



Kulrang cho‘yanlardan quyma mahsulotlar olishda yonuvchi model asosida quyish texnologiyasini takomillashtirish

Khasanov Jamshidbek¹, Turakhodjaev Nodir², Chorshanbiev Shukhrat², Parpiev Rustam², Farkhad Maksimov², Sartibaev Dilshod², Egamshukurov Jaloliddin²

¹Andijan State Technical Institute, 170100, Andijan, Uzbekistan

²Tashkent State Technical University, 100095 Tashkent, Uzbekistan

Email: khasanov9339@gmail.com

ANNOTATSIIYA

Ushbu maqolada kulrang cho‘yandan yuqori konstruksion, yupqa devorli quyma mahsulotlar olishda yonuvchi modeldan foydalanish texnologiyasi tadqiq etilgan. Tadqiqot ishida sifatli quyma mahsulotlarini uchun yonuvchan modellardan foydalanish texnologiyasi takomillashtirilga. Yonuvchi model sifatida foydalaniladigan materialning xususiyatlari, modelning o‘lcham aniqligi va sirt holatining quyma mahsulot sifatiga ta’siri tahlil qilingan. Shuningdek, modelni maxsus qoplama bilan tayyorlash hamda suyuq kulrang cho‘yan bilan o‘zaro ta’sirlashish jarayonida modelning parchalanish xususiyatlari ko‘rib chiqilgan. Tadqiqot davomida tayyor quyma mahsulotlarni olishda yuzaga kelishi mumkin bo‘lgan gazli nuqsonlar, suyuq qotishmaning qolip bo‘shlig‘ini to‘ldirishi hamda quyma sifatiga ta’sir etuvchi asosiy omillar aniqlangan. Olingan natijalar asosida yonuvchi modellardan unumli foydalanishning optimal texnologiyasi asosida kulrang cho‘yandan olinadigan quyma mahsulotlarining sifatini yaxshilash imkoniyatlarini ko‘rsatadi. Tadqiqot natijalari murakkab shaklli, yuqori konstruksion, yupqa devorli detallarini kulrang cho‘yan qotishmasidan kam miqdordagi mexanik ishlov bilan ishlab chiqarish texnologiyasini takomillashtirishda amaliy ahamiyatga ega..

Kalit so‘zlar:

kulrang cho‘yan, yonuvchan model, quyish texnologiyasi, yupqa devorli quymalar, termik parchalanish, quyma nuqsonlari, qoliplash, quyma mahsulot, CNC, EPS

Improvement of lost-foam casting technology for producing cast products from gray cast iron

ANNOTATION

This article investigates the technology of using expendable patterns for producing high-structural, thin-walled cast products from gray cast iron. In the research, the technology of using expendable patterns for producing high-quality cast products was improved. The properties of the material used for the expendable pattern, the dimensional accuracy of the pattern, and the surface condition were analyzed in terms of their influence on the quality of the cast product. In addition, the preparation of the pattern with a special coating and the decomposition characteristics of the pattern during interaction with molten gray cast iron were considered. During the study, the main factors affecting the occurrence of gas defects, filling of the mold cavity by the molten alloy, and the quality of the cast product were identified. Based on the obtained results, the possibilities of improving the quality of cast products made from gray cast iron using an optimal technology for the effective application of expendable patterns are

Keywords:

gray cast iron, expendable pattern, casting technology, thin-walled castings, thermal decomposition, casting defects, molding, cast product, CNC, EPS



demonstrated. The results of the study have practical significance for improving the technology of manufacturing complex-shaped, high-structural, thin-walled parts from gray cast iron alloy with a reduced amount of machining.

Совершенствование технологии литья по газифицируемым моделям для получения литых изделий из серого чугуна

АННОТАЦИЯ

В данной статье исследована технология использования газифицируемой модели для получения высококонструкционных тонкостенных литых изделий из серого чугуна. В исследовательской работе усовершенствована технология использования газифицируемых моделей для получения качественных литых изделий. Проанализировано влияние свойств материала, используемого для изготовления газифицируемой модели, размерной точности модели и состояния её поверхности на качество литого изделия. Кроме того, рассмотрены технология подготовки модели с использованием специального покрытия и характеристики разложения модели при взаимодействии с жидким серым чугуном. В ходе исследования определены основные факторы, влияющие на образование газовых дефектов, заполнение полости формы жидким сплавом и качество литого изделия. Полученные результаты показывают возможности повышения качества литых изделий из серого чугуна на основе оптимальной технологии эффективного использования газифицируемых моделей. Результаты исследования имеют практическое значение для совершенствования технологии изготовления сложнопрофильных, высококонструкционных тонкостенных деталей из серого чугуна с минимальным объёмом механической обработки.

Ключевые слова:

серый чугун, газифицируемая модель, технология литья, тонкостенные отливки, термическое разложение, дефекты литья, формовка, литое изделие, CNC, EPS.

Introduction. The production of cast products is one of the important technological methods for manufacturing parts with complex geometric shapes in mechanical engineering and other industrial sectors. In the production of complex-shaped parts, the proper selection of the casting method helps to minimize the volume of subsequent machining, as well as ensuring the geometric accuracy of the product, casting quality, and its mechanical properties. Therefore, the development and improvement of modern casting technologies aimed at expanding the technological capabilities of conventional casting methods is considered one of the important scientific and practical areas [1].

The production of cast products using expendable patterns (Lost Foam Casting, LFC) is considered one of the promising casting technologies that enables the production of complex-shaped, thin-walled cast products with minimal machining. In this method, an expanded polystyrene (EPS) or other polymer foam material is used to produce the pattern. In disposable molds, when molten metal is poured, the metal occupies the cavity formed as a result of the thermal decomposition of the pattern. The important advantages of this technology include the absence of a parting plane, the possibility of producing complex-shaped, high-structural parts, reduced need for the use of cores, and reduction in the volume of machining [1,2].

The properties of the expendable pattern in the LFC process are considered one of the main factors determining the quality of the cast product. The material, density, dimensional accuracy, and thermal decomposition characteristics of the pattern affect the process of filling the mold cavity with



molten metal. As a result of the decomposition of the EPS pattern under the influence of molten metal, gaseous products are formed, and their removal from the mold is important for the stability of the metal flow [3,4]. Kannan et al. analyzed physical and kinetic models of the thermal decomposition of EPS and showed that a special approach is required to describe the LFC process because the conditions of polymer decomposition differ from those of conventional thermal processing [3].

Simultaneously with the decomposition of the expendable pattern, a gas layer is formed between the metal and the pattern. The gas pressure in this layer can affect the movement velocity of the metal and the mold filling process. Mirbagheri et al. developed a mathematical model that takes into account foam decomposition, gas removal, and the permeability of the refractory coating in the LFC process. In the study, gray cast iron was poured at a temperature of 1350 °C, and the experimental and modeling results were compared [4]. Shayegh et al. proposed a two-dimensional model that takes into account the decomposition of the EPS pattern, heat transfer, and gas diffusion. Their results showed that pattern density, coating permeability, and pattern decomposition temperature are important parameters affecting the mold filling process by the metal [5].

The refractory coating applied to the surface of the pattern is also an important component of LFC technology. The removal of gases generated during pattern decomposition from the mold depends on the gas permeability of the coating. In experiments conducted by Chang and Shih with molten gray cast iron, the effects of coating particle size, type and amount of binder, and coating thickness on gas permeability were investigated. The study observed favorable conditions related to gas removal and back pressure in the mold when the coating thickness was less than 0.5 mm [6].

In LFC technology, gas defects may form if the decomposition products of the pattern are not sufficiently removed from the mold. Sun, Littleton, and Bates investigated the formation mechanism of gas cavities in iron castings. The researchers determined the carbon concentration and coating residues in the gas cavities and showed that the retention of foam pyrolysis products within the metal is an important factor in the formation of such defects. Under production conditions, a reduction in the reject rate from 25% to 5% was reported as a result of changing the technological parameters [7].

The effect of additional technological influences during the casting process on the properties of gray cast iron has also been investigated. Qiu and Xiao studied the effect of mechanical vibration on HT100 gray cast iron produced by the LFC method. According to the results of the study, changes in vibration parameters led to changes in graphite morphology, austenite structure, and mechanical properties [8]. Xiao et al. investigated the effect of vibration frequency on the primary phase, graphite morphology, and mechanical properties of gray cast iron produced by the LFC method [9].

The above studies show that several factors simultaneously affect casting quality in LFC technology, including the properties of the expendable pattern, its thermal decomposition, coating gas permeability, metal mold-filling conditions, and solidification process [3–9]. However, most existing studies have focused on individual parameters of these factors. The comprehensive evaluation of the technological sequence of expendable pattern preparation, pattern dimensional accuracy and surface condition, as well as the stages of its preparation for casting in order to produce gray cast iron cast products, requires further research.

In this regard, the aim of this study is to investigate the technology for preparing an expendable pattern for producing cast products from gray cast iron, to determine its main technological parameters, and to evaluate the effect of the conditions for preparing the pattern for casting on the quality of the obtained cast product.

Materials and methods. In this study, the technology for preparing the pattern used in the casting process of a lifting shiber component made of gray cast iron was investigated. The main focus of the study was to determine the possibilities of using an expendable pattern instead of a conventional wooden pattern, as well as to evaluate the possibilities of reducing time, raw material resources, and energy consumption during pattern preparation.

The lifting shiber component presented in the SP–1037 and SP–1033 drawings was selected as the research object. Based on the geometric shape and structural dimensions of the component, its three-dimensional digital model was developed using SolidWorks software. The prepared 3D model was subsequently used to form the geometric basis of the expendable pattern and to determine its structural parameters. Thus, the pattern preparation process was brought to a unified geometric basis for evaluating its accuracy, technological sequence, and resource consumption [Figure 1].

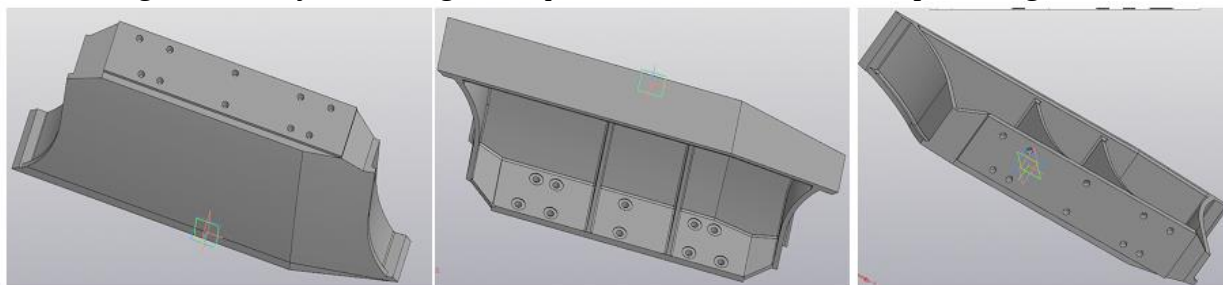


Figure 1. Views of the 3D model of the rising gate component developed in Solidworks based on the SP–1037 drawing.

Using the above-mentioned drawings, the patterns were made from polystyrene material, which is highly flammable and consists of 5% hydrocarbon styrene monomer and 95% air. The density of the selected polymer material is 11–32 kg/m³, its strength limit is 30–40 MPa, and its melting temperature is 150–200 °C. Based on this material, expendable patterns were prepared on a CNC ROUTER machine using the SP–1037 and SP–1033 drawings, and their views are presented in Figure 2.

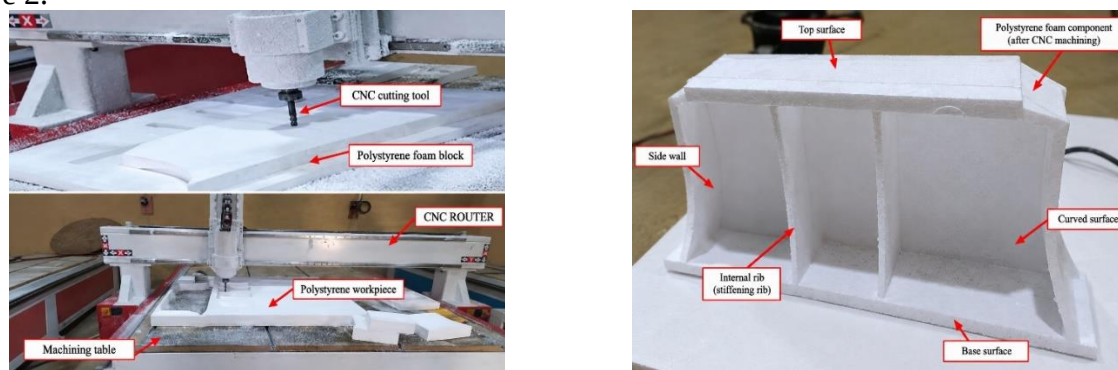


Figure 2. Models of the rising gate component made from polystyrene material using a CNC ROUTER machine.

The patterns were prepared on a CNC ROUTER machine taking into account the shrinkage of the polystyrene material of 0.2–0.3% and the shrinkage of the aluminum material of 2–3%. For the largest dimensions of the patterns, 800 mm and 990 mm, the dimensions of 818 mm and 1012 mm, respectively, were calculated by adding the corresponding shrinkage allowances.

As shown in the SP–1037 drawing, the two middle walls have a length of 250 mm and a thickness of 8 mm, while the two horizontal side walls have lengths of 240 mm and 222 mm and a thickness of 10 mm, and the outer joining radii of these walls are 185 mm. During fabrication on the CNC ROUTER machine, a casting draft of 10–15% was provided for all side, middle, and corner walls of the pattern. This eliminated defects occurring on the mold walls during separation of the pattern from the sand-clay mold and reduced the mold preparation time. Incorrect calculation of the draft radius on the rear wall of this pattern may result in a reduction in the service life of the cast part or lead to complex processes such as machining after casting. Taking into account the shrinkage, bending, twisting, compression, bending, and deformation properties of the cast part, possible defects arising from the pattern dimensions were eliminated.

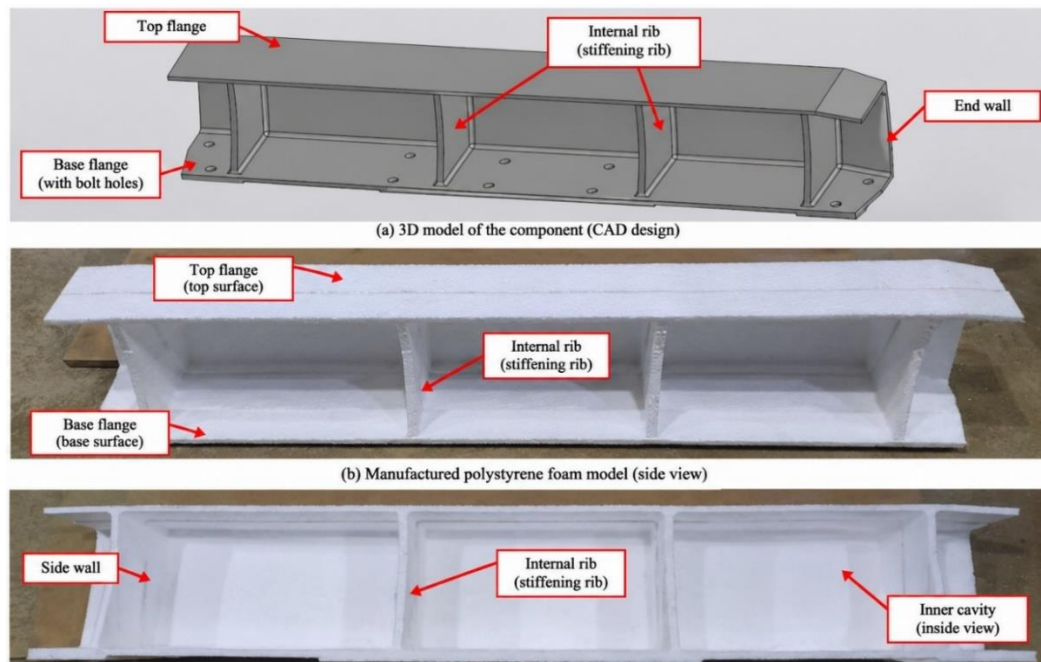


Figure 3. Model created based on the SP-1033 drawing.

Since the SP-1033 drawing of the rising gate component provided by O'zmetkombinat JSC did not contain the dimensions required to create the pattern, its 3D model was created using Kompas, and all dimensions from the 2D model were determined. The two longest walls of the pattern had a length of 990 mm and a thickness of 10 mm, while the middle walls had a length of 147 mm and a width of 8 mm. As noted above, for this pattern as well, the casting drafts for all walls were made in a conical shape, and the shrinkage values for polystyrene, duralumin, and gray cast iron materials were calculated. After the additional wall was cast from duralumin material, cutting and grinding operations were carried out. The 3D model created in SolidWorks based on the SP-1033 drawing and the pattern made from polystyrene material using a CNC ROUTER are presented in Figure 3.

The models of the rising gate components were prepared using this technological method due to their complex shape, precise dimensions, and flat surfaces, resulting in high efficiency.

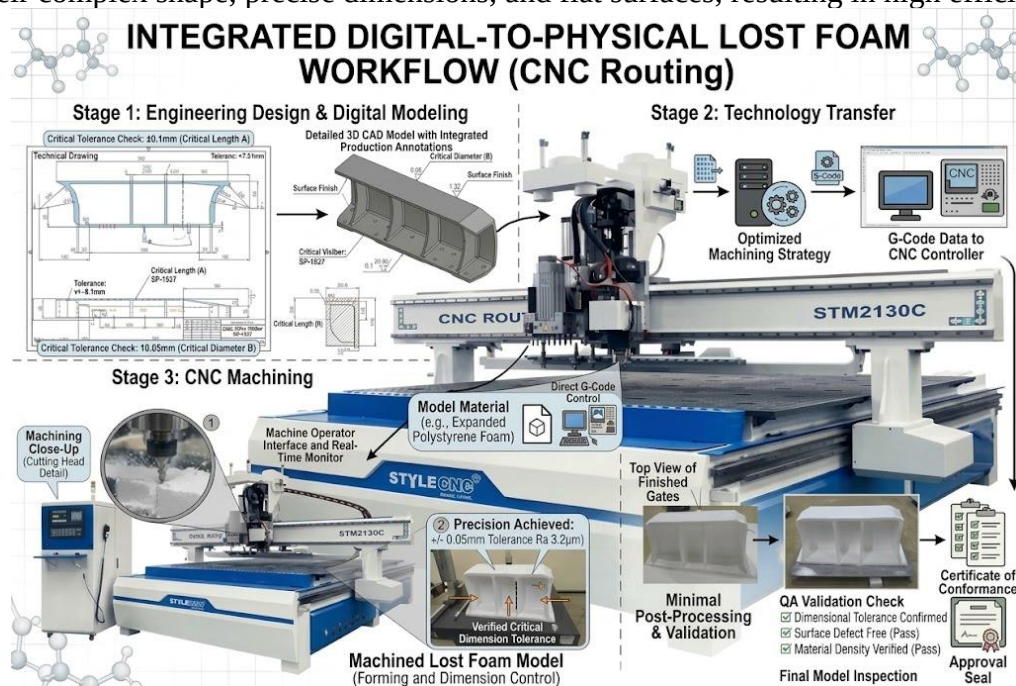


Figure 4. Integrated technological workflow for the digital design and CNC machining-based fabrication of expendable polystyrene patterns.

The technology for preparing the expendable patterns of the rising gate components included sequential stages from digital design to obtaining the physical pattern. Initially, the geometric parameters of the component were analyzed based on the SP-1037 and SP-1033 working drawings, and their three-dimensional digital models were developed in a CAD environment. At the next stage, the digital model data were transferred to the CNC ROUTER 2130 machine, and the expendable patterns were formed by machining the polystyrene material. The prepared patterns were inspected according to the main geometric dimensions, and their conformity with the working drawings and the developed 3D model was evaluated. The technological sequence from digital design to physical pattern preparation used in the study is schematically presented in Figure 4.

Based on the patterns made from polystyrene material using the CNC ROUTER machine according to the SP-1033 and SP-1037 drawings of the rising gate components, the castings from gray cast iron alloy were produced in the foundry-mechanical section of “Detalmash” LLC in Namangan Region using an IST-0.2 melting furnace. Secondary return gray cast iron alloys were used as the charge materials, with a total charge of 90 kg.

For the vacuum mold, 80–84% quartz sand, 5–6% bentonite clay, and 6–7% water were mixed in a batch mixer for 15–20 minutes. During charging of the IST-0.2 furnace, first the larger and then the smaller charge materials were loaded, while ensuring that the secondary alloys contained no moisture. The patterns prepared from the expendable material were coated with a 1–2 mm refractory coating and then dried at room temperature for 8–10 hours.

The dimensions of the vacuum mold, 150 cm, 210 cm, and 110 cm, made it possible to cast the two patterns prepared according to the SP-1033 and SP-1037 drawings simultaneously. During the molding process, the quartz sand was sieved through 0315, 025, and 016 sieves, and because its fraction belonged to the 025 group, the removal process of the polystyrene pattern after burning in the vacuum mold under a pressure of 6 MPa was accelerated. Compared with obtaining castings in conventional molds, the castings obtained by this method were characterized by their accuracy, the absence of the need for machining, and lower consumption of molding materials, while the ease of automation also resulted in a significant increase in productivity.



Figure 5. Pouring channel and feeders made from polystyrene material and cut from the finished patterns for casting gray cast iron alloy.

To ensure the high quality of the cast rising gate components, the feeders, slag traps, and pouring channels were calculated. Considering that it is important for the molten alloy poured into the mold to fill all walls of the pattern proportionally, the feeders were positioned by dividing the total length of the two side walls of the pattern by 1/4 and were prepared as shown in Figure 5.

The two feeders attached to the pattern walls and the feeder positioned above them also served as slag traps. When placing the patterns in the vacuum mold, 50–80 mm of coarse-fraction sand was first placed at the bottom of the mold, taking into account that it would not obstruct the vacuum pump from drawing air through the holes in the vacuum pump pipes. The patterns with the pouring channel and feeders attached, coated with a refractory coating containing 8–11% alumina

chamotte, 4–5% electrocorundum, 2.9–4.4% zirconium, 1.5–2.5% refractory clay, 1.5–2.9% kaolin, 4.5–5% water glass, and water, and dried at room temperature, are presented in Figure 6 [10–12].

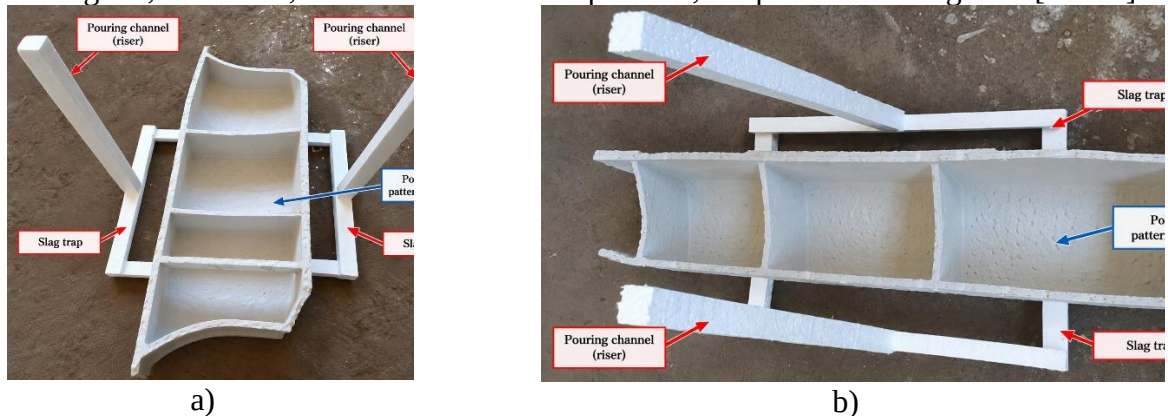


Figure 6. a) Model prepared based on the SP-1037 drawing; b) Model prepared based on the SP-1033 drawing.

Discussion. The patterns prepared from polystyrene material using the CNC ROUTER machine based on the SP-1033 and SP-1037 drawings and coated with refractory paint on their surfaces are presented in Figure 6. When placing the patterns in the vacuum mold, 5–7 cm of coarse-fraction sand was first placed, and the sand was compacted at the bottom of the mold using a specially installed pressing device.

During the study, the technology of preparing models of high-structural, complex-shaped parts from polystyrene material using a CNC ROUTER machine based on the SP-1033 and SP-1037 drawings was used. The digital control of this equipment played an important role in accurately preparing the dimensions of the models.

The feeders installed on the models based on precise calculations also served as slag traps. In addition, the pouring channels and pouring cups were prepared with equal dimensions so that the molten metal could be poured within the same time regime. These arrangements ensured the simultaneous entry of the molten gray cast iron alloy into the mold cavity from both sides.



Figure 7. Integrated technological workflow for vacuum lost-foam casting of gray cast iron alloy using CNC-fabricated polystyrene patterns



The use of a vacuum mold contributed to improving the stability of the casting process. The purpose of coating the surface of the polystyrene pattern with a refractory coating was to ensure that the patterns could be placed into the mold without damage. Overall, the CNC equipment demonstrated its effectiveness in preparing expendable patterns. In the vacuum mold, the preparation of complex-shaped parts proved to be a practical technological solution for casting.

Conclusions. In the study, the technology for preparing polystyrene patterns on a CNC ROUTER machine, corresponding to the geometric shapes of complex-shaped, high-structural components based on the SP-1033 and SP-1037 drawings, was improved. 3D models were created using SolidWorks based on the drawings. In addition, the CNC ROUTER STM2130C equipment enabled the formation of the structural elements, internal surfaces, and curved sections of the casting pattern in the required shape.

A technology for coating the polystyrene patterns with a refractory coating was developed. The optimized arrangement of the expendable patterns in the vacuum mold and the composition of the molding material contributed to the stable organization of the casting process.

To ensure the production of high-quality cast products, the technology for positioning the pouring channels and slag traps was improved. In particular, the dimensions of the main feeder were optimized to ensure that it simultaneously served as a slag trap. All technologies used during the study provide a practical possibility for producing complex-shaped, high-structural cast components.

References

1. Jiang W, Fan Z. Novel technologies for the lost foam casting process. *Frontiers of Mechanical Engineering*. 2018;13(1):37–47. DOI: 10.1007/s11465-018-0473-2.
2. Donahue R, Anderson K. Lost Foam Casting. In: *ASM Handbook, Volume 15: Casting*. ASM International; 2008. p. 640–645. DOI: 10.31399/asm.hb.v15.a0005254.
3. Kannan P, Biernacki JJ, Visco DP Jr. A review of physical and kinetic models of thermal degradation of expanded polystyrene foam and their application to the lost foam casting process. *Journal of Analytical and Applied Pyrolysis*. 2007;78(1):162–171. DOI: 10.1016/j.jaap.2006.06.005.
4. Mirbagheri SMH, Serajzadeh S, Varahram N, Davami P. Modelling of foam degradation in lost foam casting process. *Materials & Design*. 2006;27(2):115–124. DOI: 10.1016/j.matdes.2004.09.018.
5. Shayegh J, Hossainpour S, Rezaei M, Charchi A. Developing a new 2D model for heat transfer and foam degradation in EPS lost foam casting (LFC) process. *International Communications in Heat and Mass Transfer*. 2010;37(9):1396–1402. DOI: 10.1016/j.icheatmasstransfer.2010.07.015.
6. Chang AS, Shih TS. Permeability of coating in the lost foam casting process. *International Journal of Cast Metals Research*. 1999;12(4):263–275. DOI: 10.1080/13640461.2000.11819363.
7. Sun WL, Littleton HE, Bates CE. Formation mechanism of gas cavity defects in lost foam iron castings. *International Journal of Cast Metals Research*. 2003;16(6):549–553. DOI: 10.1179/136404603225006431.
8. Qiu K, Xiao B. Effect of Mechanical Vibration on Microstructure and Mechanical Properties of Gray Cast Iron in Lost Foam Casting. *Mathematical Problems in Engineering*. 2021;2021:4936147. DOI: 10.1155/2021/4936147.
9. Xiao BT, Fan ZT, Jiang WM, Xiang JH, Yan XF. Effect of vibration frequency on primary phase and properties of grey cast iron fabricated by lost foam casting. *China Foundry*. 2020;17(1):1–7. DOI: 10.1007/s41230-019-9083-9.
10. Khasanov, J., Turakhodjaev, N., Makhmudov, F., Turakhujaeva, S., Ermanov, O., & Ibragimov, A. (2023). Improvements in Obtaining Thin-Walled Casting Details Through Liquid Glass Mixtures. *Central Asian Journal of Theoretical and Applied Science*, 4(4), 51-54. <https://doi.org/10.17605/OSF.IO/6T843>



11. Kholmirzaev, N., Turakhodjaev, N., Saidmakhamadov, N., Khasanov, J., Saidkhodjaeva, S., & Sadikova, N. (2023). Development of Technology of Making Shafts from Steel Alloy 35XGCL. Lecture Notes in Networks and Systems, 762 LNNS. https://doi.org/10.1007/978-3-031-40628-7_18
12. Kholmirzaev, N., Turakhodjaev, N., Saidmakhamadov, N., Khasanov, J., Bektemirov, A., & Sadikova, N. (2024). Effects of titanium (Ti) contents on the wear resistance of low-alloy steel alloys. In E3S Web of Conferences (Vol. 525, p. 03003). EDP Sciences.
13. Khasanov J. et al. Development of technology for obtaining thin-walled details from gray cast iron in sand-clay moulds //International Journal of Mechatronics and Applied Mechanics. – 2024. –No. 18. –C. 199-209