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# Process Control of Lost Foam Casting using Slurry Viscosity and Dipping Time

[1,2]Majid Karimian, [1]A. Ourdjini, [1]M.H. Idris, [1]T. Chuan and [1,3]Hassan Jafari
[1]Department of Materials Engineering, Faculty of Mechanical Engineering,
University Technology Malaysia, Malaysia
[2]Department of Mechanical Engineering, Khomeinishahr branch, Islamic Azad University,
Khomeinishahr, Isfahan, Iran
[3]Department of Materials Engineering, Faculty of Mechanical Engineering,
Shahid Rajaee Teacher Training University, Tehran, Iran

**Abstract:** In the present study an experimental investigation on lost foam casting of Al-Si cast alloy (LM6) has been conducted to control some process variables. The main objectives were to study the effect of different slurry viscosities and dipping times on coating thickness, casting integrity and surface roughness of prepared samples with five different section thicknesses ranging from 3 to 24 mm with foam density of 20 kg $m^{-3}$. Suggested slurry for this research was Zircon flour plus colloidal silica. The different slurry viscosities and dipping times could cause different fillings at corners and edges in filled corners and sides, there was difference in surface roughness. The obtained results showed that slurry viscosity has a significant influence on the casting integrity as well as surface quality of lost foam casting of LM6 Al-Si alloy. Lower slurry viscosity provides thinner coating and as a result better gas escape, fulfilling and smoother surface. In the current research, slurry viscosity of 20 sec and dipping time of 20 sec provide the best filling the and most smooth surface finish.

**Key words:** Lost foam casting, process control, slurry viscosity, dipping time

## INTRODUCTION

LM6 aluminum casting alloy, due to its significant properties such as low density, excellent corrosion resistance in atmosphere and marine environment, good thermal conductivity (Zerouali *et al*., 2006), high strength/weight ratio, good castability and wear resistance (Farahany *et al*., 2010) is widely used in automotive and gas industries.

Lost foam casting is a new process to produce complex metal parts. Although this technology has several advantages compared to conventional casting methods, it still suffers from some inherent disadvantages, including coating penetration, surface roughness, defects and properties (Akbarzadeh *et al*., 2008; Hong, 2009). In this method, usually pattern is made of expanded polystyrene then attached to a gating system and then a thin layer of refractory coating material is applied to the entire assembly. After the coating has been completely dried, the foam pattern is entirely imbedded in unbounded sand in the container. During the sand pouring cycle, vibration is applied to the flask to compact the sand (Liu *et al*., 2007).

Lost foam casting is a much more complicated process in both physical and chemical aspects than traditional sand mold casting. One of the most important factors in lost foam casting process is properties of the refractory coating materials. The coating is essentially composed of refractory particles, binders, suspending media (especially water), surfactants, biocides, dispersing and thixotropic agents. Silica, alumina, zirconia, chromite and alumina-silicates such as mullite and pyrophyllite are used as refractory components. One binder provides adhesion and cohesion before drying, strength after drying and during pouring the molten metals whereas another binder holds together the refractory particles. Surfactants and suspending agents are used to wet and coat the foam patterns and prevent from particles agglomeration and sedimentation (Bakhtiyarov and Overfelt, 2000).

The coatings used in lost foam casting are expected to play two key roles: Limiting metal heat loss rate and facilitating a rapid foam pattern removal, both of which are critical to eliminate casting defects Sands and (Shivkumar, 2003). The performance of coating heat and mass transfer often varies as casting shape, pattern quality, or alloy change. A thorough understanding of coating structure-property relationships would allow the coatings to be modified to reduce lost foam casting defects (Chen and Penumadu, 2006).

**Corresponding Author:** Majid Karimian, Department of Materials Engineering, Faculty of Mechanical Engineering, University Technology Malaysia, Malaysia

Improvement of the lost foam casting products requires a detailed systematic study of the microstructure, permeability and rheological behavior of the lost foam coatings. This study investigates the effect of slurry viscosity and dipping time of specialized coatings. The relationship between coating thickness, casting integrity and surface roughness has been derived from experimental observations.

## MATERIALS AND METHODS

The pattern used in the present work had a step-like shape with 100×250 mm and 3, 6, 12, 18 and 24 mm in thickness (Fig. 1). The riser was made with 24×38×36 mm dimensions for better feeding with added extra 10 mm foam on top of the pattern and assembled with the aid of glue. The patterns made of polystyrene foam with the density of 20 kg $m^{-3}$ were cut using hot wire with accuracy of±0.5 mm. The prepared foam patterns were then dipped for 60 sec. into a slurry made of a mixture of Zircon (ZR-A) and colloidal silicate with four different viscosities (42, 35, 27, 20 sec). The viscosity of the coating was measured by using Zahn flow cup No. 5. Also, for slurry with 20 viscosity, three different dipping times (60, 40, 20 sec) provided.

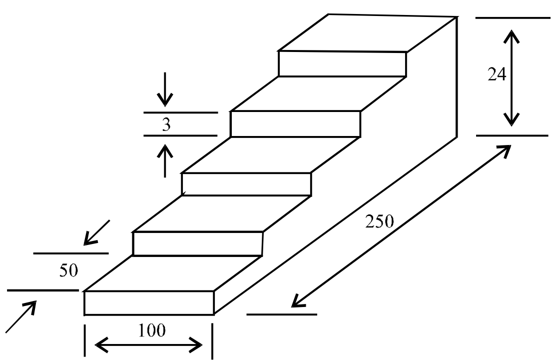


Fig. 1: Pattern dimensions (mm)

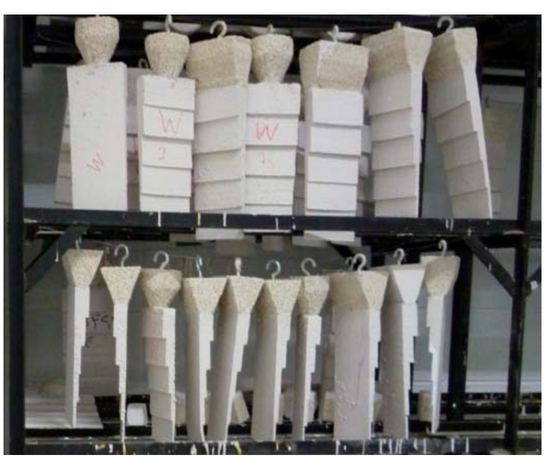

Fig. 2: Coated patterns for the purpose of casting

Coating was achieved by dipping the foam pattern into the refractory slurry and then left to drip dry for up to 24 h in the controlled room temperature (Fig. 2). Coating thickness of all samples was measured by using Image analyzer (Fig. 3).

Molding was made by filling unbounded silica sand with a grain fineness number of 40-60 (AFS). The sand is slowly introduced into the flask by hand and the filling is accomplished by gravity. Uniform vibration of the flask is facilitated by a 4 point clamping of the flask to the vibration table. The flask was thus subjected to a horizontal vibration at 50 Hz for 1 min. Figure 4 shows the pattern position inside the flask after sand filling.

The used alloy is Al-Si cast alloy (LM6). After pouring and once the castings cooled down to 3 room temperature, they were withdrawn from the mould and then were analyzed. Integrity of all castings examined by using digital camera in all portions and edges, also Surface roughness of the castings was measured by using portable roughness tester (Surftronic 3+). Surface roughness of each section was measured at four different positions and the run length was 2.5 mm.

Fig. 3: Dried coating for measuring coating thickness

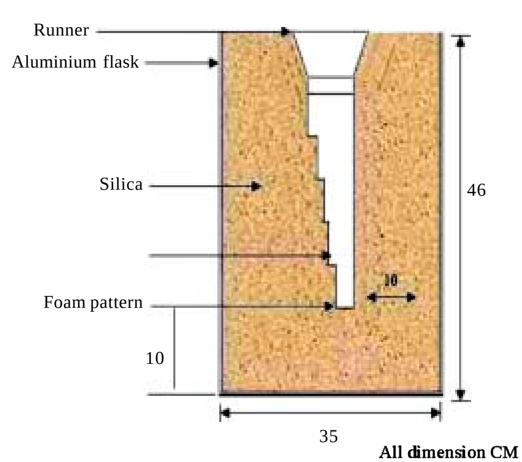


Fig. 4: Pattern position inside the flask

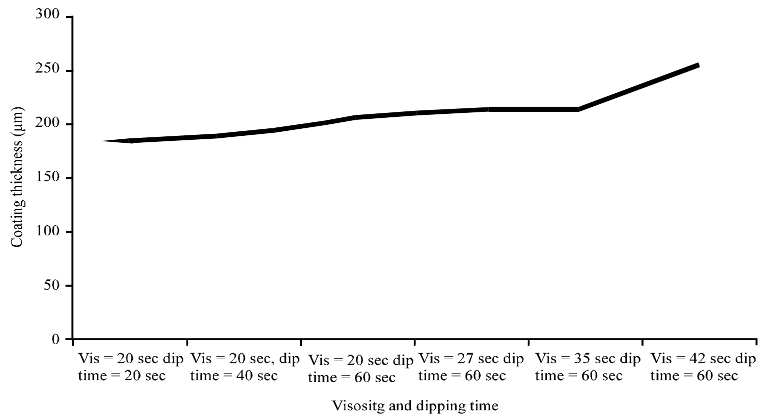


Fig. 5: Coating thickness vs. viscosity and dipping time

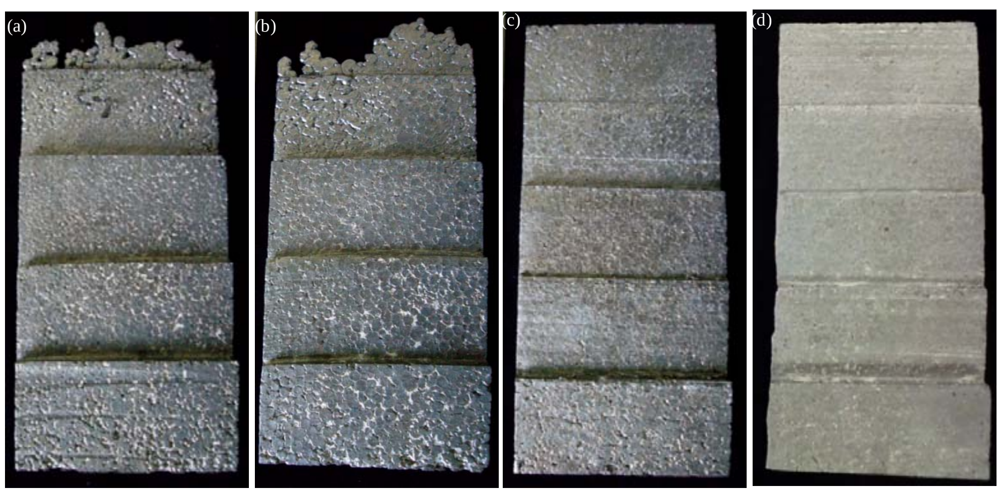


Fig. 6: Casting integrity for different slurry viscosity: (a) 42, (b) 35, (c) 27 and (d) 20 (sec)

## RESULTS AND DISCUSSION

After measuring the coating thickness of samples which was done by getting average of different fifteen points for each sample, it was concluded that in a fixed slurry viscosity, by increasing dipping time, coating thickness will be increased (Fig. 5). It means slurry particles have enough time to settle on the surface of foam sample, by passing time more particles will be settled which cause thicker coating thickness even though this increased time is not so effective on roughness. Also in a steady dipping time, by increasing slurry viscosity, coating thickness dramatically will be increased (Martinez, 1990; Griffiths and Davies, 2008) (Fig. 5).

It is due to the reason of higher percentage of zircon powder in high slurry viscosity because after drying the samples, percentage of zircon powder as a solid particle is determiner of coating thickness.

To have a better view of effect of different coating thickness on casting integrity, all samples were captured by digital camera and compared together (Fig. 6). As it can be seen in Fig. 6, by decreasing slurry viscosity, percentage of fulfilled portions would be increased also in 20 viscosity all the portions and edges is complete without missrunning. These results confirm that in lower slurry viscosity is better gas escaping from the mold cavity which results fulfilling in thin sections. In this study, among five different section thickness of sample, 3 mm section is more critical to be filled which it is satisfied on 20 slurry viscosity. To confirm the results, different dipping times in a same slurry viscosity were done which as a result no big difference in fulfilled sections observed.

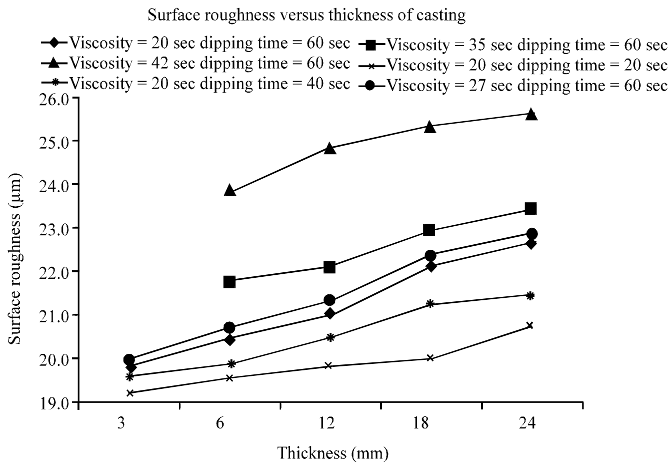


Fig. 7: Surface roughness vs. thickness of coating for different slurry viscosities and dipping times

To confirm previous results, measuring surface roughness was done in 10 readings for each section of a sample, totally after 50 measurements for each sample, sections average were achieved. Then averages of samples roughness were drawn in one graph to compare (Fig. 7).

By use of drawn graph, it can be seen that surface roughness definitely depends on slurry specification such as viscosity and dipping time. It is obvious which by increasing slurry viscosity and dipping time; surface roughness is dramatically increased. Thicker coatings due to preventing the gases to escape could cause more roughness on the casting surfaces. Most difference can be seen on higher slurry viscosities (42 and 35) which emphasis on higher effect of viscosity compare to dipping.

## CONCLUSION

By taking the results into account, it can be concluded that both slurry viscosity and dipping time have an important effect on coating thickness which indirectly affects mould filling ability, integrity and surface roughness of Al-Si lost form castings. It is suggested to apply thinner coating using lower slurry viscosities and dipping times to control lost foam casting process in terms of mould filling ability and surface roughness of casting.

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