DEVELOPMENT OF SMALL BATCHES OF FUNCTIONAL PARTS USING INTEGRATION OF 3D PRINTING AND VACUUM CASTING TECHNOLOGY

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DEVELOPMENT OF SMALL BATCHES OF FUNCTIONAL PARTS USING INTEGRATION OF 3D PRINTING AND VACUUM CASTING TECHNOLOGY

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Summary: *In conditions of dynamic market environment there is an increasing requirement for rapid development and production of complex and functional parts from different materials. In this paper, we present the process of development and production of small batches of functional parts in the integrated system of additive and vacuum casting technology. All advantages of this integrated approach were used during the research. Data obtained from the manufacturer were used for the proper selection of materials and they relate to the value of mechanical characteristics.*
Key words: Additive Manufacturing, Vacuum casting, Functional parts, 3D Printing

1. INTRODUCTION

The more time spent on the product development, the more opportunities for profit are lost. It is this philosophy that drives many industries during the development of new products. Especially, as more and more often the need for rapid design, development, testing and production of the final product, i.e., a small batch of functional parts which would be expensive to develop with conventional tools and accessories as it would not be economically justifiable. Technologies of rapid prototyping and rapid tooling provide an answer to these requirements, in this particular case technology of material extrusion and technology of vacuum casting, the integration of which are used all their advantages in the production of small batch of specific gear [1].

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2. 3D PRINTING TECHNOLOGY AND ITS ROLE IN THE INTEGRATED PROCESS

The RP technique, which was used in a specific case for making master models of gear, is a 3D printer based on FDM principle (Stratasys - Dimension Elite), which plays a key role in the integrated process [2]. Of great importance is the accuracy that is achieved in this 3D printer. It is necessary to pay special attention to the positioning and orientation of the master model on the platform during the printing process. The procedure that has been necessary to obtain a master model or prototype of gear is as follows [3]:

- Product design in one of the CAD software packages,
- Conversion of CAD models in STL format that is recognized by a 3D printer,
- Transfer of STL files to the computer that controls the three-dimensional printer,
- Processing of STL files within the CatalystEX program in which all the parameters are set and adjusted according to the required model,
- Creating a three-dimensional model using additive technology and
- Further processing of created prototypes.

The layout of the gear model designed in SolidWorks software package is shown in Fig. 1 and parameter adjustment within the CatalystEX, where the selection of the orientation of models, processing of layers and layout of models on a base on which printing on a "Dimension Elite" 3D printer will be performed, is shown in Fig. 2.

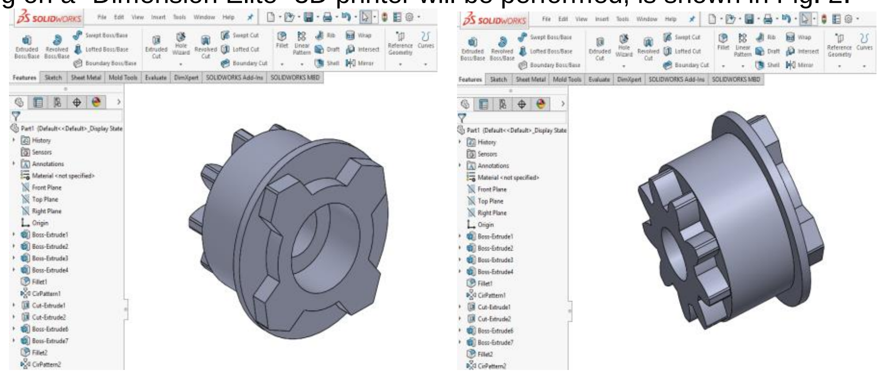

Fig.1 A gear model in Solid Works software package

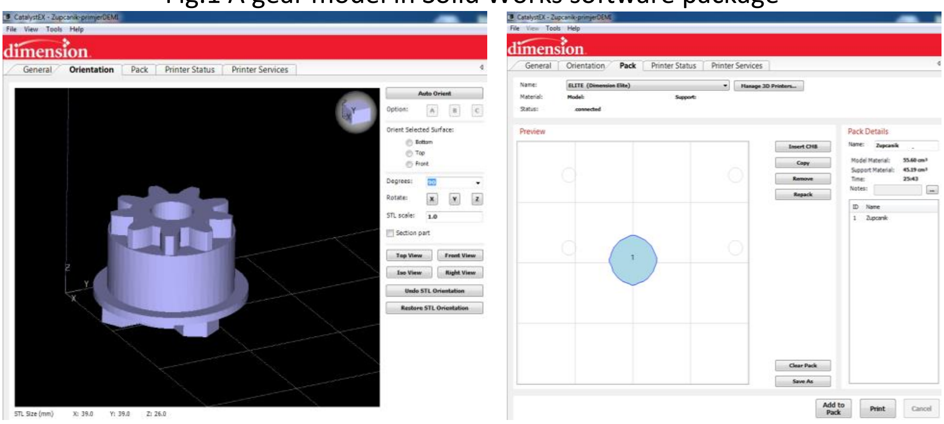

Fig. 2 Orientation and processing of models in CatalystEX

3. VACUUM CASTING TECHNOLOGY AND ITS ROLE IN THE INTEGRATED PROCESS

Vacuum casting has become a widely accepted method of soft tooling, replacing traditional methods such as investment casting [4]. Vacuum casting is a newer version of investment casting with changes to the process of creating the mold. Several needs are addressed by vacuum casting which make it extremely popular. Most importantly, vacuum casting reduces the time for part production when compared to traditional methods. This, in turn, significantly reduces costs. The additional following characteristics offered by vacuum casting justify the choice of this technology for the integrated process:

1. Accurate Castings: Textures, fine details, and complex surfaces are exactly reproduced from the master model due to the replicating nature of the silicone rubber mold.
2. Consistent Quality: Vacuum casting produces dimensionally stable and accurate castings. The technique allows castings of thin wall and void-free sections as well. Furthermore, vacuum casting in silicone molds allows producing parts with undercuts because the pliable silicone molds do not present problems when removing cast parts, even with undercuts, from the mold.
3. Up to 95% Saving in Time: After the silicone mold has been created, replicas of the master model may be fabricated within a few hours, depending on the number of parts required.
4. Fit and Function Testing: The cast parts are sufficiently accurate so that fit and function testing may be conducted to determine which modifications must be made.
5. Cost Savings: Using vacuum casting offers reductions in cost when compared to rapid prototyping or traditional hard tooling.
6. Material Choices: Vacuum casting resins simulate production thermoplastics, rubber, and glass. Additionally, the resins sustain high impact and resist elevated temperatures. With vacuum casting, users have the options to create clear or colored parts as well.

The process of vacuum casting consists of the following steps:

1. Preparation of gear negatives produced on a 3D printer for the casting process. Setting the parting tape on the gear negative that will facilitate the separation of silicone mold.
2. Bonding plastic gates on the gear negative which has a role to form an inlet channel in the silicone mold and to facilitate the positioning and fixation of the negative in the silicone casting frame, according to Fig. 3a.
3. Calculation of the necessary quantity of silicone mixture to form a silicone mold to be used for molding the gear. The silicone mixture is poured into the frame with fixed gear negatives and then the frame with the negative submerged in silicone is placed in a vacuum chamber in order to remove the residual air bubbles from silicon, according to Fig. 3b.
4. Positioning of the silicone mold in a vacuum chamber (Fig. 3a.). After solidification of silicone, silicone mold is cut to parting line, during which we

relieve the negative and get a silicone mold for casting a replica of a given negative (Fig. 3b).

a) b)

Fig.3 a) Casting silicone into the frame with the negative, and b) removing the residual air from the silicon in a vacuum chamber

5. The molding halves are then combined and the next step is to calculate necessary quantities of resin for molding of the gear. The amount of resin is commonly determined by weighing the individual master model which is increased by 20-30%, taking into account the loss of material in vessels and inlet channels. In this case, to cast the gear, components made by Axson Technologies were used, thus by mixing them in the casting process the parts with physical and mechanical characteristics according to Tab. 1 are obtained.

Tab. 1 Mechanical characteristics of components used for casting of the gear

MECHANICAL PROPERTIES AT 23°C			**PX 223 HT**
Flexural modulus of elasticity	ISO 178 :2001	PSI/(MPa)	334,000/(2,300)
Flexural strength		PSI/(MPa)	11,600/(80)
Tensile strength	ISO 527-2 :1993	PSI/(MPa)	8,700/(60)
Elongation		%	11
Charpy impact resistance	ISO 179/2D :1994	ft-lb/in^2/(kJ/m^2)	>29/(>60)[1]
Izod Impact - Notched	ASTM D256-05	ft-lb/in^2/(kJ/m^2)	3/(6)
Izod Impact - Unnotched	ASTM D256-05	ft-lb/in^2/(kJ/m^2)	>8/(>16)[1]
Hardness - at 73°F (23°C) - at 248°F (120°C)	ISO 868 :2003	Shore D1	80 >65

6. After a certain quantity of the material needed for molding and the proportion of the individual components of the material in a total amount are determined, then vacuum casting process follows. The casting process takes place in a

vacuum chamber under conditions that are recommended for corresponding elements and components of the material, according to Fig. 6.

Fig. 6 The casting process in a vacuum chamber MK-mini

7. After solidification of the molded material in a vacuum chamber, mold halves are separated and, if necessary, post-processing of the molded item follows.

Small batches of gears, made in the integrated process of additive manufacturing technology and vacuum casting in the Laboratory for Plasticity and Processing Systems at the Faculty of Mechanical Engineering in Banja Luka as a result of this study are shown in Fig. 7.

Fig.7 Small batches of gears made in the integrated process of additive manufacturing technology and vacuum casting

4. CONCLUSION

The development of a gear case study through the integration process of 3D printing and vacuum casting shows an example of a very successful application of modern technology in the rapid development of functional parts and production replicas of identical part. Replicas can be made from different materials that can be very broad spectrum in terms of physical, technical and mechanical properties. Replicas fully meet the requirements in terms of dimensional accuracy and functionality, i.e. all the details from the master model have been faithfully reproduced on its replicas. This only confirms the importance and benefits that is provided by the integration of 3D printing and vacuum casting technologies in the rapid development and production of small series of prototypes and functional parts.

5. ACKNOWLEDGMENT

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