Content / %	Density / g/cm^3
1	Foundry polystyrene, grade D-833	100	0,31
2	Experimental composition	Foundry polystyrene 58 %, granules of secondary construction polystyrene 42 %	0,29

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Table 2 **Recommended granule size**

Pattern wall thickness / mm	Granule size / mm
Over 15	1,3 – 1,9
11 - 15	1,0 – 1,4
8 - 10	0,6 – 0,9
6 - 8	0,3 – 0,6

Figure 1 The “Trough Cover” casting pattern

Table 3 **The pattern density effect on the carburization depth**

No	Density / g/cm^3	Maximum carburization depth / mm
1	0,31	0,62
2	0,37	0,68
3	0,44	0,96

Table 4 **Risers number effect on the carburization depth**

No	Risers number	Maximum carburization depth / mm
1	0	0,95
2	2	0,71
3	4	0,69

Table 5 **Steel fluidity when using different pattern compositions**

Filling the sample based on the pattern / %		Pouring temperature / ^{0}C
Foundry polystyrene	Complex pattern composition	
89	93	1 660
93	98	1 700
97	100	1 740
100	100	1 780

the cavity of the mold and provide the required bulk density and low roughness and geometric accuracy of the pattern surface. Table 2 shows the sizes of the original polystyrene granules depending on the pattern wall thickness.

The granules were foamed in hot water at the temperature of 95 - 100 ºC. The granules were poured in a thin layer into a box that was closed with a lid. The box with the granules was immersed in boiling water to such a depth that the top of the box was completely in boiling water. After holding in boiling water, the box was removed and placed in a dryer, the temperature of which was 25 - 30 °C.

Steam foaming of polystyrene granules was carried out in an autoclave at the temperature of 95 - 105 °C by the static method, in which the granules were poured in a uniform layer into a container with the bottom in the form of a copper mesh and placed in a tank over boiling water. Foaming polystyrene granules allows obtaining granules with a lower moisture content, which shortens the drying time.

The chemical composition in different parts of the samples was determined using a DFS-71 spectrometer. The melt temperature was determined using a Stal S-3000.1 pyrometer (Russia).

EXPERIMENTAL STUDIES

Equipment and tools

Patterns of the “Through Cover” casting were made of the compositions indicated in the (Figure 1).

After manufacturing castings, samples were cut out of them with a disk cutter, which were used to prepare sections for evaluating microstructures. The quantitative and qualitative assessment of microstructures was carried out using the Rhizome Pro software (Russia).

In the first series of experiments, the effect of density on the depth of carburization was assessed (Table 3).

It is obvious that reducing the pattern density has a beneficial effect on minimizing carburization of the casting surface. However, the use of a combination in the used proportion of construction and foundry polystyrene leads to the most optimal packing of the granules and thus the rate of burnout and removal of gases from the mold cavity occurs sequentially, which is practically comparable to the burnout rate of foundry polystyrene.

There were also set radial risers with equal intervals on the surface of the pattern and the expediency of their use was considered from the point of view of carburization (Table 4). The risers were set with the diameter of 6 mm.

Studies have shown that the presence of risers reduces in general the depth of carburization; however, increasing the number of risers does not affect carburization.

The presence of a solid residue also affects the fluidity of the alloy and as a consequence the quality of the casting, its geometric accuracy and dimensions.

The fluidity of steel was studied using a pattern with a complex composition. Studying the fluidity was carried out in accordance with GOST 16438 - 70. It was determined that the fluidity of steel when using the proposed composition of the pattern is 5 - 10 % higher than that of a pattern made of a purely foundry composition (Table 5), which indicates a lower amount of formed vaporous elements and solid residue. Thus, the experimental composition of the pattern makes it possible to produce castings with thinner walls and a complex configuration.

DISCUSSION OF RESULTS

Full filling of the mold with the pattern complex composition with a lower temperature (by about 40 °C) allows using less energy for preparing the melt and this fact also helps to reduce the cost of the final product (castings).

To calculate the pouring speed, it was assumed that there are 4 "Through Cover" castings (weight 12,5 kg) and 10 % per the gating system in the mold at a time. The calculation is perfromed according to the traditional method.

The duration of the mold filling can be determined as follows:

$$\tau = S \cdot \sqrt[3]{\delta \cdot m},$$

where S is the coefficient of time $\tau / S = 1,5$;

δ is the average value of the casting wall.

$$\tau = 1,5 \cdot \sqrt[3]{40 \cdot 55} = 19,51 \text{ c}$$

The average speed v of the melt rise in the mold is determined by the formula:

$$v = \frac{c}{\tau} = \frac{180}{19,51} = 9,23 \text{ mm / s}$$

where c is the casting height / mm.

That is, the design height of the metal rise is about 10 mm per second. It will have a beneficial effect on the removal of the generated gases, which ultimately will make it possible to obtain a dense casting with a smaller carburized layer over the surface.

The porograms of the foundry polystyrene and complex composition patterns are shown in Figure 2.

Analyzing the porograms shows that the pattern of complex composition contains micropores of a smaller diameter in large quantities and evenly distributed throughout the entire volume of the pattern, which allows flowing the melt simultaneously throughout the entire volume and contributes to uniform and consistent burnout of the pattern. This in turn makes it possible to remove most completely the gaseous decomposition products of the pattern through the risers when rising the metal and by suction when using an evacuated flask. Solid decay products are on the surface and can be removed by the surface treatment of the casting.

In patterns made of casting polystyrene, the pores are less evenly distributed and have different diameters. It leads to uneven gasification of the pattern, and a part of decomposition products remains in the metal or reacts with the melt saturating its individual sections with carbon.

The finished "Through Cover" part is shown in Figure 3.

There was determined contamination with non-metallic inclusions of the casting obtained by the lost foam casting method according to the experimental technology: point oxides, carbonitrides of the 4th point of the GOST 1778-80 scale (Figure 4).

The microstructure of the "Through Cover" casting is shown in Figure 5.

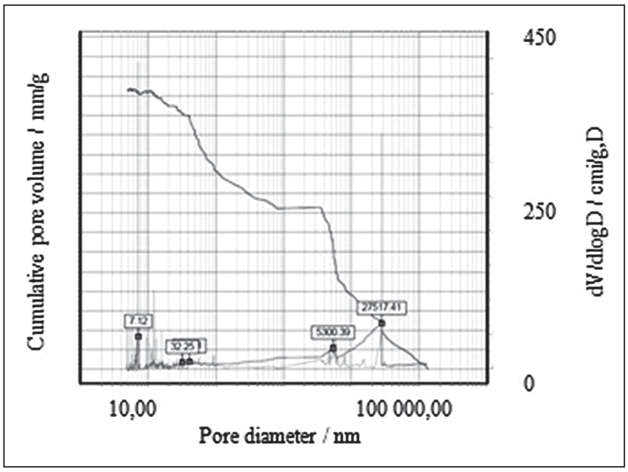

Figure 2 Pattern porograms: a – foundry polystyrene; b – complex pattern composition

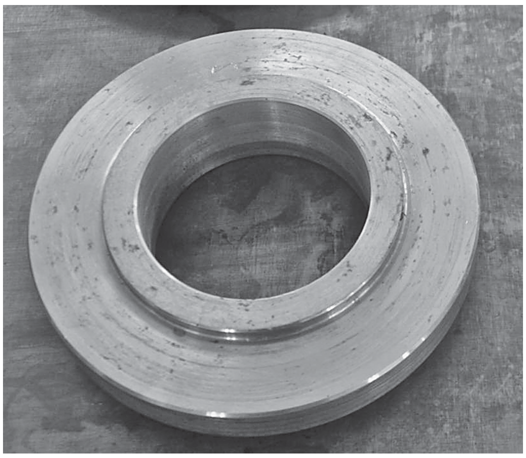

Figure 3 The finished "Through Cover" part

Figure 4 Experimental casting contamination with non-metallic inclusions, ×500

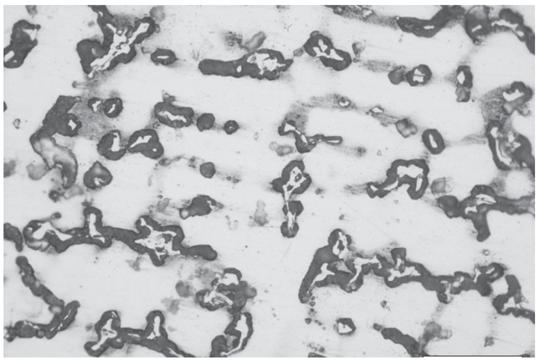

Figure 5 The casting microstructure, austenite + carbides, ×500

CONCLUSION

Thus, the proposed complex composition of the polystyrene pattern with the use of the proposed technological modes for «Through Cover" castings solves the problem of carburizing the surface layer of the casting, reducing the ingot contamination. The most optimal composition of the pattern is as follows: foundry polystyrene 58 %, granules of secondary construction polystyrene 42 %; pellets 1,3 - 1,9 mm for patterns with walls that are thicker than 15 mm; the need for 2 - 4 risers depending on the size of the casting diameter. The recommended pouring time of the casting mold for the "Through Cover" castings is 20 seconds.

REFERENCES

[1] Sedukhin V.V.; Anikeyev A.N.; Chumanov I. V. A Method of Modification Surface Mould in Gasificated Casting to Purpose Increase Wear Resistance // 5th International Young Researchers' Conference on Physics, Technologies and Innovation (PTI Местоположение: Ural Fed Univ, Inst Phys & Technol, Ekaterinburg, Russia.: May 14-18, 2018

[2] Balint, Tibor S.; Freeman, Anthony Designing the design at JPL'S innovation foundary // Acta Astronautica. 137(2017)182-191

[3] Filchakov D. S., Zhavkhalan B., Zheng K., Zhang Ya. V., Mei Sh., Lygdenov B. D. Formation of a hardened surface on steel products with lost foam casting // Polzunovsky Almanac. (2019)3, 12-14

[4] Dementyev V. B., Ovcharenko P. G., Leshchev A. Yu. Carbon in iron-carbon melts effect on the structure and composition of chromium-doped surfaces of castings when casting according to gasified patterns // Metal Science and Heat Treatment of Metals. 687(2012)9, 27-29

[5] Yakovyshin O. A. Resource-saving technology of manufacturing gasified patterns for foundry // Ecology and Industry. 59(2019)2, 24-33

[6] Walter A. I. Production of castings based on gasified patterns // Bulletin of the Tula State University. Technical science. (2018)1, 8-15

[7] Vodolazskaya N. V. Wear resistance of cast iron parts due to modification of surface layer / N. V. Vodolazskaya, O. A. Sharaya // Journal of Advanced Research in Technical Science. - Seattle, USA: SRC MS, Amazon KDP. (2020). 18. P 33 –36

[8] Izotov V. A., Rodionova N. A., Fedulova Yu. S. Determination of the flow rate coefficient of the lower gating system when casting ferrous alloys according to gasified patterns // Procurement production in mechanical engineering. 17 (2019)2, 51-55

[9] Kvon Sv. S., Kulikov V. Yu, Issagulov A. Z., Dostayeva A. M., Kovalyova T. V. Studying structure and properties of shaped ingots obtained in various conditions of crystallization // Metalurgija. 57(2018)4, 313-316

[10] Kulikov V. Y., Issagulov A. Z., Ibatov M. K., Kovaleva T. V., Shcherbakova Ye. P. Studying the properties of sand-resin molds made using a variable load // Metalurgija. 59(2020)4, 507-510

Note: Responsible for the English language is Natalya Drak, Karaganda, Kazakhstan