Enhancing the Characteristics of 3D Printed Polymer Patterns in the Rapid Investment Casting Process

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Abstract: In the rapid investment casting process, the polymer patterns replace the conventional wax patterns, which are produced on 3D printing machines within a shorter period. Though the strength of the polymer pattern is good enough, they undergo larger expansion during melting compared to wax patterns, which would break the ceramic shell. Different infill patterns were considered while developing the 3D printed patterns, out of which Gyroid and Cubic infill patterns were found to have better compressive strength, compared to the other infill patterns.

Further, the surface roughness of a polymer pattern is always inferior to that of a wax pattern. Hence, an attempt was made to enhance the surface roughness of the polymer patterns by creating a thin wax coating around them by dipping them in a paraffin molten wax bath. Several experiments were conducted by varying wax bath temperatures, dipping time, etc. It was found that the wax bath's temperature of 69^{o}C and a dipping time of 2 seconds could improve the surface roughness of the polymer pattern to a significant level.

Keywords: Rapid Investment Casting, Fused Deposition Modelling, Polymer Patterns, Surface Roughness, Wax Coatings

1 Introduction

In Rapid Investment Casting (RIC), the wax pattern is replaced with a 3D-printed pattern, which allows for more complex shapes and faster production times. The 3D printed pattern is then used to create a ceramic mould, which is then used to cast the metal part. This process is often used for prototyping and low-volume production runs, as it allows for rapidly producing complex metal parts without needing tooling. Though the strength of the polymer pattern is good enough, they undergo larger expansion during melting compared to wax patterns, which would break the ceramic shell. Further, the surface roughness of a polymer pattern is always inferior to that of a wax pattern. Hence, in the present work, some investigations were conducted to overcome these challenges.

2 Experimental procedure

Initially, polymer patterns were developed as per the geometry shown in Fig 1, using an Fused Deposition Modelling (FDM) machine (Make: Ultimaker).

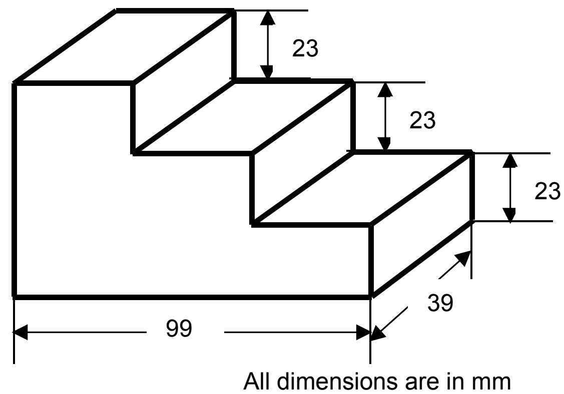

Fig. 1 Dimensions of the pattern

The raw material used in FDM is solid in the form of a wire roll. This chamber is surrounded by a heating coil which maintains the temperature of the chamber at a required level. At the entry of this chamber is a pair of wheels through which the raw material wire passes through into the chamber. At the exit, a nozzle of appropriate diameter is fixed. The nozzle diameters are varied at 0.4mm and 0.8mm.

Polymer patterns (using the materials PLA and ABS) were developed using FDM, varying the parameters like layer height, line width, infill line width, wall line width, top-bottom line width, print speed, infill speed, wall speed, and top-bottom speed travel speed. Cooling and support have been selected appropriately.

The ceramic slurry was prepared by mixing aluminum silicate with the binder (Ethyl silicate), along with some wetting agents and anti-foaming agents. The ingredients and the process parameters of the ceramic slurry are shown in Table 1.

Table 1 Process parameters of ceramic slurry

Coat	Slurry type	Stucco	Dip time (s)	Drain time (s)	Dry time (h)
1	Primary	Zircon 80/120	30	60	24
2-5	Secondary	Zircon 16/30	30	60	4
6	Outer	N/A	30	60	24

The ceramic shells developed are shown in Fig. 2. These shells were fired inside an oven and the polymer pattern material was removed from the ceramic shell. Molten metal was then poured into the dried ceramic shell and the casting was taken out after the solidification.

Fig. 2 Ceramic shells during drying

Influence of Pattern Interior

The problems with the solid pattern are wastage of material and cracking of ceramic shell due to excessive thermal expansion of polymer while melting. Hence, hollow patterns were printed initially at 90% infill and gradually the infill was reduced to 10%.

Influence of wax coating

The 3D printed polymer patterns have an inadequate surface finish compared to the wax patterns. Hence, an attempt was made to enhance the surface roughness of the polymer patterns by creating a thin wax coating around them by dipping them in a paraffin molten wax bath. Several experiments were conducted by varying wax bath temperatures, dipping time, etc.

3 Results and discussion

Influence of pattern interior:

Even at 10% infill, the patterns were found to be suitable for foundry requirements without compromising factors like strength, surface finish, etc. The different hollow pattern interiors are shown in Fig. 3.

Influence of wax coating:

A thin coating with wax could successfully improve the surface roughness of the polymer pattern.

Fig. 3 Pattern interiors used in the present study

4 Conclusions

By reducing the infill of the pattern material, the thickness of the ceramic shell could also be reduced by reducing the number of coatings around the pattern, which in turn would optimize the strength and stability of the ceramic shell.

A thin wax coating around the polymer pattern could successfully improve its surface roughness. A wax bath's temperature of 69ºc and a dipping time of 2 seconds could improve the surface roughness of the polymer pattern to a significant level.

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