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THE PROCESS OF DEVELOPING CONCEPTUAL DESIGN OF A PRODUCT USING RAPID PROTOTYPING TECHNOLOGY

Dr.Sc. Amra Talić – Čikmiš
Amir Durmić
Faculty of Mechanical Engineering
Zenica
Bosnia and Herzegovina

Dr. Sc. Milan Šljivić
Mr. Sc. Mićo Stanojević
Faculty of Mechanical Engineering
Banja Luka
Bosnia and Herzegovina

ABSTRACT
The process of developing conceptual design of a product using modern tools, such as 3D modeling software and rapid prototyping equipment, lowers the costs of product development and enables evaluation of specific part's functionality. This paper describes development of conceptual design of dispersive cup using corresponding RP technology as a method of evaluating its functionality. Basic steps of obtaining prototype from a 3D model and production of the prototype on 3D printer are shown.
Keywords: *3D modeling, 3D printing, rapid prototyping*

1. INTRODUCTION
Global economy is nowadays witnessed with terms like recession or slow down. This on the other hand means that the only imperative to remain in competition is to develop new product which are cost efficient and friendly too the nature and societies. Before starting a production it is necessary to perform a variety of tests like evaluation the parts shape, functionalities, mechanical properties, materials with their treatments… In order to reduce development time it is important to build a prototype in the early stages which will serve for testing purposes. This process is being repeated until satisfying results in all fields are met: aesthetics, functionality, safety, etc.[1]. Rapid prototype model development became a reality with the introduction of 3D printers. Using a CAD drawing to create a physical prototype is quite simple for the user. First, the machine reads the data from the provided CAD drawing. Next, the machine lays a combination of liquid or powdered material in successive layers. The materials used in rapid prototyping are usually plastics, ceramics, wood-like paper, or metals such as stainless steel and titanium. This example's prototype was built on Thermo Jet machine made by 3D SYSTEMS and material used is thermojet 88 thermopolymer.

2. PREPROCESSING OF STL SURFACE MODEL AND RAPID PROTOTYPING
2.1. Optimal mesh tessellation and stl generation
In preprocessing stage, after parametric CAD design of assembly, the parts are tested and prepared into CATIA V5, module STL Rapid Prototyping. It provides high control of mesh size with keeping high edge and surface reconstruction robustness from nominal CAD boundaries into stl surface model, see Figure 1.
It has been provided an optimal meshing in accordance with resolution and repeatability of Stratasys Dimension Elite system with keeping high surface reconstruction. It is the so called "sag parameter" which is about 0,02mm, what means the normal distance between corresponding CAD geometric entity and the nearest point of mesh boundary. Also, in some cases if it is necessary, stl editing tools gives an opportunity to make cutting or merging of the components by hybrid modeling, like in the cases of large parts.

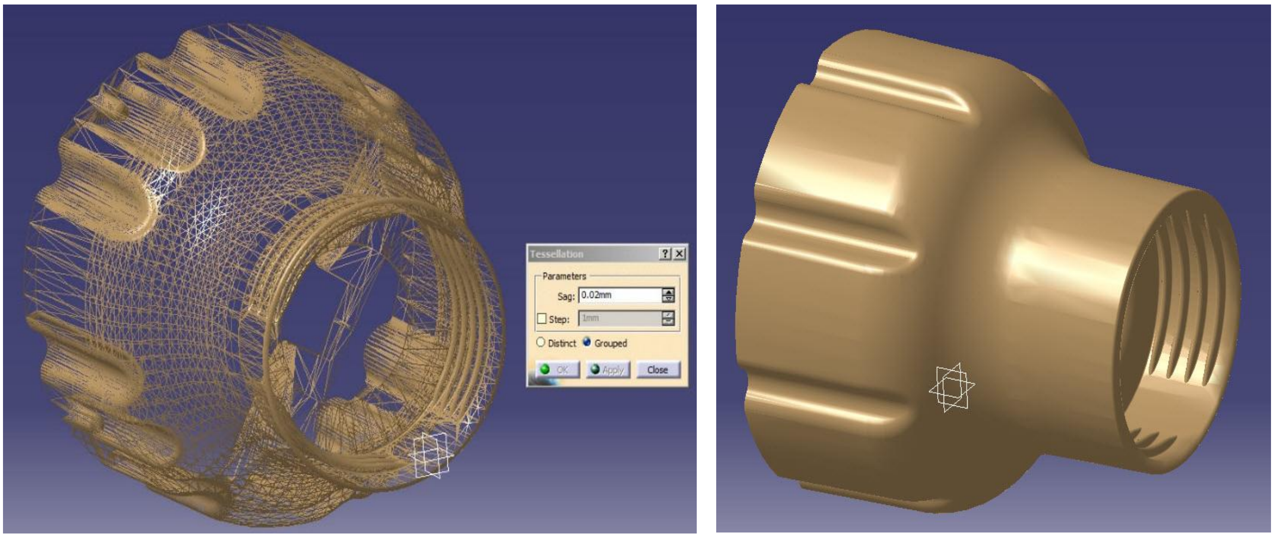


Figure 7: Optimized mesh tessellation according to the performance limits of rapid prototyping machine

2.2. G-code postprocessing for fdm rapid prototyping system

After generation of stl surface mesh model, the next step is the preparation of cmb file which represents a path definition for printer's nozzles. Firstly, it is determined the adequate parameters, as follows: the layer resolution, type of model interior filling, type of support filling. Also, it should be determined the optimal orientation of model according to the mechanical performance requirements, minimization of material consumption and minimization of time processing. It has been made the variation of parameters for layer resolution between 0.1778 and 0.254mm, but the parameter for model interior filling is kept for solid, since the model has mostly the small wall's thickness. In that case, the other parameter's options for model interior filling hasn't big influence in 3d printing, see Figure 2.

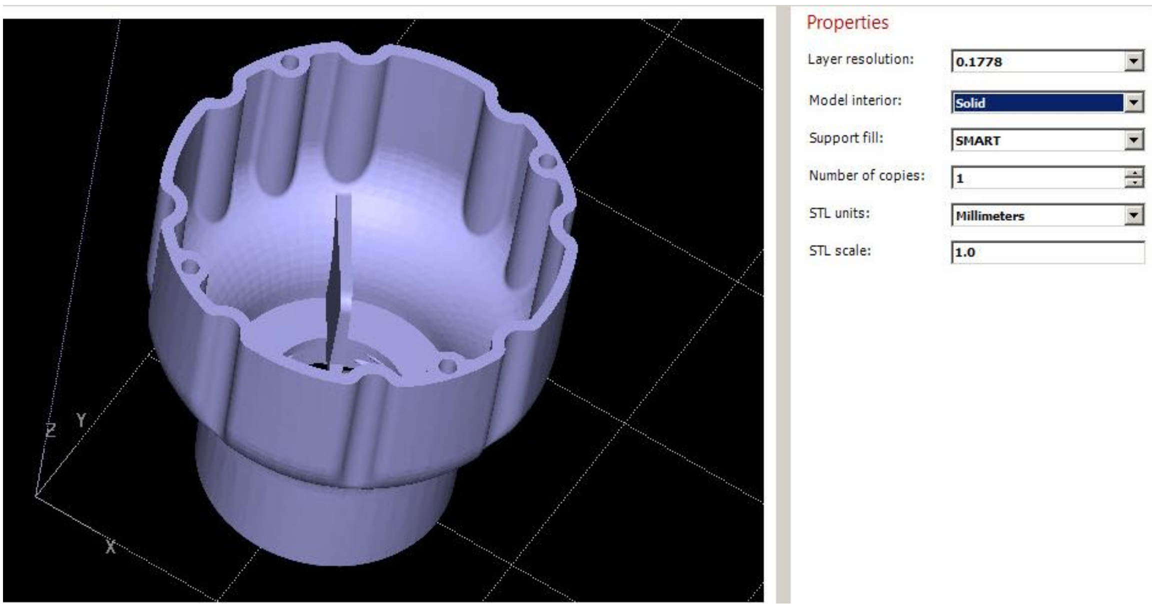
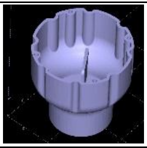
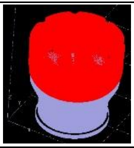
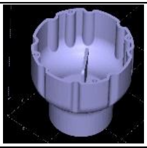
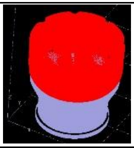
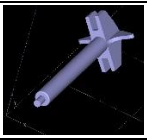
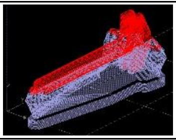
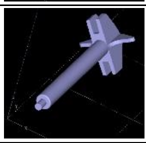
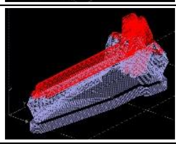
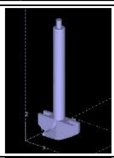
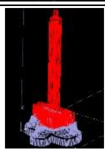
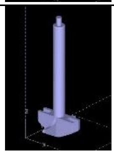
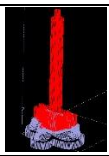


Figure 8: Definition of RP parameters before 3D printing

In order to select proper technology parameters, it has been made the printing simulation with different printing parameters and orientations, like in the following table.

Table 1: Influence of technology parameters on time processing, model material and support material consumption

	Stl model	Previewed RP model	Input parameters	Output parameters
1			LR: 0,1778mm MI: solid	TP: 4:05 M: 11,93 S: 6,22
2			LR: 0,254mm MI: solid	TP: 2:36 M: 11,72 S: 6,64
3			LR: 0,1778mm MI: solid Orientation: “down”	TP: 0:31 M: 0,91 S: 1,28
4			LR: 0,254mm MI: solid Orientation: “down”	TP: 0:18 M: 0,87 S: 1,33
5			LR: 0,1778mm MI: solid Orientation: “up”	TP: 0:37 M: 0,86 S: 0,68
6			LR: 0,254mm MI: solid Orientation: “up”	TP: 0:21 M: 0,83 S: 0,63

LR: Layer resolution, MI: model interior, TP: time processing (h:min), M: consumed material (cm3), S: consumed support material (cm^3)

One may notice in table 1, the importance of orientation and layer resolution for technology performance. Fpr example, in the case 1. and 2., the higher layer resolution causes higher filling density of model material, but lower consumption of support material. Also, the higher resolution produces much bigger time processing (4h and 5min) comparing with lower resolution and its processing time of 2:36.

As for part orientation, it is important influence to keep good mechanical properties of model. It depending of its form and geometrical topology. If model has got thin and long, “pin-like” or “tube-like” geometry, it is recommendable to have the orientation: “down”. It means the cured model material fibers are packed better to keep higher model flexibility and higher bending strength (case 3. and 4.). In the case 5. and 6., orientation is “up”, what causes a little bit longer time processing, but significantly lower support material consumption. As the conclusion, depending on the prototyping requirements, one can select various parameters to get optimized quality of model and affordable technology.

3. RAPID PROTOTYPING OF FUNCTIONAL PARTS

Since the requirements of this research has been the testing of conceptual design solution, it was important to select proper RP technology which provides the functional parts. It has been used so called FDM technology based on Stratasys Dimension Elite System. It provides the highest resolution in mid-range class of RP FDM systems, see figure 3. Processed functional parts are made in acrylonitrile butadiene styrene(ABS) with good mechanical characteristics comparing with other materials, commonly used for rapid prototyping. Supporting material is based so called Soluble Support Technology.

After processing, it is necessary to remove the support structure in WaveWash Cleaning System. Ecoworks cleaning agent is eco-friendly and use-friendly. It is possible to make cleaning without Wavewash system, but it is very recommendable, since it provides permanent flowing of soluble agent with constant and optimal temperature around model. It accelerates the cleaning process, but also provides quality of surface quality, especially for the porous structures.

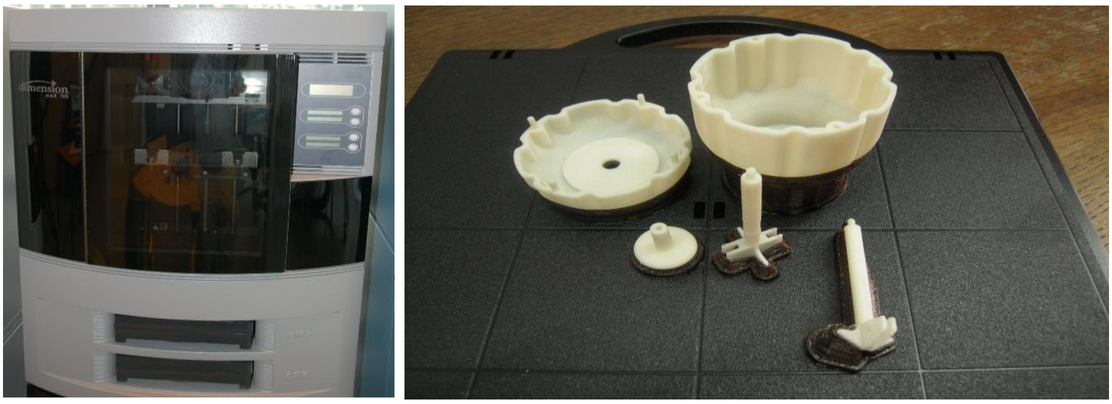


Figure 9: Rapid prototyping system based on FDM technology (Dimension Elite) and processed functional parts on working platform

In the following picture, one may see the post-processed functional parts, ready for the further assembling, evaluation and functional testing.

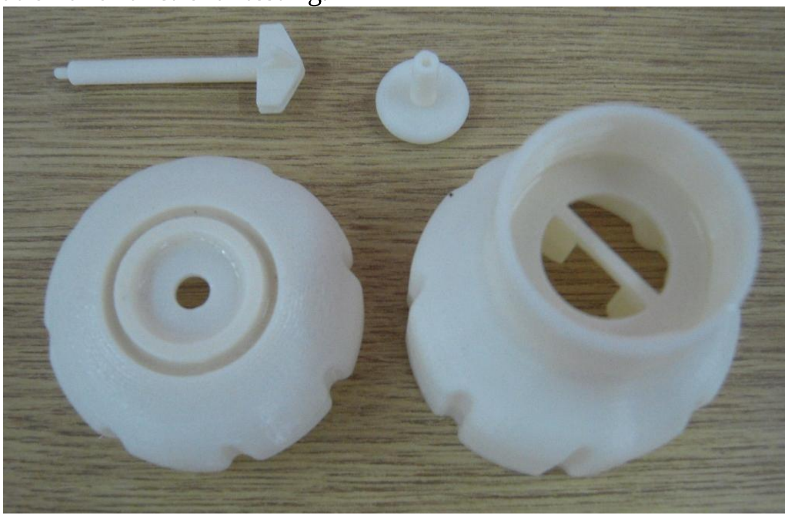


Figure 10: Finished post-processed functional RP parts

4. CONCLUSION

RP technology refers to building of a physical model of a future product or a tool in development phase based on which necessary testing, evaluations, optimizations and possible corrections are performed, as well as marketing presentations and making the final decision regarding product development and its production. The goal is to find optimal combination of three basic factors in product development phase from idea to beginning of serial production for every product: quality, costs and time. That is of a particular importance when new product concepts are concerned.

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