Optimization of the investment casting process

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OPTIMIZATION OF THE INVESTMENT CASTING PROCESS

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Rapid prototyping is an important technique for manufacturing. This work refers to the manufacture of hollow patterns made of polymeric materials by rapid prototyping technologies for its use in the preparation of ceramic molds in the investment casting process. This work is focused on the development of a process for manufacturing patterns different from those that currently exist due to its hollow interior design, allowing its direct use in the fabrication of ceramic molds; avoiding cracking and fracture during the investment casting process, which is an important process for the foundry industry.

Key words: Foundry, hollow pattern, Rapid prototyping, moulding

Optimiranje postupka kalupljenja u ljevačkom procesu. Brzo razvijanje prototipa važna je proizvodna tehnika. Ovaj se rad odnosi na proizvodnju šupljih kalupa izrađenih od polimerskih materijala pomoću tehnologija brzog razvijanja prototipa za uporabu u izradi keramičkih modela u postupku kalupljenja ljevačkog procesa. Ovaj rad je usmjeren na razvijanje postupka za proizvodnju kalupa drukčijih od onih kakvi trenutno postoje i to zbog svoje šuplje unutarnje izvedbe čime se omogućava izravna uporaba u izradi keramičkih modela te se izbjegava pucanje i lom tijekom postupka kalupljenja ljevačkog procesa koji predstavlja važan postupak u ljevaoničkoj industriji.

Ključne riječi: ljevaonica, šuplji kalup, brzi prototip, lijevanje

INTRODUCTION

Manufacture of molds is a very important step of the casting process, in order to obtain a non defect surface piece, high quality molds must be used during the process in order to obtain a good casting [1,2].

This work consists in the manufacturing of hollow patterns made of polymeric materials, using rapid prototyping technologies. Such patterns are used on the investment casting process to fabricate ceramic molds.

The investment casting process, also known as the lost wax process, consists on making a model, used in the manufacturing of the wax patterns. This pattern is coated with ceramic materials and then dried. Afterwards, the wax is removed in order to obtain a shell in which the liquid metal is poured [3].

The patterns used currently on the investment casting process are too complex, highly accurate size is needed. These patterns are made of raw materials with low melting points such as: wax, gels, tin, bismuth, antimony, etc. [4]. However, during the removal of these patterns from inside of the ceramic mold, is common to develop cracks or, in more severe cases, fracture of the mold due to the expansion of the raw material with increasing temperature [5]. Therefore, this innovation of hollow interior patterns of polymeric materials has the advantage to avoid cracking and fracture of the ceramic mold during the removal of the pattern, in which, the thermal expansion of the raw material is inwards by pressure difference and not outward enclosed by the walls of the ceramic mold.

Based on the above, the fabrication of hollow models of polymeric materials by any prototyping technique saves time and material when used directly as patterns on the manufacturing of ceramic molds for the investment casting process, avoiding the wax patterns fabrication and the appearance of cracks or fractures.

There have been several techniques in the model manufacturing field, such as the development of completely filled patterns with low melting point materials, produced by a computer controlled laser [6, 7]; highly soluble ceramic molds, used directly as patterns, all this is contemplated in the lost model method [8]. However, the use of hollow prototypes as patterns has never been proposed.

EXPERIMENTAL PROCEDURE

The experimental procedure consisted on a comparison of the lost model method existing with filled patterns against the proposed method of hollow patterns.

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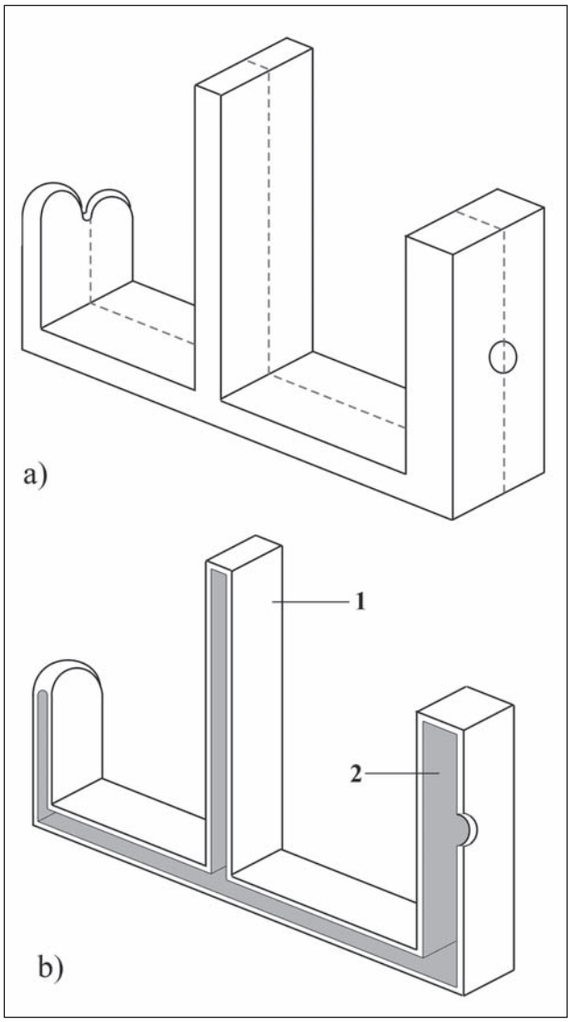

Figure 1 a) Polymer piece draw , b) transversal section of the polymer piece, showing the interior hollow (showing: 1, the polymer; 2, hollow interior).

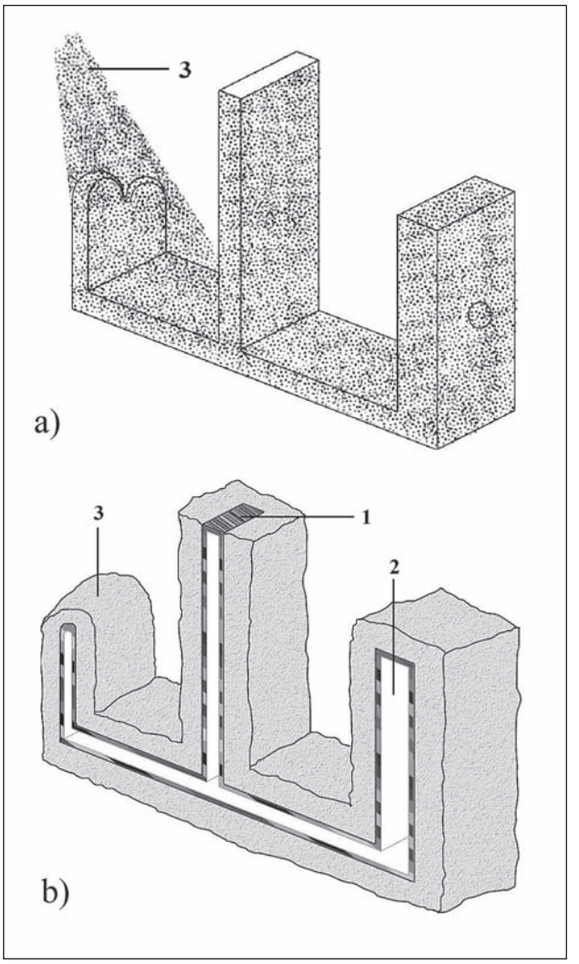

Figure 2 a) Ceramic shell fabrication, b) transversal section of the piece with the ceramic layers ready for the polymer extraction. (Showing: 1, the polymer; 2, hollow interior and 3, the shell).

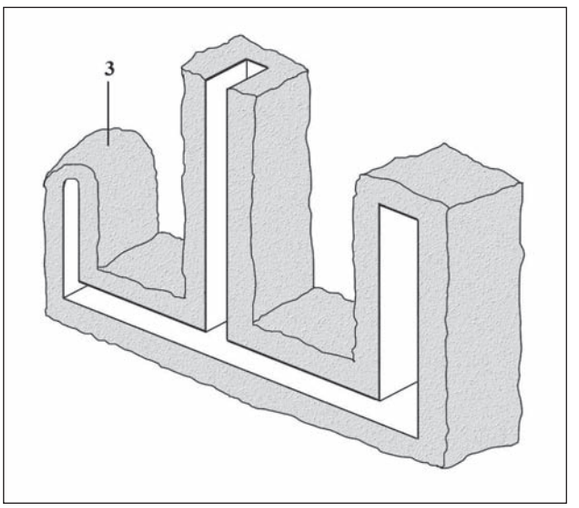

Figure 3 Final ceramic shell transversal section.

A CAD of the piece of interest is made using design software (Figure 1a). The file is then imported to the rapid prototyping machine. The work parameters are then established to start the manufacturing of the hollow and filled patterns through layers of polymeric material (Figure 1b). Once the patterns are finished, they are washed with acetone to remove impurities, scraps or organic matter; promoting the adhesion of the ceramic shell.

Ceramic shell are fabricated using several materials such as silica sand and ceramic slurry which is fabricated with colloidal silica binder and finer silica sand. This mixture is agitated before its use.

The process consists in the preparation of 3 to 15 ceramic layers leading to a final 1 to 20 mm thickness. The first layer corresponds to the immersion of the patterns in the ceramic slurry; which is the most important step as the mud is in direct contact with the pattern reproducing its surface. Subsequent layers are formed in two steps: the immersion of the piece in the slurry that acts as a binder and the adhesion of the silica sand on the piece surface (Figure 2a). The pieces are then left to dry 30 minutes to 24 hours between each ceramic layer,

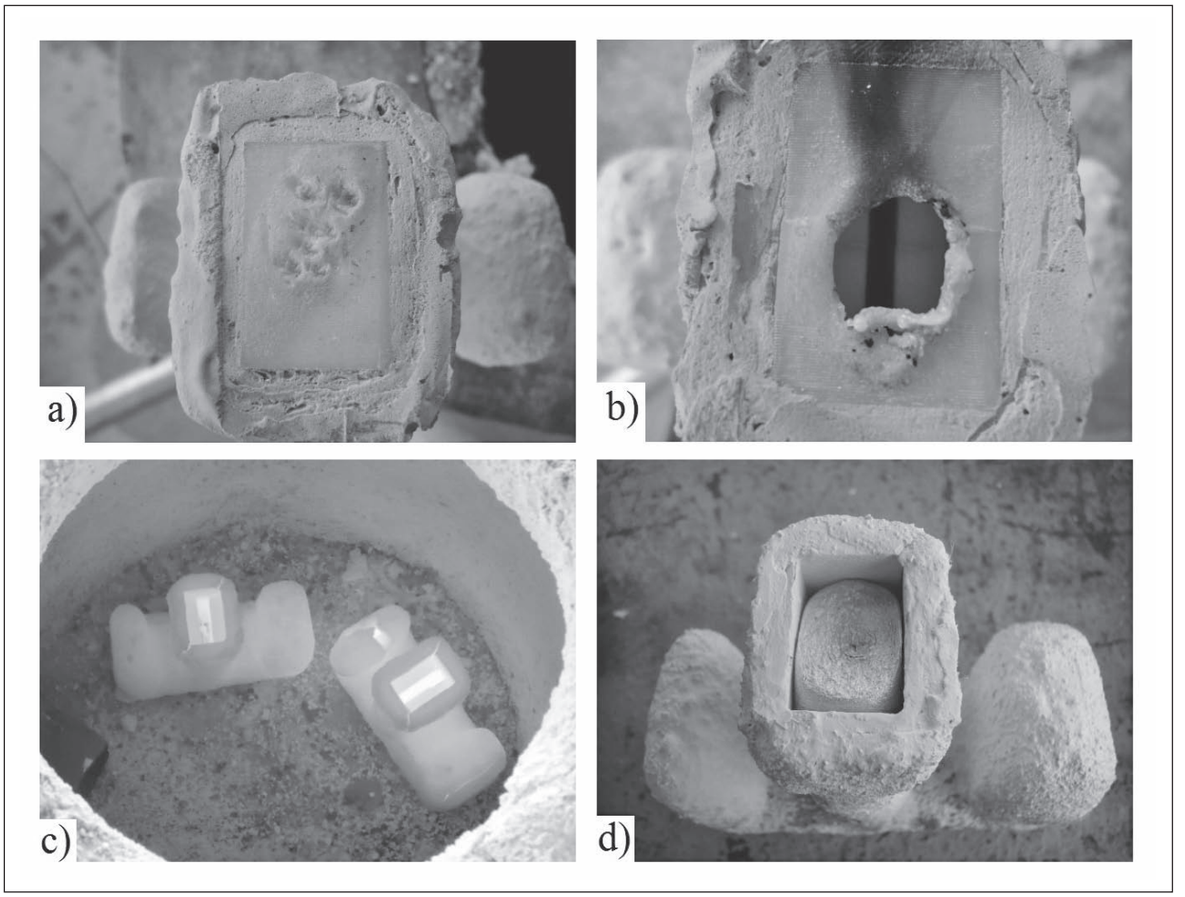

Figure 4 a) Filled pattern shell, b) hollow pattern shell, c) fractured molds obtained from the filled patterns, and d) no fractures and cracks mold were observed from hollow pattern with aluminum alloy.

allowing to proceed with the extraction of the polymer (Figure 2b) after the last layer.

Patterns extraction is made when the ceramic shell is heated between 400 to 900 ºC to achieve the burning of the polymer; temperature is then raised to a range of 900 to 1300 ºC to remove the polymer by evaporation (Figure 3) and sintering the shell ceramic in order to support the metallostatic pressure during the casting and increasing its hardness and strength, leaving the cavity completely free for the entry of the molten metal.

RESULTS AND DISCUSSION

The two different fabricated molds are shown on Figure 4a and 4b, corresponding to the filled pattern and the hollow pattern, respectively.

The shells in the filled patterns case showed cracks or fractures during or after the removal of the polymer on the process of sintering (Figure 4c) due to the expansion suffered by the polymer. On the other hand, on the hollow patterns method no cracks or fractures are showed (Figure 4d) as physically the expansion is inwards and no outwards as in the previous case, avoiding with this crack formations even in right in cases with right angles as this case.

Finally an aluminium alloy was previously prepared, melted and degassed for several minutes and cast at 750 ºC. Obtaining a good quality sample.

CONCLUSIONS

A comparison of the lost model method existing with filled patterns against the proposed method of hollow patterns was performed.

A new method of manufacturing shells from patterns of polymeric material was developed; fabricated by rapid prototyping technologies, with hollow interior optimizing the investment casting process.

No cracking or fracture was found in the ceramic shell obtained, produced by this new method.

It was observed a considerable time and material savings compared with traditional investment casting process, because the model is used directly as a pattern without having to go through the traditional wax lost manufacture process.

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