Application of Rapid Tooling approach in process of thermoforming mold production

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Abstract. Additive technologies often referred to as 3D printing gain more and more applications that have been the domain of traditional technologies. One of the areas where the 3D printed parts closes the gap between applications as a conceptual model or as a ready to use part is the Rapid Tooling. The technology of plastic thermoforming is well suitable for application of molds manufactured by 3F(Fused Filament Fabrication) technology. The mold in the process of thermoforming is not exposed to high load and high temperatures, therefore the 3F made molds can withstand application in thermoforming machine. The present paper deals with Rapid Tooling with FF technology and its application to manufactures small series thermoforming mold. 3D printed mold was designed for manufacturing of lid tray and printed from Ultem9085 (PEI), utilizing possibilities offered by 3F technology. At the first stage for the production of moldings were used PET and Hi-PS foils to determine process interaction between mold and various materials. At the second stage a small series of 500 lid trays was produced to determine feasibility of mold to withstand production load. The results show the applicability of 3F technology for thermoforming mold production, which offers the designer greater freedom in design compared to conventional technologies.

Keywords: FDM, Rapid Tooling, thermoforming

1 Introduction

The fused deposition modelling (FDM) is one of the most widely used rapid prototyping systems in the world. The main reasons of its increasing popularity and use have been its reliability, safe and simple fabrication process, low cost of material, and the availability of a variety of building thermoplastics. Ever since the first FDM system was launched in early 1990s, the Stratasys Inc has been marketing improved FDM systems on a regular basis. However, research has also been going on in universities and research institutions around the world to increase its applications, to develop new materials and to improve the FDM process.

The FDM systems, developed by Stratasys Inc, currently fabricate parts in variety of thermoplastic materials including ABS, PC, PEI, PSSF, PA12 and their combinations (nine commercially available grades) using the layer by layer deposition of extruded material through a nozzle using feedstock filaments from a spool. The parts fabricated in these materials have wide application starting with design verification, and ending with end use parts. Fused deposition modeling (FDM) is one RP system that produces prototypes from plastic materials such as ABS (Acrylonitrile-Butadiene-Styrene) by laying tracks of semi-molten plastic filament onto a platform in a layer wise manner from bottom to top . In the FDM hardware, the FDM head moves in two horizontal axes across a foundation and deposits a layer of material for each slice. The material filament is pulled into the FDM head by the drive wheels. It is heated inside the liquefier in the FDM head so it comes out in a semi-liquid state. The successive layers fuse together and solidify to build up an accurate, three-dimensional model of the design. (fig.1).

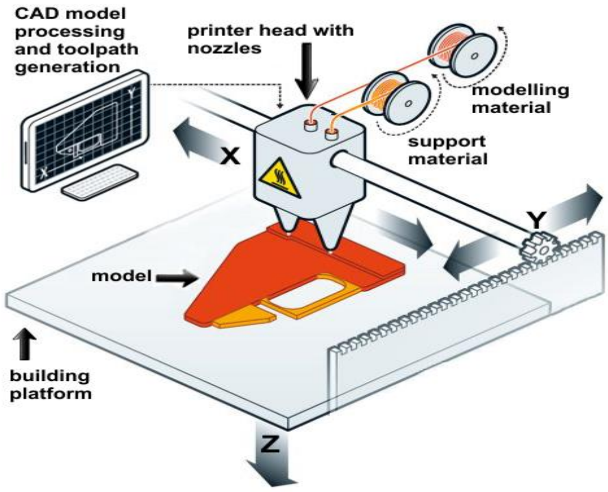

Fig. 1. Sketch of FDM technology and model building

Several works are aimed on application of additive technologies for building of mold for polymer processing. Mostly in the Rapid Tooling (RT) for injection molding process are used the SLS and SLM technologies because of their high layer resolution and durable metal materials[1,2,3]. Application of FDM technology for manufacturing of thermoforming mold is evaluated in [4], but without test porformed on real production equipment. This paper presents designing and production of thermoforming mold for producion of small series (up to 500 pieces) of moldings, made by FDM technology and installed on production thermoforming device.

2 Designig and manufacturing of mold

As mentioned in previous chapter a goal was to design and produce a thermoformimg mold for small series production of molding. In this case, based on request of enterprise partner, a mold for production of protective transpor lid was designed and produced by Fortus 400mc 3D printer. Lid had to be made out of 0,3 mm thick PET foil with demand of 500 pieces. Limitations in mold design resulted from technical specification of available thermoforming production machine (press) and size of production envelope of 3D printer. As the size of the lid (resp. size mold core) was smaller than the production envelope of Fortus 400mc, design of the mold was split into three parts, to keep the mold as universal as possible and usable for production of other moldings. Mold base size was determined with respect to frame sizes that could be installed on the thermoforming press.Mold base size was determined to 308x308x30 mm (fig.2). Mold core was designed according the shape of molding from molding CAD data. Between mold base and mold core a frame was designed, that hold the core in place. In future when there is a need to produce another molding with size equal or smaller than lid, base and frame can be reused and only new core is needed. When the molding would be larger than lid also the frame has to be replaced.

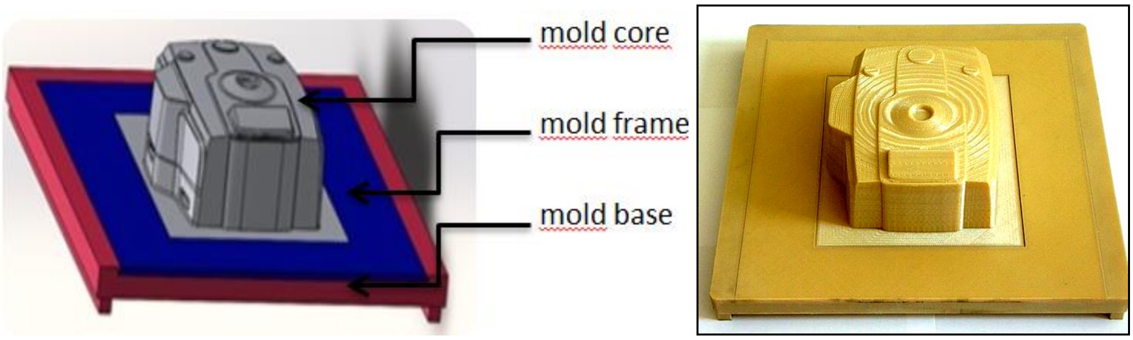

Fig. 2. CAD model of mold (left) and 3D printed mold assembly

To save the building material mold core was designed as shell with wall thickenss of 5 mm. Part of mold were produced from ULTEM 9085 (polyetherimide) a material that can be continuosly exposed to tempratures up 180^{o}C and therefore well suited for thermoforming with PET foil.

Tab.1 Building time and material consuption

Mold part	Modeling material [cm^3]	Support material [cm^3]	Time [hour]
Base	490,10	112,86	10,87
Frame	212,72	22,87	4,28
Core	286,97	87,84	10,70
TOTAL	989,79	223,57	25,85

For this case slice height 0.254 mm was used. For ULTEM 9085 is also a slice height 0.33 mm available, and can be used and reduce the building time. Production time and used material for building all parts of mold are listed in table 1.

3 Experimental producion

Printed and assembled mold was installed into thermoforming press and set of 500 pieces of lid was produced. For the production of lids a 0.3 mm thick PET foil was used. During the forming process no problem was observed, compared to experience with compareable formig process with auluminium mold. Lid produced with FDM mold is presented in figure 3.

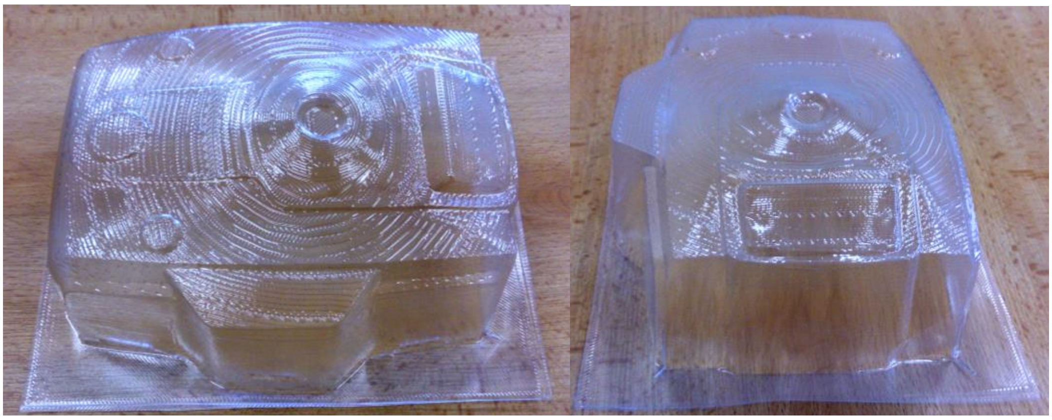

Fig. 3 Lid made from PET foil on FDM mold

After 500 lids produced from PET, the mold had no visible signs of wear another 500 lids, from black and white HIPS 0.8 mm foil were produced (fig.4). Also when thermoforming with HIPS no problems during forming were observed.

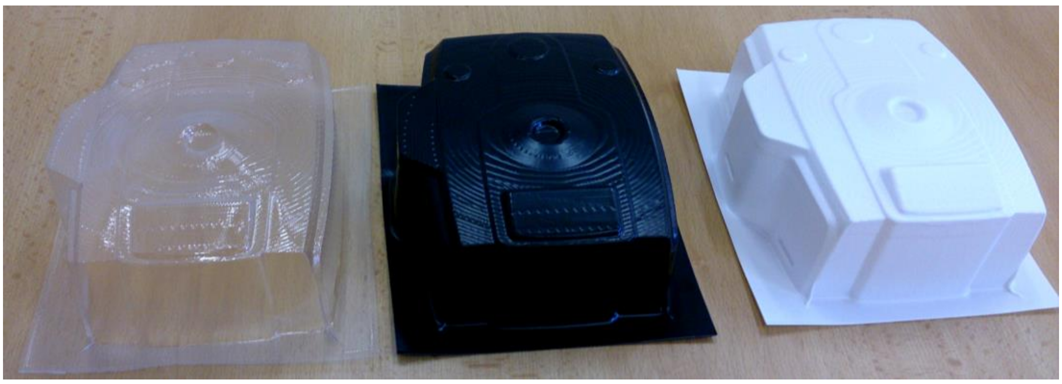

Fig. 4 Lid made from PET(left) and HIPS foil on FDM mold

4 Conclusions

In this paper were presented some issues concerning application of FDM technology for production of vacuum thermoforming mold. Designed and manufactured mold was tested under production conditions. Set of 500 moldings from PET and 500 moldings from HIPS was produced. Even after production of 1000 lids no visible wear of the mold is observed (fig.5).

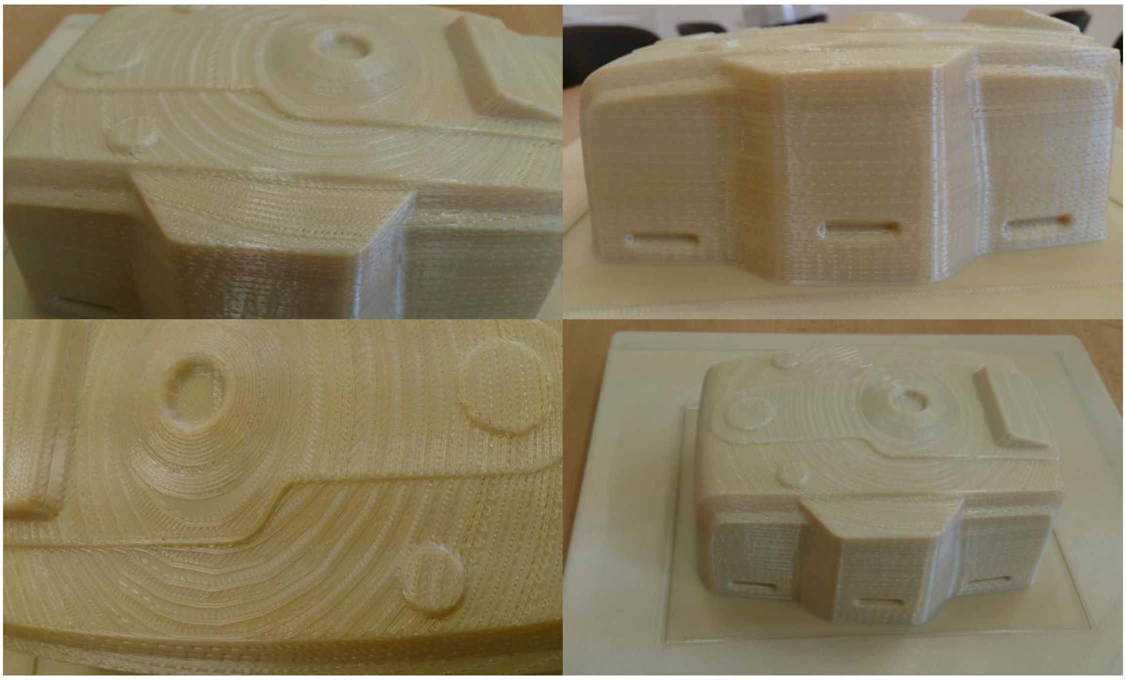

Fig. 5 Lid made from PET(left) and HIPS foil on FDM mold

Results of mold testing undrer real production conditions shows that the mold made with FDM technology is full suitable for thermoforming process. One limitation od FDM mold is visual quality of molding produced with this mold. FDM mold is directly not suitalble when a high surface quality is needed. On the molding made of thin PET foil, all layers and rasters from mold are copied. When fine surface quality is needed , some surface finish techniques are required. Advantage of this approach is possibility to have ready to use mold within hours (depending on size of molding) or days with air suction from whole mold surface and low cost compared to classical technologies. The further research will be focused on the improvement of mold surface finish.

Acknowledgement 12 pt

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