DOI 10.52209/2706-977X_2024_1_9 **IRSTI 55.15.09** **UDC 615.49203.07**

Studying the Depth of Carbonifying Castings Obtained by the Lost Foam Casting Method with a Complex Polystyrene Composition

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Abstract. At present, lost foam casting method is an updated, long-term and the most economically feasible method in the foundry industry. Despite the fact that the casting technique is relatively simple, high demands are placed on the model materials. Carburization of the surfaces of steel castings obtained by the lost foam casting method is one of the main and the most significant problems in the use of this casting method. One solution is to use a complex composition of the material: a combination of cast and construction polystyrene. It was determined that the complex composition of the cast and construction polystyrene model in the ratio of 60 to 40% helps to reduce the depth of carburization and the percentage of internal defects. In addition, the cost of 1 kg of the complex composition models is 25% lower than the cost of 1 kg of models made of cast polystyrene.

Keywords: complex polystyrene, carburization, quality, roughness, casting defects.

Introduction

Producing the domestic high-precision castings for any country is a task of strategic importance, because it ensures economic independence and determines the basis for the development of national mechanical engineering. According to [1], now in Kazakhstan the share of imported foundry products is about 80%. Meanwhile, the country has both sufficient raw material resources and basic means for manufacturing foundry products for various purposes, including high-precision castings.

Recently, much attention has been paid to the technology of producing castings with the use of the lost foam casting method (LFC), and in Kazakhstan this technology is beginning to spread. The Parkhomenko KMZ LLP in Karaganda was the first to introduce the LFC method. The method showed that its scope can cover almost all the traditional sand molding. This is especially true in single and small-scale production.

The lost foam casting method is a low-waste production. One of the disadvantages of this technology is the carburization of the surface of the castings during the destruction of polystyrene. For most parts, a layer of steel containing a high carbon content is a defect, since such a layer is brittle and hard, removes the cutting tool during processing, and during operation of the part can lead to its destruction. The casting polystyrenes PSV-1L currently used in production in Kazakhstan, despite fairly complete gasification, are sources of increasing the carbon content of the surface of the castings to a depth of 1.5-2 mm. At the same time, cast polystyrene foam, which has small grains, has a relatively high density. It is known that reducing the density of the model reduces the depth of the loaded layer of steel castings [2-3]. In this case, it becomes possible to obtain a complex composition of a polystyrene foam model from a mixture of casting and construction polystyrene granules, which have a lower density. At the same time, the cost of the model will also be lower, since construction polystyrene is 30-40% cheaper than foundry polystyrene. It is proposed to use PSV-1L grade polystyrene, traditional for the Karaganda region.

1. Methods and Experiments

According to the proposed technology [4], in the foundry shop of the Parkhomenko KMZ LLP (Karaganda) there were carried out studies of the quality of castings made by the LFC method with the use of the complex composition of the gasified model.

A new composition of the model material for LFC was proposed:

- construction polystyrene PPS-20–40%. The size of the granules is 0.5-0.8 mm;
- cast polystyrene PSV-1L – 60%. The size of the granules is 0.2-1.2 mm.

The models were produced from a mixture of cast polystyrene with fractions of 0.7...1.0 mm (the size of the supplied granules) in an amount of 60% and construction polystyrene foam granules up to 3.0 mm in size (the main dimensions of construction polystyrene granules) in an amount of 40%. Polystyrene, according to the technology adopted at the plant, was pre-foamed with steam and dried, then blown into a mold, which was kept in an autoclave until the polystyrene granules were sintered [5].

The studies were carried out on the “Case” casting made of 35L steel. The melt was obtained in an induction furnace, pouring was carried out at a temperature of 1540-1560 ^{0}C.

Use sand grades 1K02 and 1K016 as filler for the casting mold in a ratio of 70 to 30 in order to increase the density and strength of the mold.

Metallographic studies to assess the quality and properties of metal materials were carried out using an Altami POLAR 3 microscope (Russia).

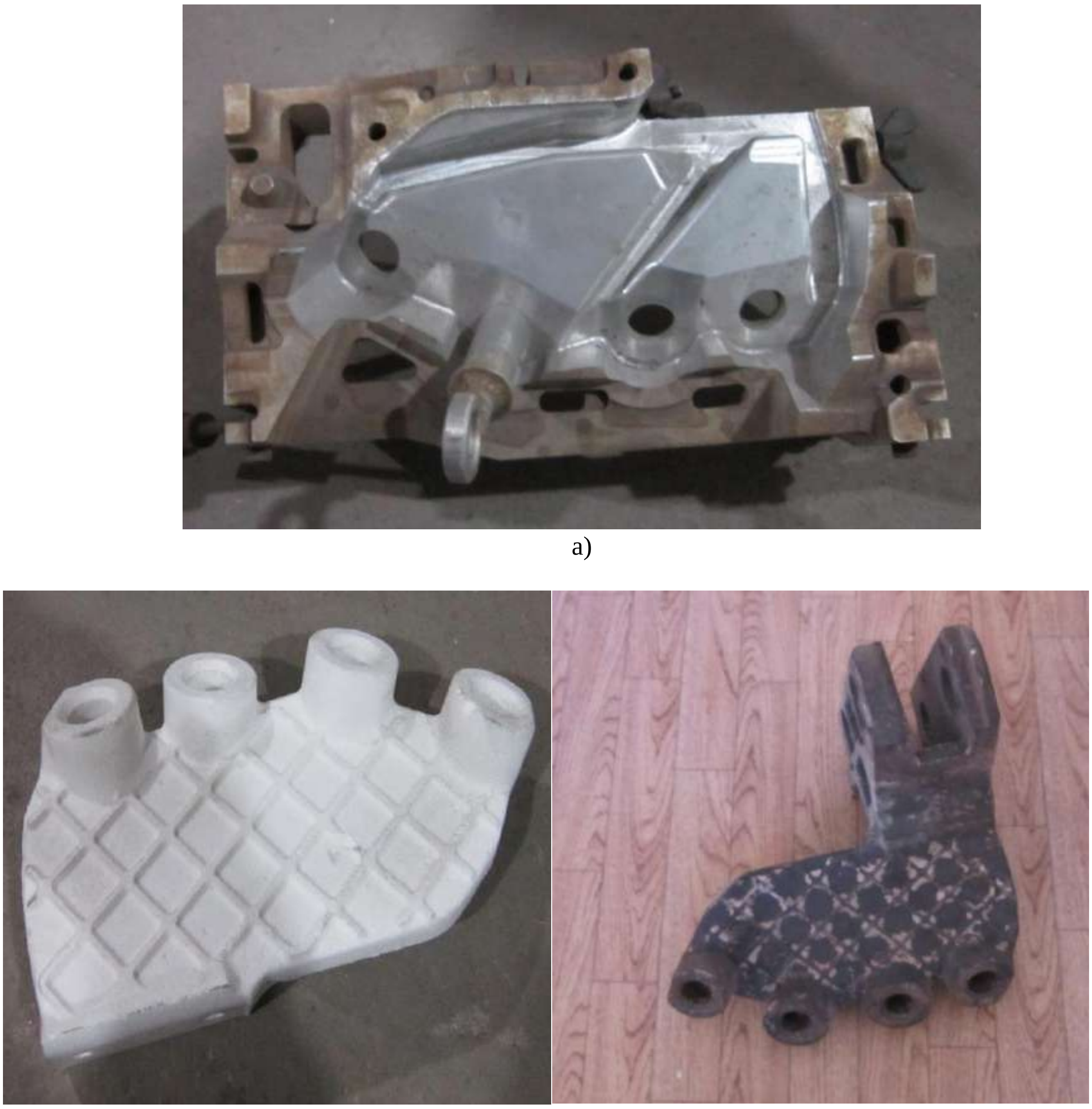
After the castings were made, samples were cut out from them with the use of a disk cutter. They were used to prepare thin sections to evaluate the microstructures. Quantitative and qualitative assessment of microstructures was carried out using the ThixometPro program (Russia).

The discontinuities in castings were studied with the use of an ultrasonic flaw detector USD-50 (Russia).

It is known that when a model obtained by LFC interacts with the molten metal, the following combustion products are formed: water vapor, liquid phase, 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 it exceeds 70%. Carbon and soot constitute the solid phase, which contribute to the carburization of the casting both on the surface and in the volume of the ingot as a whole [6, 7].

Using the compositions indicated in Table 1, casting models “Case” were made (Figure 1). Studying the castings showed that the castings obtained with the use of the new technology had high geometric accuracy (allowances of 0.5-1%), low roughness (Rz 60-90), and there were no external and internal defects.

The trend of transition from casting in sand-clay molds to lost foam casting models is explained by the fact that this contributes to sharp reduction in the total labor costs, the metal intensity of the resulting castings, and the achievement of high and often fundamentally new physical and mathematical characteristics and operational properties of cast products.



a)

b) c)

Fig. 1. – Manufacturing the “Case” casting: a) compression mold; b) model; c) casting

1. Results and discussion

There were studied three castings obtained with different composition of polystyrene models (Table 1).

Table 1. The composition of polystyrene models

Sample No.	Cast polystyrene, %	Construction polystyrene, %
1	80	20
2	100	-
3	60	40

In the first series of experiments, the effect of the model density on the depth of carburization was assessed (Table 2).

It is obvious that reducing the model density has a beneficial effect on minimizing carburization of the casting surface. However, the use of a combination of construction and cast polystyrene leads to the most optimal placement of granules. Thus, the rate of burnout and removal of gases from the mold cavity occurs consistently, which is almost comparable to the burnout rate of casting polystyrene [8].

Table 2. The model density effect on the carburization depth

Sample No.	Density, g/cm^3	Maximum carburization depth, µm
1	0.31	62.2
2	0.37	68.5
3	0.44	82.3

There were also radially placed risers at equal intervals on the surface of the model and considered the feasibility of their use from the point of view of carburization (Table 3). The risers were placed with the diameter of 6 mm.

Table 3. The number of risers in the casting mold effect on the carburization depth

Sample No.	Number of risers	Maximum carburization depth, µm
1	0	79.9
2	2	66.1
3	4	64.5

As studies have shown, the presence of risers generally reduces the depth of carburization, however, increasing the number of risers does not affect carburization.

The microstructure of the sample surface layer depth is shown in Figure 2.

It can be seen in the microstructure that the maximum depth of carburization when using the complex composition of polystyrene reaches 56.4 microns. It is known from a number of studies [2-3] that the depth of carburization of steels with the carbon content of 0.3-0.4% averages 76-105 microns, which is significantly greater than the depth of carburization with the use of the proposed technology due to decreasing the density of the model with the use of construction polystyrene. This generally reduces the amount of carbon generated as a result of the model destruction. Thus, the proposed complex composition of the polystyrene model with the use of the proposed technological modes for specific types of castings solves the problem of carburization of the surface layer of the casting.

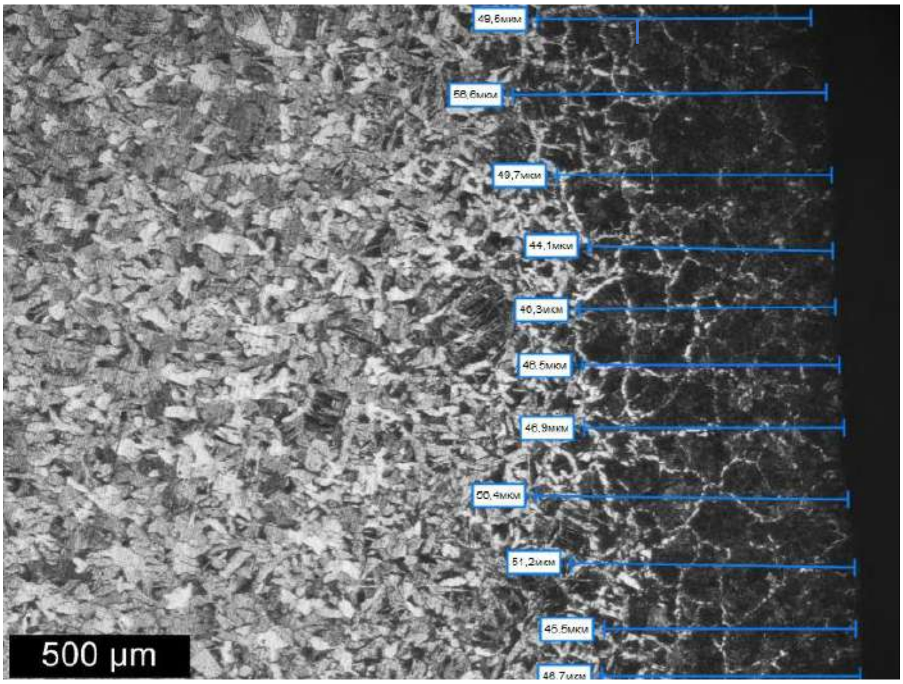
The carried out studies suggest that the use of polystyrene composition 3 for the model contributes to the formation of a homogeneous structure throughout the entire volume of the melt, helps to exclude slag, gases, etc. from the melt.

This was also confirmed by studying the discontinuities with the used of an ultrasonic flaw detector.

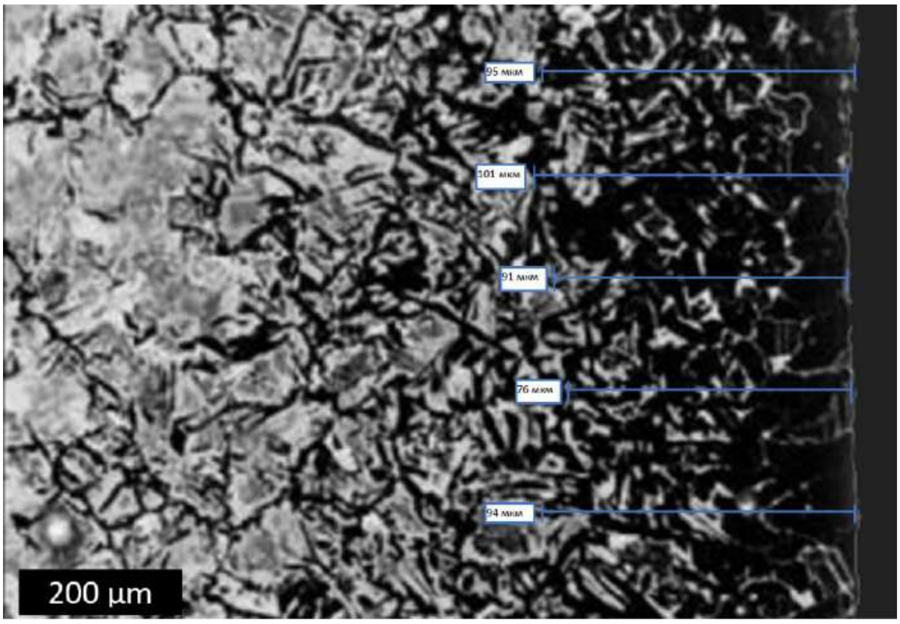
The analysis and studies of the technological process of lost foam casting allowed making a reasonable comparison of the technological, operational, economic and environmental indicators of the casting processes in sand-clay molds and in sand molds of the LFC method (Tables 4-7).

Table 4. Performance indicators

Indicator	LFC with the use of cast polystyrene for models	LFC with the use of the complex polystyrene composition for models
Technological		
Mixture composition	Single-component	Multi-component
Carburization	More than 100 µm	Less than 80 µm
Ga permeability	High	High
Roughness	Low	Low
Burning	Medium	Low
Operational		
Power consumption	Low	Low
Current operation	Medium	Medium
Area occupied by the equipment	Small	Small



a)



b)

Fig. 2. - Microstructure of the St 35L casting and determining the carburization depth of the surface layer using the ThixometPro program, obtained by the lost foam casting method with complex polystyrene (a) and cast polystyrene (b)

Table 5. Statement of capital investments in molding sand and models for LFC with the use of cast polystyrene for the model

Material	Cost of one *kg* or one *l*, tenge	Quantity of the material, *kg* or *l*	Total amount, tenge
Sand of the K0315A grade, SS 2138-84, kg	12	50	600
Cast polystyrene PSV-1L, kg	3000	25	75000
Paint	1000	10	10000
TOTAL			85600

Table 6. Statement of capital investments in molding sand and models for LFC (comparison)

Material	Cost of one *kg* or one *l*, m^3, tenge	Quantity of the material, *kg* or *l*	Total amount, tenge
Sand of the K02A grade, SS 2138-84	10	15	1500
Sand of the K0315A grade, SS 2138-84	12	35	420
Cast polystyrene PSV-1L	3000	15	45000
Construction polystyrene PPS-20	1200	10	12000
Paint	800	9	7200
TOTAL			66120

The charge materials are no different.

A comparative analysis of defects in castings and molds when using LFC molds is presented in Figure 3.

In total, the percentage of defects during LCM using cast polystyrene for a model is ~1.8% of the casting volume, and during LCM using polystyrene of a complex composition for a model, it is significantly lower and amounts to less than 1.0% of all manufactured castings.

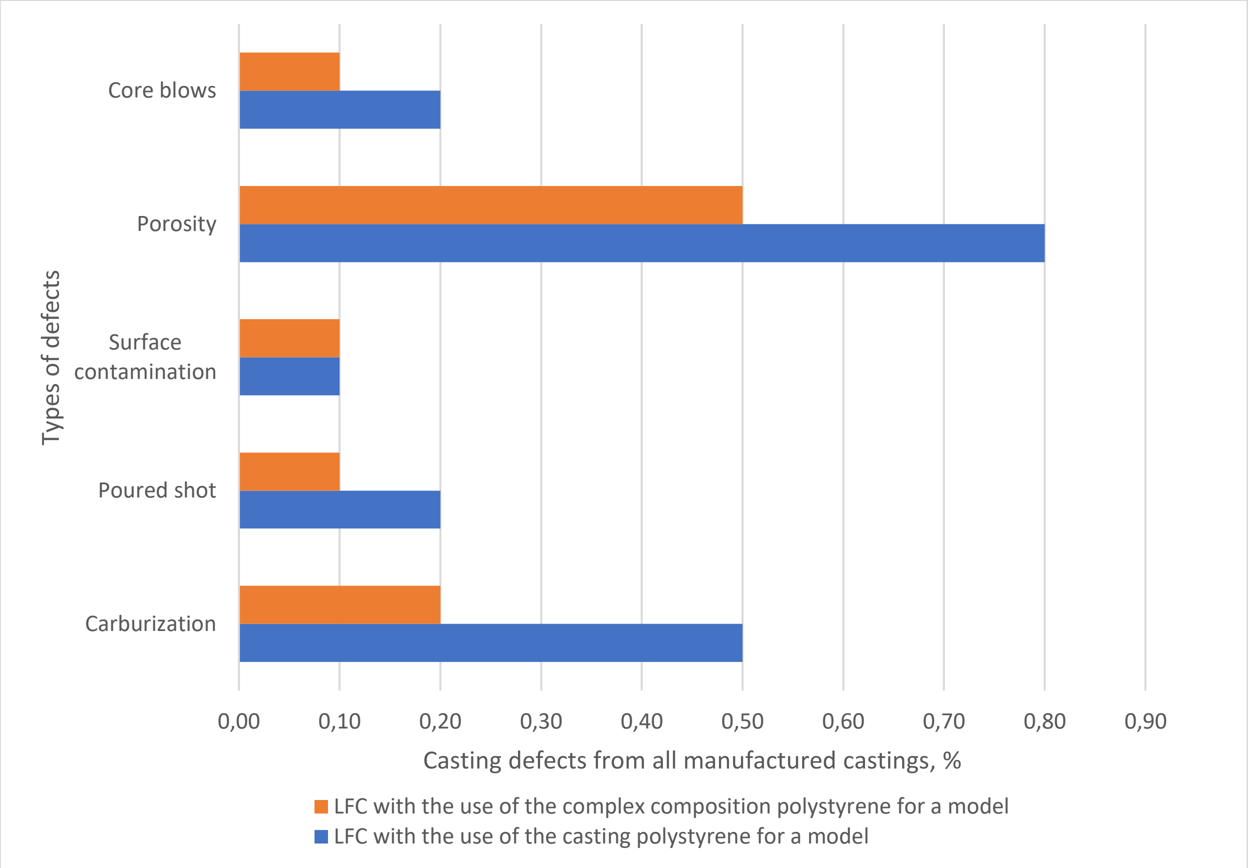


Fig. 3. - Types of defects in LFC with the use of models of various compositions

Conclusions

Research has shown that the use of a casting and construction polystyrene model composition in a ratio of 60 to 40% contributes to the formation of a homogeneous structure throughout the entire volume of the melt, helps to exclude slag and gases from the melt, which is confirmed by a decrease in the percentage of castings rejected by porosity and cavities.

The depth of carburization is also reduced if the technological conditions of pouring (number of blows, pouring speed) and melt temperature are observed (for steel grade 35 L it is 1540-1560 ^{0}C). This occurs due to a decrease in the density of the model and its faster gasification

At the same time, the introduction of construction polystyrene into the model reduces its cost and, as a consequence, the cost of castings.

Acknowledgements

These studies were carried out as part of implementing grant funding from the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan under the project AP15473207 "Developing the technology of producing defect-free homogeneous castings by the lost foam casting method" (agreement with the Committee on Scientific Education of the Ministry of Education and Science of the Republic of Kazakhstan No. 337/ZhG-3-22-24 dated 11 November 2022).

References

[1] Issagulov A.Z., Kulikov V.Yu., Tverdokhlebov N.I., Shcherbakova Ye.P., Kovalyova T.V. Obtaining castings by the loas foam casting method using molds of construction polystyrene // University Proceedings, Publishing House of KSTU, Karaganda, 2017, No. 3, P. 30-32.

[2] hhttps://on-v.com.ua/novosti/texnologii-i-nauka/kak-snizit-nauglerozhivanie-pri-lgm/

[3] Khaydorov A.D., Kondratyev S.Yu. Formation of the steel casting structure obtained by the lost foam casting method with subsequent heat treatment // Procurement production in mechanical engineering No. 12, 2014, P. 3-9.

[4] Issagulov A.Z., Kulikov V.Yu., Kvon Sv.S. Kovalyova T.V. The composition of the polystyrene mold effect on the properties of the "Through Lid" casting // Foundry Production, Foundry Production Publishing House, M., 2021, No. 3, P. 25-28.

[5] Kulikov V.Yu., Issagulov A.Z., Kovalyova T.V. Study of the properties of polystyrene with the addition of secondary granules of construction polystyrene // Bulletin of the Magnitogorsk State Technical University named after. G.I. Nosova, 2017, T. 15, No. 4, P. 40-46.

[6] Kovalyova T.V. Thermodynamic modeling of an alloy with the use of lost foam casting method // Proceedings of the International scientific and practical online conference "Integration of science, education and production as the basis for implementing the Nation's Plan" (Saginov's Readings No. 13), dedicated to the 30th anniversary of Independence of the Republic of Kazakhstan, June 17-18, 2021 Karaganda Technical University. Karaganda: KTU Publishing house, 2021, P. 1313-1314.

[7] Issagulov A.Z., Kulikov V.Yu., Tverdokhlebov N.I., Shcherbakova E.P., Kovalyova T.V. The influence of paint on the quality of cast iron and steel castings of complex configurations during forestry and metallurgy //Foundry production, 2015, No. 7, P. 17-19.

[8] Kovalyova T.V., Issagulov A.Z. Modeling temperature fields of castings with the use of lost foam casting method // Mechanical engineering: new concepts and technologies. Collection of articles of the All-Russian scientific and practical conference of students, graduate students and young scientists. - Krasnoyarsk: Siberian State University named after M.F. Reshetnyova, 2020. - P. 79-83.

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