Effect of thickness of refractory coating on the Lost Foam Process

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Abstract

The analysis of the influence of the thickness of refractory coating on the production process of casts in the Lost Foam process was introduced in the work. It was conducted in the peculiarity the analysis simulating investigations the influence the coating thickness on the pouring rate, pressure in the gas gap and gas gap size. For simulation tests of the Lost Foam process, a mathematical model presented in this study was used. For calculations, the author's own algorithm was applied. Investigations have proved that with increasing thickness of coating the pouring rate decreases, while pressure in the gas gap and the size of the gap are increasing. The author's own investigations have proved a very significant effect of the coating thickness on the Lost Foam process, and specially on the mould pouring rate.

Keywords: Foundry engineering, Lost foam, Foamed polystyrene patterns

1. Introduction

The growth of the interest in the process of making castings by Lost Foam technology invented by Shroyer [1] became at the close of the eighties of past century when this technology started being used for mass production of castings characterised by high accuracy and repeatability of dimensions, made of light metal alloys and ferrous alloys both. The great interest in the Lost Foam technology was mainly due to a definitely lower cost of castings manufacture and financial outlays very encouraging when compared with the traditional process [2]. Respective of the traditional casting process using standard moulding sands, this novel technology offers a number of undeniable advantages, including also the following ones:

- significantly lower costs of the production,
- it is possible to reproduce holes in castings without the necessity of using cores,
- the lack of parting planes and drafts improves in a natural way the dimensional accuracy of castings and reduces the number of operations necessary for casting fettling and finishing,
- the use of pure sand instead of moulding mixture eliminates the effect of moisture causing casting defects, with an extra advantage of cheaper sand reclamation,
- less of foundry tooling and equipment is needed (no moulding machines, mixers for moulding sand, etc.),
- lower labour input in final fettling operations due to the absence of flashes, burn-on defects, etc.

Many factors have an influence on the quality of casts made by this technology among other things: density of foamed polystyrene from which its the strength depends of the pattern and the quality of its surface; the kind of sand, and in the peculiarity its permeability, and refractory coating applied on the pattern which makes the working surface of the mould. This coating allows to obtain a necessary quality of cast surface and prevents metal penetration inside the sand grains. This layer should be characterised by high permeability so the existing gases would be able to abandon the mould cavity. The results of property of refractory coating applied on the polystyrene patterns used in lost foam process was presented in previous author’s works [2].
Investigations were carried out for two Ashland’s coatings - water coating KERNTOP L87 and alcoholic coating KERNTOP Z85 and two Huettenes-Albertus’ coatings, water coating DISOPAST 6230/7 for cast iron and DISOPAST 6779 designed for aluminum alloys. From results carried out investigations follows that the coating KERNTOP Z85 have the best permeability about 3.5*10⁻⁶ m²/Pa.s. However, permeability of coating is about 1000 times smaller than dry sand and its has the crucial influence on the filtration of the gaseous products of the polystyrene decomposition. The influence of the permeability of the refractory coating on the Lost foam process was introduced in the author work [3]. The influence of the thickness of refractory coating on the production process of the casts by method Lost Foam was introduced in the present work.

2. Technological aspects of the refractory coating applied on the pattern

Before moulding pattern equipment coats by refractory coating. Purpose of this is decrease the frequency occurrence of penetration of the liquid metal alloy in the matrix of the mould, burning of sand, the erosion and collapsing of mould and assurance of the required small surface roughness of casts [4, 5]. Protective coatings should be characterized by compatibility with the pattern material, assuring the cast smooth surface, good adhesive properties, the large speed of drying, resistance on the abrasion, durability enabling to manipulate of pattern equipment and possibly large permeability for gases. Typical protective coatings consist of refractory materials (silicates, clay-silicates, mica, Mullite), binder (bentonite, vinyl resins), rheological ingredients (thinner, alcohol or water), the wetting measures, the anti-fermentation measures and dyes [6]. Tiksoetric components are added to coating applied on the pattern which prevent trickling the coating from pattern. Coatings can be deposit by means of the brush, sprays and dipping. Spraying is the most suitable for pattern devoid internal channels. Dipping is recommended for spreading the coating on pattern with complicated internal channels. After plotting the coating, it should be to allow on flowing down excess of coating what assures receipt of the equal suitable thickness of the coating. The thickness of refractory coating beside his permeability is one of the most significant parameters of the coating, because the large influence has on the filtration speed of the gaseous products of the polystyrene decomposition. The thickness of the coating is of great importance in the filling process of mould cavity through the liquid melt, as also it decides about the cast quality in the essential way [7, 8].

3. Investigations of a effect between coating thickness and the process of mould cavity filling by molten alloy

3.1. System of equations describing the process of mould filling by molten alloy

The remarks reported [9] concerning kinetics of the evaporation process of foamed polystyrene pattern, on the dynamics of the mould cavity filling process and changes of gas pressure in the gap enabled the process of pattern evaporation and mould filling to be written as a system of differential equations presented below:

stage I

\[
\frac{dV}{d\tau} = \left( \frac{\alpha_0 + \frac{\Delta \tau}{L_{\text{top}}}}{C_{\text{top}} - y_1 - k} \right) \left( -T_{2,\text{par}} \cdot F_{\text{stwd}} + \left( \alpha_0 + \frac{\Delta \tau}{L_{\text{top}} - 1} \right) \left( -T_{2,\text{par}} \cdot F_{\text{stwd}} \right) \right) +
\]

stage II

\[
\frac{dV}{d\tau} = \left( \frac{\alpha_0 + \frac{\Delta \tau}{L_{\text{top}}}}{C_{\text{top}} - y_1 - k} \right) \left( -T_{2,\text{par}} \cdot C_{\text{top}} + C_{2,\text{par}} - T_{2,\text{top}} \right) \frac{F_{\text{par}}}{C_{\text{top}} - y_1 - p_g} +
\]

\[
\frac{dP}{d\tau} = \left( R \cdot F_{\text{par}} \cdot R \cdot F_{\text{par}} \cdot R \cdot F_{\text{par}} \right) \left( \frac{L_{\text{in}}}{d_{\text{top}} \cdot F_{\text{par}}} + \frac{L_{\text{out}}}{d_{\text{out}} \cdot F_{\text{par}}} \right) \frac{p_g}{F_{\text{par}}} \frac{1}{y_1 - 1} \frac{d\rho}{d\tau}
\]
For simulation testing of the full mould process, and specially of the effect of coating thickness on mould filling with casting alloy, the presented mathematical model of the process was used along with the author’s own algorithm for calculation of the effect of pattern thickness on, among others, raising of metal column surface in the mould, gas pressure in the gap, the size of the gap, etc.

### 3.2. Simulation tests of the Lost Foam Process

#### 3.2.1. The scope of simulation tests

Tests enclosed analysis of the thickness of refractory coating in the range of $s = 1.1 - 1.0$ mm. Moreover, in simulation tests the following parameters were adopted: density of pattern $\rho = 90$ kg/m$^3$, permeability of refractory coating $K_p = 7.7 \times 10^{-9}$ m$^2$/Pa·s, pressure in mould $P_k = 00$ Pa, ingate section $F_{wd} = 5.5$ cm$^2$, pouring temperature of molten alloy $T_i = 98$ K, size of foamed polystyrene granules $d_g = mm$. The simulation tests of an effect of parameters on the process of mould cavity filling were carried out for AK1 silumin.

#### 3.2.2. Analysis of simulation tests

Simulation tests were carried out on a model mould shown in Figure 1, and parameters comprised in the range of investigations. On the basis of the obtained results of calculations, a dependence was plotted for time-related changes of the main parameters, characteristic of the process of mould filling with molten metal.

![](http://example.com/fig1.png)

**Fig. 1.** Scheme of the process of mould cavity filling and pressure distribution inside mould

One of the most important parameters affects the process of mould cavity filling with molten alloy is the thickness of refractory coating. The influence of thickness coating on pouring rate is shown in Figures 2 and 3.

The nature of the changes of the pouring rate for the different thicknesses of the coating $s$ is very similar to the nature of the changes of the pouring rate which it was observed at the influence of the coating permeability on the pouring rate $K_p$ [3].
Fig. 2. Changes in pouring rate $\dot{V} = \varphi(\tau)$ for different refractory coating thickness $s$.

Fig. 3. Mean pouring rate vs coating thickness $s$.

Fig. 4. Change of pressure in the gas gap $p_g = \psi(\tau)$ for different refractory coating thickness $s$. 


From the presented results follows that with increasing refractory coating thickness, the pouring rate decreases equally significantly. May be inference that applying of the refractory coating with the thickness above \( s = 1.5 \text{ mm} \) is unfavourable because the pouring time lengthens very much.

From the dependence showed above follows that with increasing thickness of coating \( s \) the mean pouring rate decreases.

The effect of refractory coating thickness on pressure in the gas gap is shown in figures 4 and 5. From the showed dependence follows that an increase in the thickness of refractory coating causes increased pressure in the gas gap. This is well understood because gas filtration through thicker coating is much more difficult.

This is confirmed by the nature of changes in mean pressure in the gas gap in function of the coating thickness was shown in Figure 5.

The change of the gas gap size for different coating thickness is shown in Figures 6 and 7. Analyzing the change of the gap size in the time for the different thicknesses of the refractory coating it should be notice that the gas gap size increases very quickly to the value somewhat above 1 \( \text{mm} \) for the small thicknesses, meanwhile for the large thicknesses of the protective coating more initially quickly, and in the final stage of filling considerably slowly. In the case of the coating thickness \( s = 1 \text{ mm} \) the gap stays practically unchangeable in the latter part of pouring. The average size of the gas gap in the whole filling process increases with the increasing coating.

Fig. 5. Mean pressure in gas gap vs coating thickness \( s \)

Fig. 6. Changes in the size of gas gap \( (y_{2} - y_{1}) \) = \( f(\tau) \) for different refractory coating thickness \( s \)
4. Summary

Presented simulation studies in this article enable to analyse of an effect that the refractory coating thickness to mould filling rate, pressure in gas gap, and size of this gap. The studies enable the select of the best refractory coating thickness, which should provide correct filling of mould with molten. With decreasing coating thickness the pouring rate increases, while the pressure of gas in the gas gap decreases, similar as the size of this gap. An increase of the pouring rate ensures correct making of castings even of very intricate shapes and small wall thicknesses. The smaller dimensions of the gas gap and lower pressure of gas in this gap reduce the risk of mould “collapse”.

Researchers simulating investigations used the author’s mathematical model of the Lost Foam process and the worked out calculations algorithm allow to choose the right parameters of the protective coating.

References