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Influence of Temperatures of Melt Overheating and Pouring on the Quality of Aluminum Alloy Lost Foam Castings

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Abstract—Lost foam casting (LFC) is currently one of the most efficient and promising methods of fabricating high-quality thin-wall castings possessing specified dimensional accuracy, required surface roughness, and other properties. This technology is widely used in the production of aluminum alloy products. To minimize costs in the fabrication of wares and to fabricate high-quality castings, it is reasonable to use an increased amount of secondary materials in the charge, herewith paying attention to the melt overheating temperature and holding time. The results of studying the temperature modes of smelting pouring aluminum alloys in the LFC are presented. The most efficient modes in manufacturing conditions under consideration which provide the best quality characteristics of leak-tight castings by dimensional accuracy and surface roughness were as follows: the melt overheating temperature is 880–890°C and the melt pouring temperature into the casting mold is 820–830°C. The influence of various variants of temperature parameters of smelting and pouring the melt of the AK7 composition during the LFC on the content of nonmetallic inclusions in the cast state is investigated. It is revealed that the minimal γ-Al_2O_3 content in the final alloy is provided by a melt overheating temperature of up to 880–890 or 940–950°C and a melt pouring temperature into the casting mold of 820–830°C.

Keywords: aluminum alloys, silumins, smelting, melt, pouring, casting, casting quality, nonmetallic inclusions, gasified models, resource-saving technology

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INTRODUCTION

Lost foam casting (LFC) technology is one of the most progressive methods of fabricating high-quality castings [1–4]. This technology becomes increasingly widespread in the production of aluminum wares [5–20].

The LFC production process is very complex and includes many operations, staring from the preparation of polysterene and finishing with the knocking-out of castings.

It should be noted that the smelting technology and melt state before pouring into casting molds can substantially affect casting quality. This circumstance is especially urgent when implementing resource-saving technologies, when an increased amount of secondary materials in the charge is used [21–23]. However, the questions of smelting technology are poorly understood in LFC technologies, and all efforts are usually concentrated on the problems associated with the casting-mold technology, notably, manufacturing processes of models, model blocks, and the gating system; the arrangement of "bushes" in casting boxes, forming, evacuation, pouring; etc.

In this article we present the results of studying the influence of temperature modes of smelting and pouring the AK7 alloy on the quality of Gas Analyzer Case Cap thin-wall castings fabricated by the LFC method in conditions of OOO NPP Vektor Mashinostroeniya (Novokuznetsk) with the application of an increased amount of secondary materials in the charge (50–55% of scrap and wastes).

The quality of these castings in manufacturing conditions is evaluated by characteristics such as surface roughness, dimensional accuracy, tightness, and strength (the microstructure was not analyzed). An analysis of defects of castings showed that it is necessary to select rational temperature parameters of melt smelting and pouring into the casting mold. To minimize costs for the production of the wares, it is reasonable to use an increased amount of secondary materials in the charge, and herewith attention should be

Fig. 1. Bushes of completed Gas Analyzer Case Cap castings.

paid to the overheating temperature, melt holding time, and pouring temperature in the casting mold.

EXPERIMENTAL

The object of the investigation was the AK7 industrial aluminum alloy (*GOST* (State Standard) *1583–93*). Ingots of the AK7 alloy, as well as secondary materials of the same alloy as a scrap of parts and wastes of the foundry and mechanical shops, were used for its preparation. Secondary materials in all variants contained ~50 wt % fine scrap and alloy wastes and ~50 wt % briquetted shavings. All wastes were preliminarily purified and treated according to the standard requirements.

The composition of charge materials includes the AK7 ingot silumin (45–50 wt %) and return and wastes of the AK7 alloy (about 50–55 wt %). Smelting was performed in an IST-0.06 furnace; herewith, the melt overheating temperature (T_{over}) was varied from 800 to 1000°C with a step of ~50°C. The melt pouring temperature (T_{pour}) was varied from ~800 to ~900°C, depending on the smelting variant, and pouring was performed through an SSF-0.6 filtration glass mesh.

To perform forming, the $2K_1O_302$ quartz sand was used. When fabricating gasified models, we used polysterene produced by STYROCHEM (Montreal, Canada). Ready model blocks (four "bushes," eight models each) were arranged vertically in a suspended state into a casting box 700 × 700 × 700 mm in size with the help of a special facility. Sand was poured into a casting box simultaneously with its vibration at a frequency of ~36 Hz, which was performed by means of two electrical vibrators fastened on it (3000 rpm). Then the casting box was coated with a film, the pouring facility was arranged, the casting mold was evacuated, and the melt was poured. After cooling, the castings were knocked-out and lopping off and sand blasting were performed. To reveal the qualitative characteristics of castings, the surface smoothness and dimensional accuracy of castings was evaluated by comparison with reference samples.

If more than 3 castings in one series in 4 bushes of 32 castings (Fig. 1) summarily or separately did not satisfy one or another required characteristic, then the overheating and pouring variant was considered ineffective for this technology. If the insufficient burnability of a foam polysterene model block in its any part was observed in some variant in any series, then the technology variant was attributed to ineffective ones. In addition, if at least one casting had a porosity ball higher than the third one (this was determined by the VIAM technology according to *GOST 1583–93*) in a single variant of any series from the random sampling of ten good castings, then this technology variant was also considered ineffective.

The content of nonmetallic inclusions was determined for specially prepared specimens (from poured samplings) with the help of an XRF-1800 X-ray fluorescent wave-dispersion sequential action spectrometer (Shimadzu, Japan). According to each variant of smelting and pouring technology, three series were worked-out. Thus, the content of nonmetallic inclusions (γ-Al_2O_3) according to the concrete variant was calculated as the arithmetic mean of 96 samplings.

INFLUENCE OF TEMPERATURES OF MELT OVERHEATING AND POURING ON THE SURFACE SMOOTHNESS, DIMENSIONAL ACCURACY, AND POROSITY OF CASTINGS

The influence of temperatures of melt overheating (T_{over}) and pouring (T_{pour}) on the quality characteristics of castings in the course of performing several series of production approbation is shown in the Table 1.

Experimental results showed (Table 1) that, out of the 12 technology variants of melt smelting and pouring, variants *5* and *8* are efficient. It should be noted that variants *2* and *7* satisfy the necessary requirements by dimensional accuracy and surface smoothness of castings but do not correspond to them by porosity. This is explained by the fact that sufficiently high smelting and pouring temperatures positively affect the change in the melt microinhomogeneity level [21, 23, 24], but lead to an increased content of nonmetallic inclusions and do not make it possible to implement efficient occurring refining methods with fluxes. The applied melt-refining technology through an SSF-0.6 glass mesh does not provide the necessary removal of nonmetallic inclusions and gases, which gives the porosity higher than the 3rd grade.

It should be noted that, in variant *10*, despite the satisfactory characteristics with respect to dimensional accuracy and surface smoothness of castings, increased porosity of the samples under study is also

Table 1. Influence of temperatures of melt overheating and pouring on the quality of castings (by 3 series of each variant of smelting and pouring technology)

Variant	T_{over}, °C	T_{pour}, °C	Quality characteristics of castings		Porosity[2]	Burnability[1]	Process conclusion[3]
			surface smoothness[1]	dimensional accuracy[1]			
1	990–1000	870–880	–	+	+	+	–
2		820–830	+	+	+	+	–
3		780–790	–	–	+	–	–
4	940–950	870–880	+	–	+	+	–
5		820–830	+	+	–	+	+
6		780–790	–	–	+	–	–
7	880–890	870–880	+	+	+	+	–
8		820–830	+	+	–	+	+
9		780–790	–	–	+	–	–
10	830–840	820–830	+	+	+	+	–
11		780–790	–	–	+	+	–
12	790–800	780–790	–	–	+	+	–

[1] "+" satisfactory, "–" unsatisfactory; [2] "+" yes, "–" no; [3] "+" efficient, "–" inefficient.

observed. This is apparently associated with the fact that an insufficiently high melt overheating temperature is applied in this process mode, which does not make it possible to level the undesirable influence of the amount secondary materials used in smelting on the casting quality.

Thus, the most rational variant in these process conditions is variant *8*, in which T_{over} is ~880–890°C, while T_{pour} is ~820–830°C. Variant *5*, with the same positive characteristics of casting quality, has a higher melt overheating temperature when compared with variant *8*, which is more expensive economically.

INFLUENCE OF TEMPERATURES OF MELT OVERHEATING AND POURING ON THE CONTENT OF NONMETALLIC INCLUSIONS IN CASTINGS

It is known [6, 9, 12, 21, 23, 24] that the content of nonmetallic inclusions on aluminum alloys above the regulated amount can lead to various casting defects and, correspondingly, to casting rejects (mainly to porosity).

Figure 2 shows the results of studying the influence of temperature modes of smelting and melt pouring on the content of nonmetallic inclusions (γ-Al_2O_3) in the samples under study made of the AK7 alloy.

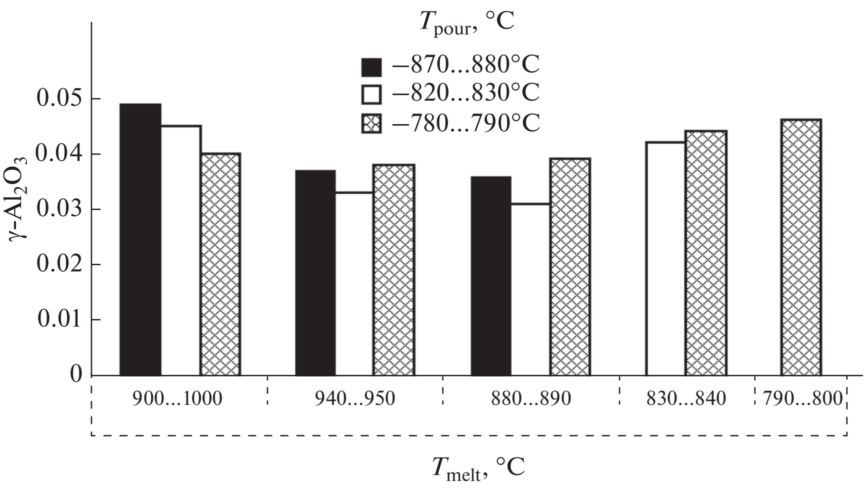

Fig. 2. Influence of temperatures of melt overheating and pouring on the content of nonmetallic inclusions (γ-Al_2O_3) in the samples of the AK7 alloy fabricated by the LFC method.

Our data show (Fig. 2) that, among the 12 implemented variants of the technology of smelting and melt pouring, variants *5* and *8* are most efficient from the viewpoint of minimizing nonmetallic inclusions (γ-Al_2O_3) in the AK7 alloy. They correspond to T_{over} ~ 940–950°C, T_{pour} ~ 820–830°C, and T_{over} ~ 880–890°C, T_{pour} ~ 820–830°C, and provide the required decrease in the microinhomogeneity level, but they do not lead to an increased content of nonmetallic inclusions. This fact is explained by rational magnitudes of temperatures of melt overheating and pouring into the casting mold.

It should be noted that very efficient methods of melt refining with the fabrication of aluminum castings are developed now [22, 25–30]. However, in the case of casting using gasified models, it seems impossible to implement most of them because of the high temperatures of smelting and casting. The use of filtration during pouring into the casting mold is most reasonable as the reliable refining technology in this case.

Other various methods of affecting the melts—both physical and manufacturing—have large prospects for manufacturing high-quality cast alloys and wares in addition to high-temperature overheating [31–37]. The development of these methods will make it possible to lay the theoretical and process foundations of production of castings with the required structure and properties.

CONCLUSIONS

It is shown that, when implementing the fabrication technology of thin-wall castings of the AK7 alloy by lost foam casting, the smelting and casting modes most efficient in production conditions under consideration and providing the best quality characteristics of tight castings by dimensional accuracy and surface smoothing are as follows: the melt overheating temperature is 880–890°C and melt pouring temperature into the casting mold is 820–830°C. Herewith, it is established by the investigation into the influence of various temperature modes of smelting and melt pouring (the AK7 composition) during the LFC on the content of nonmetallic inclusions in the cast stage that the minimal content of γ-Al_2O_3 in the alloy is provided by a melt overheating temperature up to 880–890 or 940–950°C and a melt pouring temperature into the casting mold of 820–830°C.

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