AP15473207 “Developing the technology of manufacturing defect-free homogeneous castings by lost foam casting method” – p.m. Kovaleva T.V.

Relevance. In our country, a number of casting methods are used: sand-clay mold casting, investment casting, and die casting. One of the most common and promising methods is lost foam casting (LFC). It is necessary to strive to reduce the specific consumption of castings for manufacturing industrial products. The use of lost foam casting leads to increasing the geometric and dimensional accuracy of castings, metal consumption is reduced, and cost is reduced. The cost of mechanical treatment in manufacturing castings using LFC is reduced by approximately 25% or more due to the exclusion of complex machining of internal surfaces; in many cases, mechanical treatment of castings can be completely eliminated or reduced to the minimum, so cleaning of castings is simplified and is performed faster. Implementation of the project will allow for the further commercialization of the obtained results in production, for example, at the enterprises of the Kazakhmys Corporation LLC, the Parkhomenko KMZ and others.

The project purpose is obtaining dense and homogeneous in composition and structure castings with low cost with prospects for further commercialization.

Expected and achieved results:

- a new composition of polystyrene lost foam model with a low cost price;
- the technology of manufacturing defect-free castings with a dense, homogeneous structure using new technological modes of lost foam models;
- obtaining a pilot batch of castings, a technological flow chart developed and agreed with representatives of production, an act of testing the technology in industrial conditions;
- publication of two articles in foreign journals from the first three quartiles by impact factor in the Web of Science database or having a percentile according to CiteScore in the Scopus database of at least 50%, two articles in journals from the CQASHE database, 1 monograph on the topic of the project.

In 2022. Optimal modes of casting melting by the LFC method were selected. It was determined that the pouring speed should be within 20-30 seconds. The pouring temperature was within 1550-1650 degrees, the pouring height was 50-100 mm.

The analysis of the current state of the issue of casting melting modes in LFC in the world practice was carried out. It was revealed that lost foam casting method is one of the promising methods of producing castings compared with more traditional casting in sand-clay and sand-resin molds; it has a number of advantages, such as minimal mechanical treatment of finished products and high quality of the casting surface.

The essence of the LFC process is the transition of the polystyrene foam model when pouring it with molten metal into a gaseous state and subsequent hardening of the casting in the flask. Since pouring results in the formation of lost foam model products, which, if gases are not removed correctly, can negatively affect the quality of the casting, it is necessary to pay close attention to the composition of the model, the pouring mode and the method of vacuuming the flask. The quality of the casting is affected by such parameters of the melting mode as the pouring method, the pouring speed and the fluidity and temperature of the melt, as well as the vacuuming mode of the flask. The literature analysis of the current state of the issue of melting modes of castings by LFC method in the world practice and a review of the factors influencing the technological modes and composition of the model on the structure and properties of castings when casting on gasified models is carried out.

The analysis of literature sources confirmed that the following process parameters had a significant impact on the quality of the casting: the temperature that affected the final structure of the solidified casting. Increasing the pouring temperature leads to decreasing the quality of the casting, since porosity increases and the primary grain size increases. In turn, with decreasing the pouring temperature, the fluidity of the melt decreases, which is also a negative factor during pouring. It is necessary to find the melt temperature during pouring that will ensure a balance between these process parameters.

As a result of pouring the mold with the melt, gasification (burnout) of the model occurs. The model must have a density that will allow it to quickly and completely pass into a gaseous state and not have a negative effect on the pouring speed and melt flow. In addition, one should strive for the minimum ash residue of the model so that the amount of burn-on is minimal. Another factor that affects the quality of the casting is the non-stick coating, which is applied to the model to reduce interaction at the "casting-mold" boundary. Such a coating should have the thickness that will ensure minimal interaction between the melt and sand, but at the same time the gas permeability of this coating should ensure a uniform gas flow through it so that no gas defects are formed in it when the casting hardens.

A matrix of experiments was compiled to achieve the research objectives.

Mathematical planning and processing of the experimental results were carried out according to the method of V.P. Malyshev.

In 2023. A comprehensive composition of a polystyrene foam model using granules of foundry and construction polystyrene was selected. Optimal gas permeability and density of the model will be determined to ensure a dense homogeneous structure of the formed casting.

A composition was selected and modes of application of non-stick paint to the polystyrene foam model were chosen to prevent burning while maintaining the required gas permeability; an article has been published in a journal from the CQASHE database.

Technological modes of manufacturing and using a lost foam model and non-stick paint were selected.

An article was published in a journal with a CiteScore percentile in the Scopus database of 64.

A patent of the Republic of Kazakhstan for a utility model has been received.

In 2024, pouring modes were selected: the pouring temperature of steel samples, the pouring height, the hydrostatic pressure to optimize the speed and completeness of burnout of the polystyrene foam model. It was determined that from the point of view of forming the most favorable structure (homogeneous, defect-free, with a minimum depth of surface carburization), an integrated approach to pouring steel castings was important. The pouring temperature is 1640-1680 ^{0}C, the pouring speed is 1-2 cm/s, when using inoculants made of the same material as the poured melt, their size in the model should be about 120-150 µm. In this case, complete uniform melting of inoculants and complete burnout of the polystyrene model with the removal of combustion products into the crust layer of the casting are observed.

Two articles were published in the journal from the CQASHE database.

The modes of mold vacuuming were selected in relation to gas permeability and the rate of suction of the formed gases.

It was determined that the most optimal vacuuming mode from the point of view of removing the products of destruction of the polystyrene model is the value of 30-40 kPa. It was also proven in industrial conditions that it is technologically important to locate gas channels not only at the bottom of the flask but also on its side walls. The defective castings in such a flask design decreased to 2-3%.

An article was published in the Q2 journal by impact factor in the Web of Science database.

List of publications:

1. Kovaleva T.V., Issagulov A.Z. Studying the possibility of using complex composition models in the technology of lost foam casting models. University Proceedings. No. 2, 2023, p. 85-88 (DOI 10.52209/1609-1825_2023_2_85)

2. Tatyana Kovalyova, Yevgeniy Skvortsov, Svetlana Kvon, Michot Gerard, Aristotle Issagulov, Vitaliy Kulikov and Anna Skvortsova. Titanium Carbide and Vibration Effect on the Structure and Mechanical Properties of Medium-Carbon Alloy Steel. Coatings 2023, 13, 1135. (https://doi.org/10.3390/coatings13071135)

3. Patent of the Republic of Kazakhstan for utility model No. 8240 "Method of manufacturing a lost foam model using polystyrene", Bulletin. No. 37 of 15.09.2023

4. Kovaleva T.V., Issagulov A.Z. Studying the depth of carburization of steel castings obtained by lost foam casting method. Foundry production, No. 3, 2024, pp. 20-225.

5. Kovalyova T.V., Issagulov A.Z. Studying the Depth of Carbonifying Castings Obtained by the Lost Foam Casting Method with a Complex Polystyrene Composition. Material and Mechanical Engineering Technology, №1, 2024., p. 9-14 (DOI 10.52209/2706-977X_2024_1_9)

6. Kovaleva, T.; Issagulov, A.; Kovalev, P.; Kulikov, V.; Kvon, S.; Arinova. Structural Anisotropy Parameters Effect on the Low-Temperature Impact Strength of Alloy Steels in Rolled Products. Metals 2023, 13, 1157. (https:// doi.org/10.3390/met13071157), Q2.

Research team:

1. Kovaleva Tatyana Viktorovna – research director, master, teacher
Hirsch index – 4;ORCID 0000-0002-1186-1805;
Researcher ID A-2567-2017;
Scopus ID 57211297553;
SPIN-код: 6151-2800.

2. Aristotel Zeinullinovich Issagulov – scientific consultant, Doctor of Engineering, Professor, Executive Director of Abylkas Saginov Karaganda Technical University NJSC.
Hirsch index - 8ORCID 0000-0003-2174-9072;
Researcher ID C-7415-2016;
Scopus ID 57211295299;
SPIN-код: 3643-2646.

a *b* *c*

Figure 1 – Holding a sample in the furnace at different temperatures:
a – initial sample; b – sample residue after holding in the furnace at 200°C, c – sample residue after holding in the furnace at 850°C)

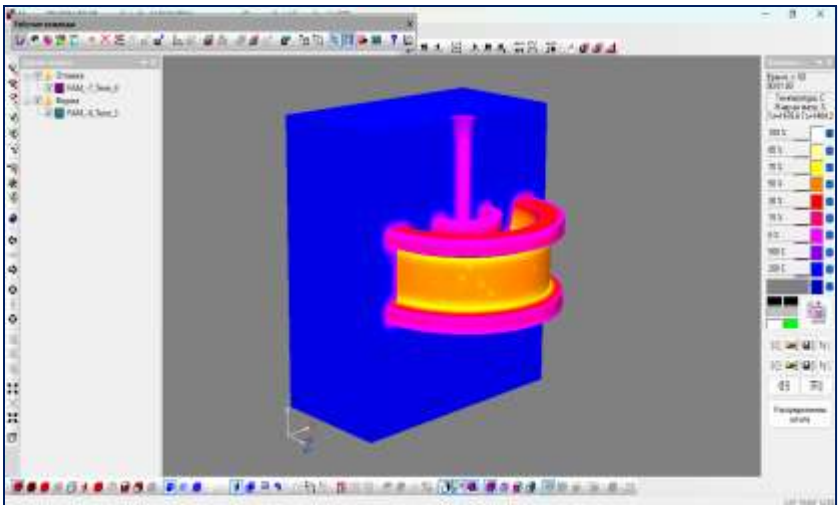


Figure 2 – Modeling of the casting solidification process

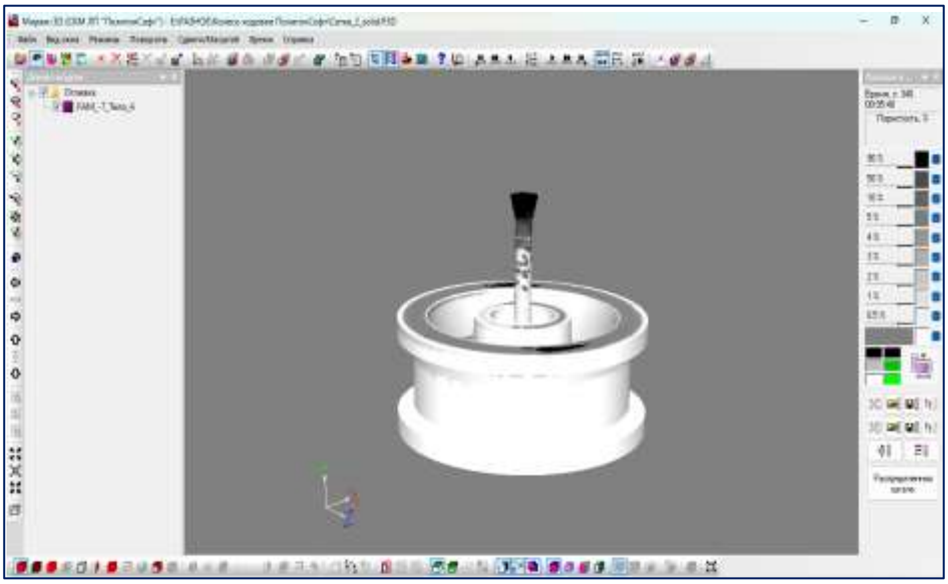
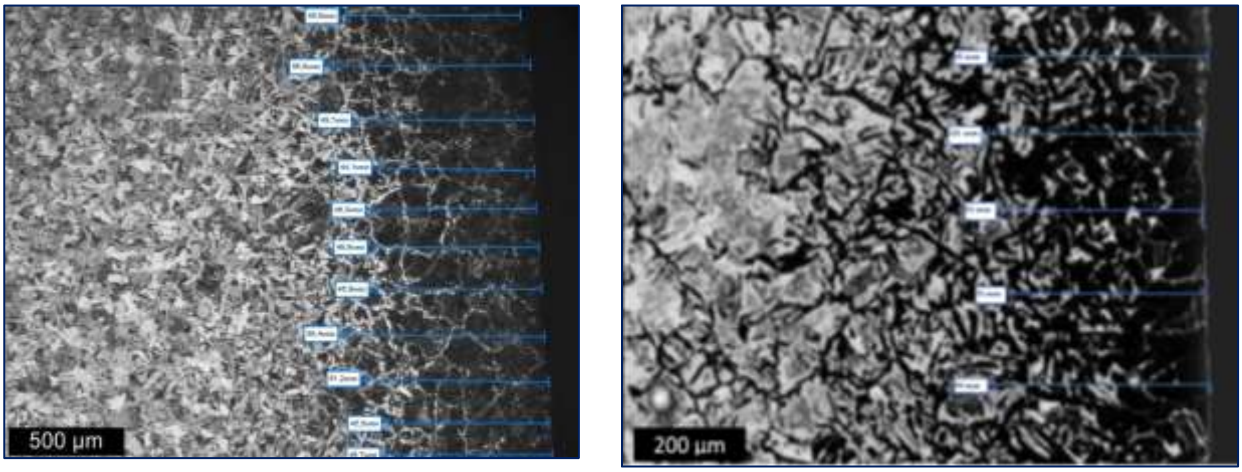


Figure 3 – Distribution of porosity in the casting “Running wheel”

Figure 4 – Suspension polystyrene granules



a *b*

Figure 5 – Microstructure of casting grade St. 35L and determining the carburization depth of the surface layer using the ThixometPro program
a – obtained by lost foam casting models with complex polystyrene;
b – with casting polystyrene

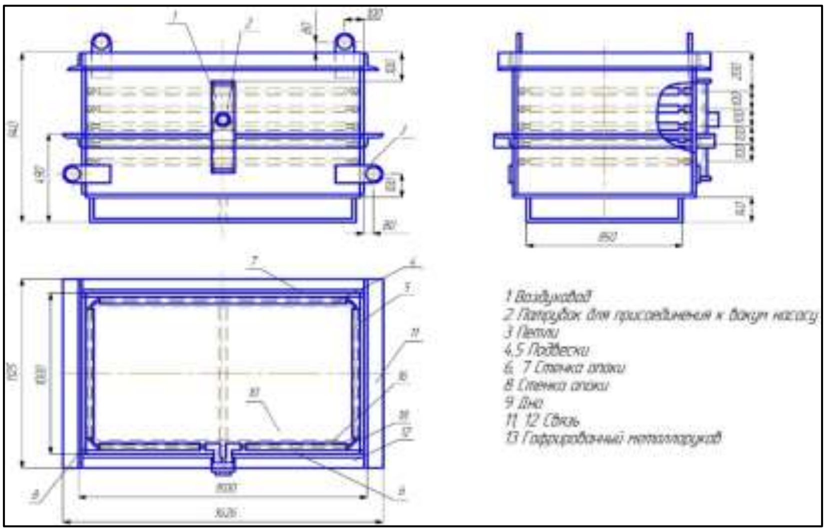


Figure 7 – Vacuum flask with corrugated metal sleeve

Information for potential consumers:

The obtained results can be implemented in the blank shops of the machine-building production; the theoretical and practical results of this work can be used in the foundry production, as well as for educational purposes.

Scope: foundries of machine-building plants.

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