Peculiarities of producing decorative articles by the method of lost foam casting

Oleg Utyev¹, Anna Lukyanchenko²
Tomsk, 634050, Russia, National Research Tomsk Polytechnic University
E-mail: ¹ utiev@mail.ru, ² annlukyann@gmail.com

Abstract. This paper investigates the method of lost foam casting performed with consumable patterns. The dependence of the fluidity of the silumin on the polystyrene’s characteristics, casting temperature and the pattern’s parameters is revealed. Recommendations regarding the application of various polystyrene types for artistic casting are provided.

1. Introduction
The lost foam casting (LFC) method is one of the cutting edge techniques for producing castings, which appeared in the second half of the XXth century. Lost foam casting is a casting method with the use of patterns, which are not removed from the mold but remain in it and are gasified under the action of the heat energy of a metal being poured into the mold. The described technique was firstly patented in 1958 by the American architect F.H. Schroyer [1].

2. Theoretical background
The LFC method is consist of following main stages.

- Production of a pattern. For decorative castings a pattern is produced from the ready-to-use foamed polystyrene slabs by using high-speed milling or a device which has a heated nichrome wire with a current flowing through it at 12V. Separate parts of the pattern can be glued together with the easily burnable materials while the defects can be removed by the use of wax materials (paraffin, stearin, etc.).
- Assembly of the pattern blocks. For the LFC method, the bottom gating system, desirably with air gates, is used. The pattern blocks are assembled by gluing.
- Dressing of a pattern. A pattern is dressed with non-stick paints to prevent the burn-on of the casting surfaces and the deformation of the pattern.
- Molding of a pattern. When molding with a dry filler without a binder, we use perforated flasks the bottom of which is covered with a layer of sand. A pattern block is then affixed to the bottom of the flask. Vibration is applied to ensure better compaction of the sand.
- Pouring of a metal. The metal pouring rate affects the casting surface quality: it should not be too high or too low.

The downside of the lost foam casting method is a single use of a pattern [2]. The lost foam casting method is mostly applied in industrial production. It is used to simplify the molding process, increase productivity, enhance the casting quality, reduce the production costs, etc [3].

For artistic works of authorship, which are normally produced in a single copy, packaging polystyrene and a polystyrene commonly applied for heat insulation are used. The present paper provides an investigation of the polystyrene brands used to produce consumable patterns, as well as the optimum sections and lengths of the samples, proper casting temperature and method for the specified alloy.

As with any other method of casting, lost foam casting is characterized by a number of technological features. In this paper, the relationship between the cross-section and the length of the pattern is examined on the example of the AL12 (10-13% Si, the balance Al) and AL5 (1-1,5% Cu, 4,5-5,5% Si, 4,5-5,5% Si, etc.).
the balance Al) silumin alloys and initially two polystyrene brands (expanded polystyrene (EPS-25) and extruded polystyrene Penoplex 35). Further on, Penoplex 31 is added to extend the range of the investigation.

To determine the lowest possible cross section of a casting, test samples of the 150 mm length and the 5×5mm (S=25 mm2), 10×10mm (S=100 mm2), 15×15 mm (S=225 mm2) cross-sections have been made. The 100×100×20 mm test samples of each polystyrene brand are weighed and measured with the accuracy of ± 0.05 mm. By using the obtained data, density of the samples of each polystyrene brand is found: 15 kg/m3 for EPS-25, 29 kg/m3 for Penoplex 31, and 31 kg/m3 for Penoplex 35. Then, three samples of the different cross sections of each polystyrene brand are assembled into the pattern blocks. The AL12 silumin alloy is used for casting at a pouring temperature of 600, 700, 800, 900°C. The obtained samples have been measured at the gating system. The data are presented in the diagram (figure 1). Polystyrene EPS-25 appeared to provide the best results allowing the production of the casting with the 100 mm2 section for the entire length of the pattern. The other polystyrene brands demonstrated excellent results at the 225 mm2 cross sectional area of the samples and a melt pouring temperature of above 800°C.

![Figure 1. Dependence of length and cross section area of the samples on the silumin’s pouring temperature](image)

Based on the results analysis of the described investigation stage it can be stated that small cross sections of the patterns (≈25 mm2) are acceptable when the product’s length is limited (20-40mm). The best results of casting by the LFC method can be achieved by using the EPS-25 polystyrene and a pouring temperature of 800°C. Max results are achieved with the 100 and 225 mm2 cross sectional area of the samples [4].

The next step is to study the dependence of the AL5 silumin’s fluidity on pouring temperature using spiral test samples. To determine fluidity, different test samples cast in the molds of a special design are used. The most common varieties are different spiral samples. Molds designed for casting such samples have an extended spiral channel located in the horizontal plane. The cross section of the channel is constant on its entire length and typically has a trapezoid shape of the 8 mm height, 8 mm width at the top, and 7 mm width at the bottom. One of the spiral samples’ designs is shown in figure 2. Fluidity is measured in millimeters along the length of the cast spiral. For the convenience of measurement, protrusions are made in the upper part of the channel; the distance between them is 50 mm [5].
The spiral test sample of the specified construction has been designed in the SolidWorks software and produced on a milling machine.

![Figure 2. Spiral fluidity test sample](image)

The polystyrene foam Penoplex 35 with the given average density characteristics is used for milling (table 1). The quality certificate data are verified under laboratory conditions.

| Density characteristics | Density (kg/m³) |
|-------------------------|----------------|
| Technical requirements of the 5767-016-56925804-2011 specification | 25.0-35.0 |
| Data in the certificate of quality | 28.1 |
| Data obtained in the laboratory | 31 |

The selection of the polystyrene brand and its treatment are characterized by the following features:

- EPS-25 is a soft, relatively coarse-grained and easily delaminated material. Hence, it is hardly suitable for milling treatment;
- the properties of Penoplex 31 are similar to those of Penoplex 35 [6], although Penoplex 31 is more dense, easily machined by milling equipment, which makes it possible to obtain small parts without layering of the polystyrene foam.

In the course of the investigation spiral test samples are cast by the LFC method from the AL5 silumin alloys. The metal fluidity along a curved trajectory is analysed (figure 3).

![Figure 3. Dependence of the spiral test samples’ length on pouring temperature](image)
It should be noted that the surface quality vary when using different polystyrene brands for the production of the patterns (figure 4). The patterns are not coated with any non-stick coatings or coatings aimed at improving the casting surface. The length of the samples cast into consumable patterns which are made of a less dense, coarse-grained EPS-25 polystyrene foam is maximal. However, their surface quality is much worse compared to that of the samples cast into the patterns which are made of a denser, fine-grained Penoplex 35. Therefore, it is preferable to use Penoplex 35 as it will reduce costs of the follow-up mechanical treatment of an article. In the case when the cross section and the length of a pattern do not allow the use of Penoplex 35, surface of the EPS-25 polystyrene foam pattern should be treated with paraffin.

Figure 4. Appearance of the sample surface:
  a) EPS-25 pattern; b) Penoplex 35 pattern

3. Results
For the production of bulky castings of a complex geometrical shape it is better to use the LFC method at a pouring temperature of 800°C. The best mold filling is achieved by using the EPS-25 polystyrene foam patterns.

For the production of articles with long curved elements it is reasonable to use EPS-25 polystyrene foam since it ensures the maximum mold flow but requires manual treatment. Penoplex 35 allows the production of articles of a sophisticated configuration and with small parts even by using metal-cutting equipment.

References
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