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(REVIEW ARTICLE)

Rapid prototyping of wax models for investment casting

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Abstract

This article discusses making wax models for precision casting technology. Our chosen method of making these prototypes consists in printing the positive of the model on 3D printer, which is then molded into rubber. The resulting rubber mold is used for casting the wax models. The focus of the article is mainly on the quality, speed, and accuracy of making wax models, while they will be compared with commonly produced wax models.

Key words: Additive technology; Wax models; Precision casting method; Fused deposit modeling

1. Introduction

The production of castings using the investment casting technology is one of the oldest and most accurate methods of making castings. The production process starts with the design of the model of the part required by the customer, in contrast to conventional casting methods, it is possible to produce castings with any shape as well as the possibility of producing very thin-walled castings. The absence of the need to solve the parting plane is a fundamental advantage that only very few types of casting methods have.[1], [2]

After the design of the product is completed, a mold for the production of wax models is made. This step represents one of the biggest investments, as it is a very technologically demanding process. Precision casting foundries make molds for wax models mostly from low-melting alloys by milling a block of material. The negative of the model is created in this cavity. The mold represents a large initial investment, as well as the risk that the model will be modified and tuned for the needs of the casting or the customer after the first batch of products is created.[2],[3]

After creating a sufficient number of models, the individual parts are attached to the sprue system in the so-called "tree", this grouping can be seen in the Figure 1. The tree is equipped with all the technology necessary for the correct casting process, such as additional sprues or venting channels. [2], [4]

After the tree is finished, the assembly is alternately dipped in ceramic slurry and sprinkled with zirconia sand. This process creates a covering shell on the surface of the wax tree. Between each additional layer, the shell is dried to gain strength.

The next step is to melt the wax from the shell, which creates the mold itself for casting the metal. If necessary, the mold is further rinsed to clean the interior from residual ash. [2], [6]

Before casting, the shell is heated to approximately 1000°C and then filled with the desired metal. After casting, the shell casing is removed, the models are cut from the sprue, and finally finishing operations are implemented. [2], [7]

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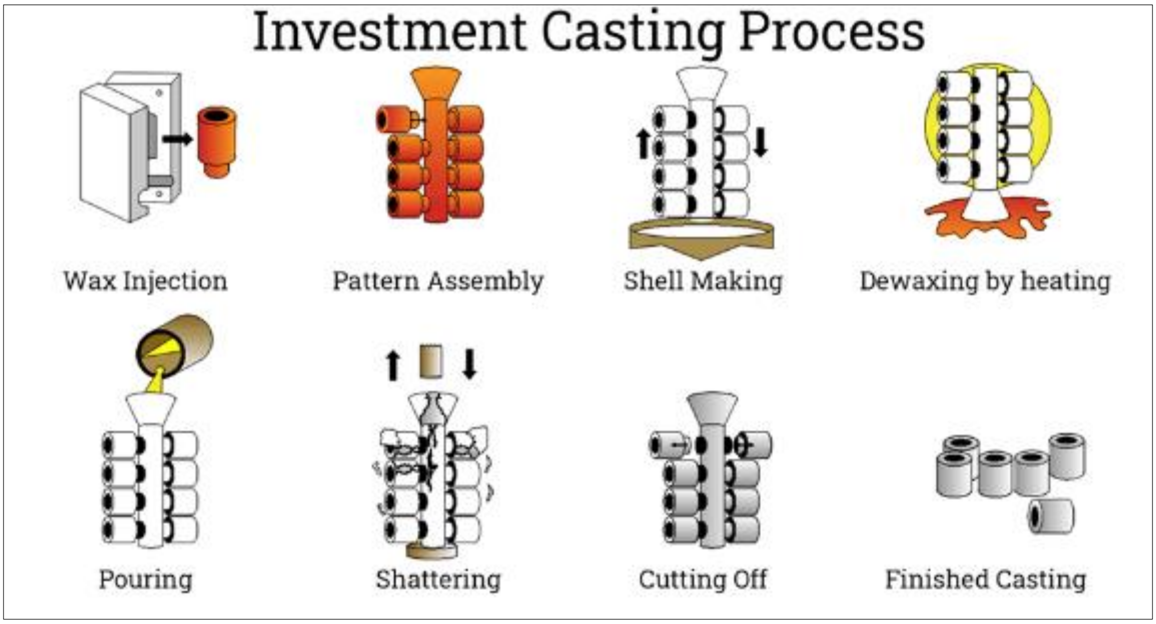

Figure 1 Investment casting process [5]

2. Rapid prototyping of wax models

As mentioned in the introduction, one of the most complicated steps in the production of castings using the fusible model technology is the production of a wax model. Creating a model that can be tested or even produce a prototype series of products for the customer to test, is a very appropriate step before the production of an expensive milled mold. The complex issue of producing prototypes applicable to production is a complex process that is also highly individual for specific production and its possibilities. [8]

One solution is to create models on 3D printers using wax-like filaments. This method is clearly the fastest, if the goal is to make a small sample of models that will then be molded and casted. Perhaps the most ideal way of using this technology is to print different types of parts in minimal numbers, combine them into one sprue system and cast them all at once. In this way, the need to produce a separate shell for each type of part is eliminated and the process will be very fast. [9]

Even such an advanced solution, unfortunately, is not without problems. A fundamental complication in the procedure mentioned above is the use of the same material when casting the combined tree, which may not meet the requirements of the various customers for whom the individual parts were created. Another pitfall is the length of the print itself. It is true that a printout from the printer can be made in a relatively short time, but the precision casting process has a very high proportion of transferred surface structures from the model to the final casting. For this reason, wax models are made extremely precisely and with a very high-quality surface, which means that parts produced on 3D printing, if they are to be usable, must be printed with high quality, and therefore slowly. A normal print with dimensions of approximately 5cm3 at a layer thickness of 0.07mm for the best possible surface can climb to 20 to 30 hours per printout. Of course, if we need more of these models for the test series, the printing itself will take a few days, to which must be added the time during which the shell itself will have to be produced. Here we start to move about 2 weeks delivery time

Another pitfall is the already mentioned technological compatibility of the companies themselves when working with materials printed on 3D printing, they can cause complications in the production process, either when melting the wax, when the 3D printed material can crack the shell, or during casting, if some residual waste is left inside the ceramic form, which subsequently degrades the castings.

3. Rubber molds

The solution to the problem of the production of wax prototypes, which is the focus of this article, is the production of non-permanent rubber molds for casting models directly from wax.

The production of a common mold consists of 3 basic steps. This involves making the positive of the model with the help of 3D printing technology, the production of the rubber mold itself and the subsequent casting of the wax models. In order to make the mold correctly and achieve the best possible final quality of the models, it is necessary to use the right materials for the production of individual sub-products.

3.1. PolySmooth™

In the process of 3D printing, it is possible to achieve different results with the help of technology applied in the material used for the production of models. Polymaker company has developed PolySmooth™ material with optimal properties for flawless printing. This 3D printing filament also has a technology that allows surfaces to be smoothed after printing by exposing the surface of the model to aerosol Isopropyl alcohol cloud, thus it is possible to achieve exceptionally high-quality surfaces for models. [10] [11]

An overview of the technological possibilities of the material PolySmooth™ :

- JAM-FREE™ technology improves the thermal stability of the filament at temperatures above 140 °C. The result is very good meltability of the filaments and a smooth flow through the printhead with minimal risk of clogging the nozzle. [11]

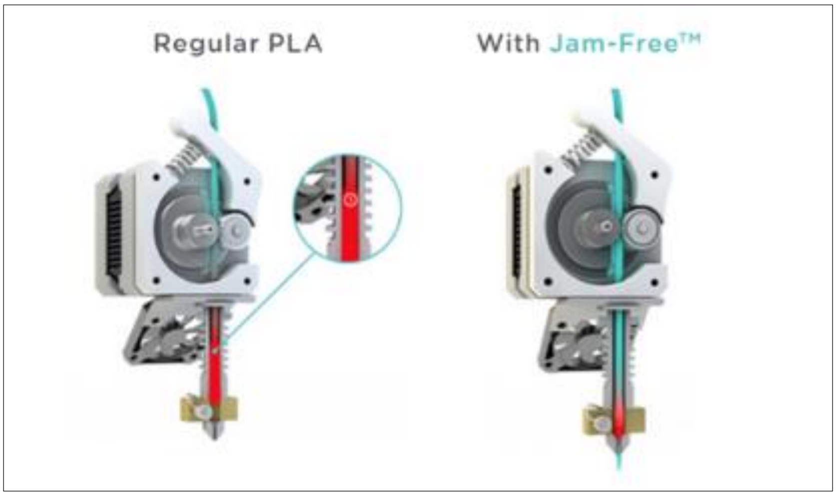

Figure 2 Visualization of the Jam-Free™ technology [11]

- LAYER-FREE™ is a post-production process designed to remove rough surface caused by 3D printing from the model. The process consists of exposing model to isopropyl alcohol (IPA) cloud. Isopropyl alcohol is applied in specialized aerosol devices called Polysher™. For worse parts, it is recommended to sand the surface with sandpaper before inserting it into the aerosol machine to achieve the best possible results. [11]

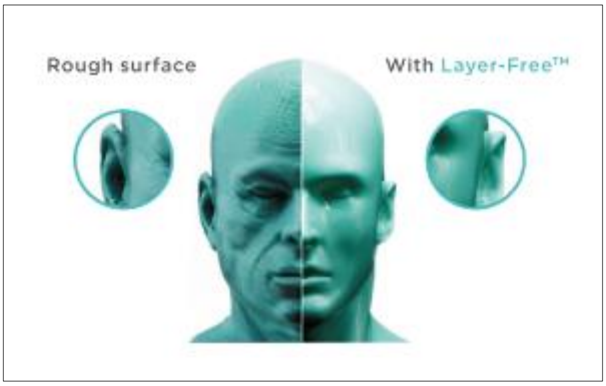

Figure 3 Visualization of Layer-Free™ technology [11]

In Figure 4, it is possible to observe the experimentally produced models for the production of rubber molds from the PolySmooth™ material. The models were subsequently processed using the Polysher™ device for 20 minutes. Models for enclosures were made using PLA material for easier molding into rubber.

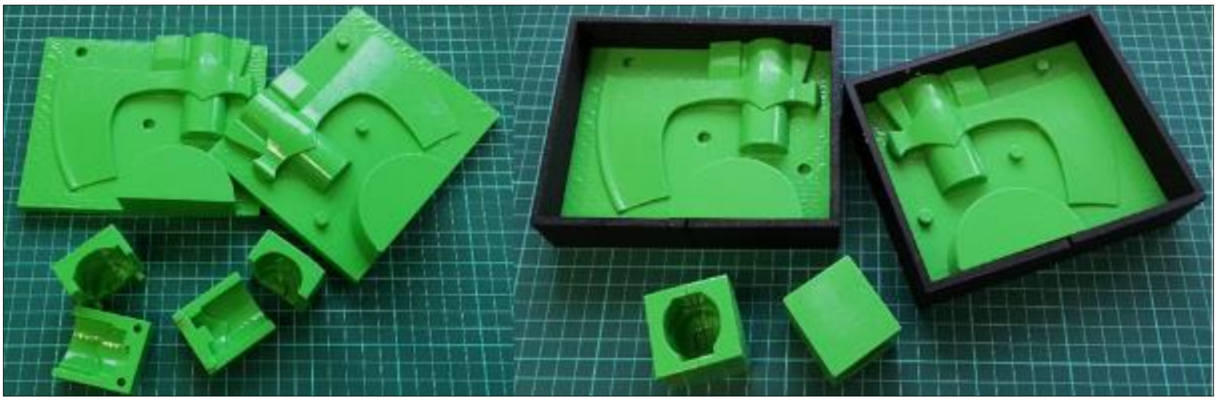

Figure 4 Models for rubber mold form PolySmooth™ material

3.2. Rubber

Two-component silicone rubber of the brand Lukopren N 1522 was chosen for the production of the molds themselves used for making wax models. [12]

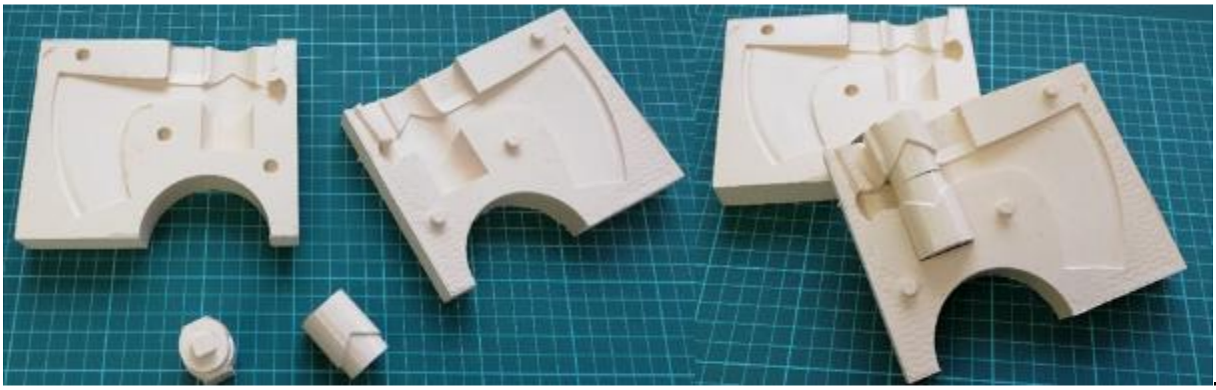

Figure 5 Finalized rubber parts from Lukopren N 1522

Lukopren N 1522 is a polymeric, medium-viscous paste, with good convergence, which, after mixing with a catalyst, vulcanizes at normal temperatures to a harder silicone rubber. The material is also characterized by very precise copying of the surface of the part, which enables us to achieve the required surface quality even on wax models. Another significant advantage of rubber molds made of Lukopren N 1522 material is the very low adhesion of this material, which allows the removal of wax models after casting into molds without major problems and the risk of wax sticking to the walls of the mold. [12]

Figure 5 shows the finalized rubber parts of the mold for casting wax models. The mold consists of two main pieces and one core composed of two parts

Figure 6 shows an example of a finished wax model made using a rubber mold manufactured by usage of 3D printed matrices.

Compared to wax models of regular productions, the models made in this way are, unfortunately, still prone to 3D printing marks and surface imperfections, as can still be observed on the wax parts in Figure 6.

Figure 6 Wax models

4. Conclusion

Making wax models using rubber molds is an advantageous compromise between the speed of prototyping and the quality of the resulting castings.

Rubber molds represent a great financial saving for a customer requiring small series production or individual prototypes. This solves the most expensive point in the production of investment casting process, without the need to invest in milled molds.

One of the other advantages of this type of rapid prototyping is the fact that the models are made directly from modeling wax. This fact makes it possible to put wax models into normal operation without any problems during the production and firing of the ceramic mold. Working with these models is completely feasible with ordinary wax models, it is not necessary to train the staff how to properly attach the models to the wax tree, unlike 3D printed models made of wax-like materials.

There are processes and materials that can be machined or chemically processed after printing to achieve the most perfect surface possible, like the PolySmooth™ material we used, but complete removal of traces after 3D printing is not always possible. Another of the disadvantages of rubber molds is the small coefficient of heat transfer, after pouring the wax into the mold, it therefore takes a relatively long time for the model to harden to a state in which it can be safely removed. This rapidly reduces the speed of model production compared to metal molds.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest.

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