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Effect of pattern coating thickness on characteristics of lost foam Al−Si−Cu alloy casting

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Abstract: An experimental study on lost foam casting of an Al−Si−Cu alloy was conducted. The main objective was to study the effect of pattern coating thickness on casting imperfection and porosity percentage as well as eutectic silicon spacing of the alloy. The results showed that increasing slurry viscosity and flask dipping time influenced the casting integrity and microstructural characteristics. It was found that thinner pattern coating produced improved mould filling, refined microstructure and higher quality castings containing less porosity.

Key words: aluminum alloy; lost foam casting; coating thickness; slurry viscosity; dipping time; porosity

1 Introduction

Lost foam casting (LFC) as a cost-effective and environmentally friendly casting process is widely used for aluminum alloy castings to produce complex engineering components [1,2]. The layer of coating applied on the pattern foam is a crucial parameter for producing high quality castings [3]. It was proposed that in lost foam casting process, refractory coating is developed on the pattern surface to provide support against the weight of the sand before the liquid metal solidifies as well as withstands the high temperature of molten metal [4]. Recently, it was reported [5] that the coating also provides an insulation barrier to keep the molten metal from losing too much heat, which may result in premature solidification. Thus, the coating may facilitate elimination of the degraded foam products including liquid and gases. In addition, LIU et al [4] reported that the coating layer decreases the heat transfer coefficient between the liquid metal and sand, resulting in the improvement of metal fluidity. Although, several studies have investigated the influence of coating in LFC [6−8], better understanding of the effect of coating on casting quality in LFC process is essential. Moreover, the effect of foam coating layer can be more complex due to the effect and interactions of several process factors. In the literature, some research work was conducted in order to improve the pattern coating properties. Zircon flour, kaolin and talc as suitable refractory compositions were proposed for coating preparation in LFC of Al–7% Si [9], while a mixture of zircon flour together with aluminum silicate and bentonite was also suggested as a slurry composition for the same cast alloy [10].

The composition and thickness of pattern coating are two critical factors governing the LFC. Limited studies have been carried out on the effect of coating thickness on other process parameters in LFC, but due to lack of knowledge on this area, it is therefore necessary to investigate how coating thickness would affect the casting characteristics. The present paper is aimed to investigate the effect of coating thickness through different slurry viscosities and dipping times on casting imperfection, porosity percentage and eutectic silicon spacing (ESS) of an Al−Si−Cu cast alloy.

2 Experimental

A five-step pattern with the dimensions shown in Fig. 1 was designed and prepared for the LFC experiment

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using a hot wire cutter with an accuracy of ±0.5 mm from a foam (polystyrene) block with 20 kg/m^3 in density. The thickness of the steps was designed as 3, 6, 12, 18 and 24 mm. For the purpose of improving liquid metal feeding during pouring, extra 10 mm-long polystyrene foam was added to the top-thickest section of the pattern. In addition, a pouring cup was cut from the same foam material and attached to the top of the pattern.

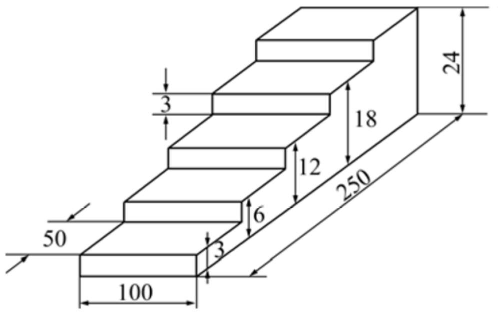

Fig. 1 Stepped pattern designed for experiments (Unit: mm)

In order to deposit a suitable coating on the pattern, a mixture of zircon flour and colloidal silica having different viscosities of 42, 35, 27 or 20 s, measured by Zahn cup No. 5, was prepared. Coating was achieved by dipping the patterns into the slurry for three durations of 20, 40 and 60 s followed by drying at room temperature for up to 24 h. A scanning electron microscope (SEM) was used for measuring the coating thickness. An cast Al−Si−Cu alloy with the chemical composition given in Table 1 was melted in a 60 kg-induction furnace and the molten metal was poured at 740 °C. The temperature was controlled within ±5 °C variation. All castings were removed from the moulds upon cooling to room temperature.

Table 1 Chemical composition of Al−Si−Cu alloy used (mass fraction, %)

Si	Fe	Mg	Mn	Cu	Ti	Zn	Al
10.55	0.62	0.27	0.23	1.79	0.04	0.85	Bal.

For the purpose of the casting integrity/geometry analysis, the sections with 3 and 24 mm in thickness of the castings were evaluated for incomplete filling, surface imperfection as well as deficient edges and corners (misrun). Gas porosity and shrinkage defects within the 12 mm section of the castings were measured by an optical microscope equipped with an image analyzer and SEM. In addition, the average eutectic silicon spacing (ESS) of the microstructures was also measured by linear intercept method according to ASTM E112 standard within the same section of the castings.

3 Results and discussion

3.1 Coating characteristics and casting integrity

Coating on foam pattern is a significant parameter in producing high quality casting by LFC process as it maintains the shape of the mould cavity in the gap between the receding degradation of the pattern and advancing liquid metal filling the mould. In fact, the mould filling time is controlled by how fast the gases are generated and escaped through the mould sand. To allow rapid elimination of the gases both coating and mould sand should be permeable enough. Figure 2 shows the variation of coating thickness as a function of slurry viscosity for different dipping time. It is evident that with increasing the slurry viscosity from 20 to 35 s there was no significant change in the coating thickness, but as the viscosity increased to 42 s, the coating thickness increased significantly to a value of 0.26 mm for the 60 s dipping time. Moreover, increasing dipping time raised the coating thickness on the foam pattern due to more availability of the slurry to precipitate on the foam surface.

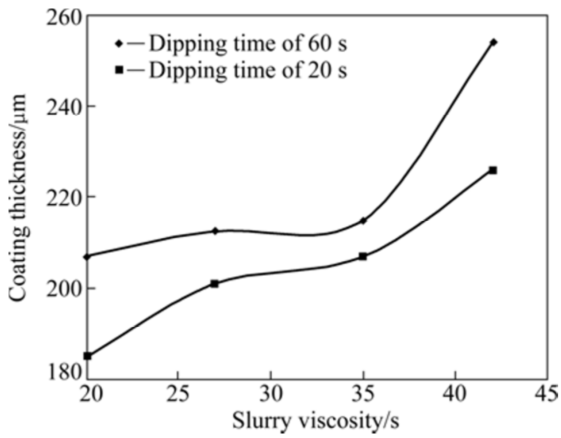

Fig. 2 Effect of slurry viscosity and dipping time on coating thickness

Figure 3 shows the cross sections of the coating layers produced with viscosities of 20 and 42 s after dipping for 60 s. It can be seen that the coating thickness is proportional to the slurry viscosity, as higher viscosity slurry produces thicker coating. Due to the reduced permeability in the thicker coatings, gas escaping through the coating and mould sand is slower, which retards the downward flow of the metal and causes misrun and entrapped gases. Figure 4 demonstrates the effect of coating thickness on the produced castings. As can be seen, increasing the coating thickness affected the quality of the casting and brought about misrun, which is in agreement with the results of GRIFFITHS and DAVIES [8]. From Fig. 4 it is also observed that by