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COMPARATIVE ANALYSIS OF DIMENSIONAL ACCURACY FOR Z-CORP, RTV AND CUBE 3D RAPID PROTOTYPING PROCESSES

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ABSTRACT
Three commonly used processes of rapid prototyping are RTV, Zcorp 3D print, Cube 3D print. This paper briefly explains these three methods. If we create the same part using these rapid prototyping methods, its dimensions will not have the same accuracy. Some method has higher and another lower accuracy. The comparative analysis of three rapid prototyping methods to the dimensions' accuracy has made in this paper. The goal is to get a recommendation whichone of three methods to use, if we want the greatest dimensional accuracy.
Keywords: Dimensional Accuracy**,** Additive Manufacturing**,** RTV, Zcorp 3D, Cube 3D

1. INTRODUCTION
The technologies of 3D printing (so called additive processes ar additive manufacturing [1, 4, 7]) are being developed from the 90s of the 20th century. They were firstly used for the rapid prototyping for conceptual and presentation models, and are increasingly used to produce functional parts, which are built into the products.
It has developed a number of procedures and methods, such as: 3D Inkjet Printing (ZCorp method); Stereolithography Apparatus – SLA; Solid Ground Curing – SGC; Laminated Object Manufacturing – LOM; Fused Deposition Modelling – FDM; Selective Laser Sintering – SLS; Room Temperature Vulcanization - RTV or Silicone Rubber Moulding - SRM) etc. [1, 2, 5].
We are the most commonly encountered: 3D Inkjet Printing, Fused Deposition Modelling – FDM and Room Temperature Vulcanization - RTV, although rarely we can found the other methods in use. Dimensional accuracy of parts produced by above mentioned three methods are examined in this paper.

2. 3D INKJET PRINTING (ZCORP METHOD OF 3D PRINTING)
We make three-dimensional part's solid model using a software for 3D modelling and convert it into STL format (also supported .wrl, .ply and .sfx formats [2]). Then the model is divided into thin layers for printing using the software of company ZCorporation. In the printer ink jet head lays liquid binder after each passing of the powder. The powder hardens when the binder occurs, and unhardened powder creates the support for the part.
After the printing part is removed from the printer and we remove the excess powder with compressed air. We carry out a postprocessing, which includes infiltration (reinforcement) with resin, wax, urethane, cyanoacrylate, etc. [2]. Also, we perform a short thermal processing of part to dry it. The powder that is not used can be used again.

For this study we have made parts of solid material on the basis of gypsum powder zp102, binder zb56 in the ZCorp printer. Afterwards, we infiltrated the parts with cyanoacrylate.

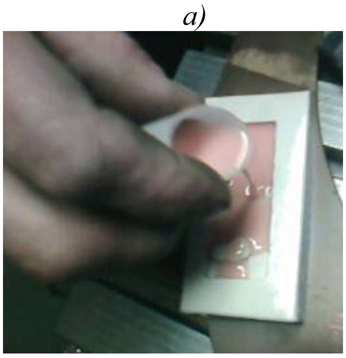
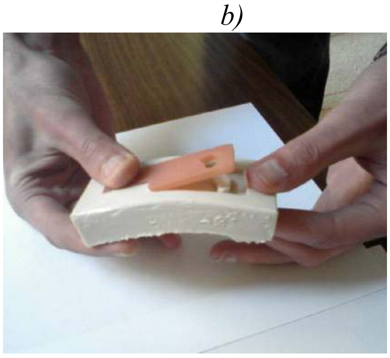
Figure 1. ZCorp printer which made the parts for the research

3. SILICONE RUBBER ROOM TEMPERATURE VULCANIZING - RTV

Making RTV silicone rubber mold (Silicone Rubber Room Temperature Vulcanizing - RTV) is the main type of indirect making of soft molds [2]. The process takes place in several phases (Figure 2). First, we need a model by which we create mold. It is part with the same shape and size we want to get by the casting (Figure 2.a), and in this study, the model was obtained by the method of ZCorp three-dimensional printing.



a) *b)* *c)*


d) *e)* *f)*

Figure 2. Phases of the RTV casting: a) model; b) casting the silicon over models; c) extracting the model from the mold; d) casting the polymer in the mold; e) removing the hardened parts from the mold; f) the mold, model and cast part.

Then we make the silicone - rubber mold. The process of the RTV mold making begins with placing the model in a box, which is usually made of wood or cardboard. The two-component TEKASIL is most commonly used for mold. When the silicone - rubber is mixed, it is poured from a height in a thin stream to the model (Figure 2b). Thus allowing the silicone to fill all the holes and push out the air, causing the part to be made without air bubbles**.** It is necessary to wait about 48 hours for the mould reaches the final mechanical properties of vulcanized silicone and the model can be removed. The silicone mold is cut and separated, for removal of the model (Figure 2 c). Then we can go with the pouring the polymer in the mold (Figure 2 d). The most commonly used materials for casting are: the polyurethane, polyester, the two component epoxy, alloys with low melting point (tin lead alloy (200°C]), tin (230°C) and zinc alloys) [1, 3]. In this study we have used material methyl methacrylate.

4. FUSED DEPOSITION MODELING (FDM) - CUBE 3D PRINTING

All FDM methods operate on the principle presented in Figure 3. The material in the form of wire is brought into the extruder, where it melts and is deposited layer by layer. Each layer solidifies and the workpiece receives a specified shape and dimensions.

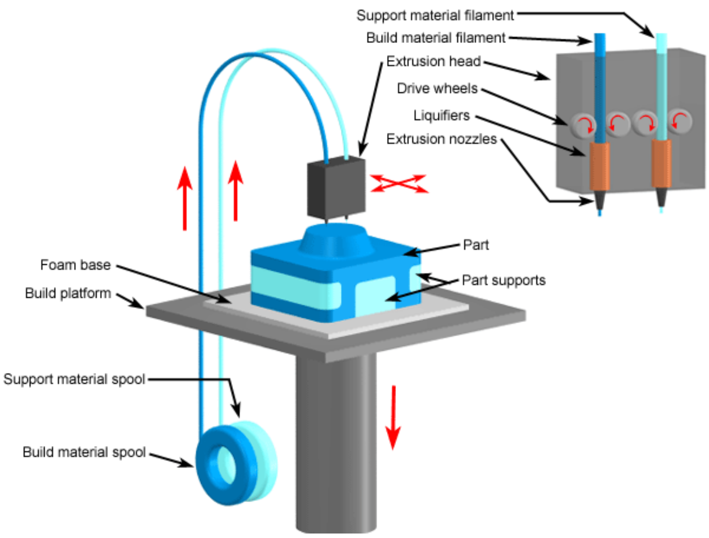


Figure 3. FDM method [6]

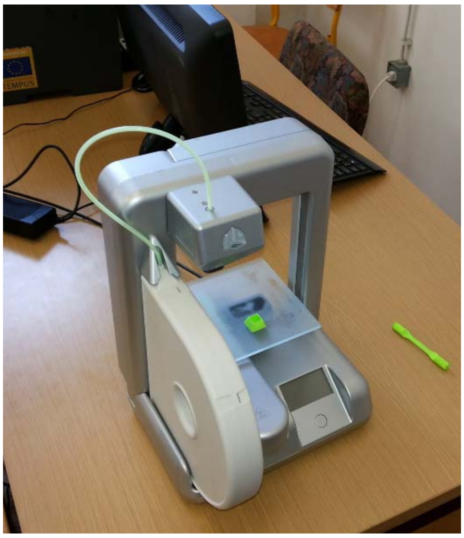


Figure 4. Cube 3D printer

Cube 3D printer is one of many that use FDM technology. The company 3D Systems with Cube 3D printer provides a simple software, which converts STL file into CUBE file. In this study we have used material PLA - Polylactic Acid, which is a biodegradable material and obtained from biomaterials. This material is odorless, so it can be used for printing in the office.

5. DIMENSIONAL ACCURACY TESTING

We made 10 specimens by each of the three methods (Figure 5). We measured the dimensions l_3 (x-axis), b_2 (y-axis) and h (z-axis) in Figure 5. Measuring devices we used are: the sliding caliper 1/20mm (graduation value 0.05 mm) and the measuring range 0-150 mm and micrometer (graduation value 0.01 mm) and measuring range 0-25 mm.

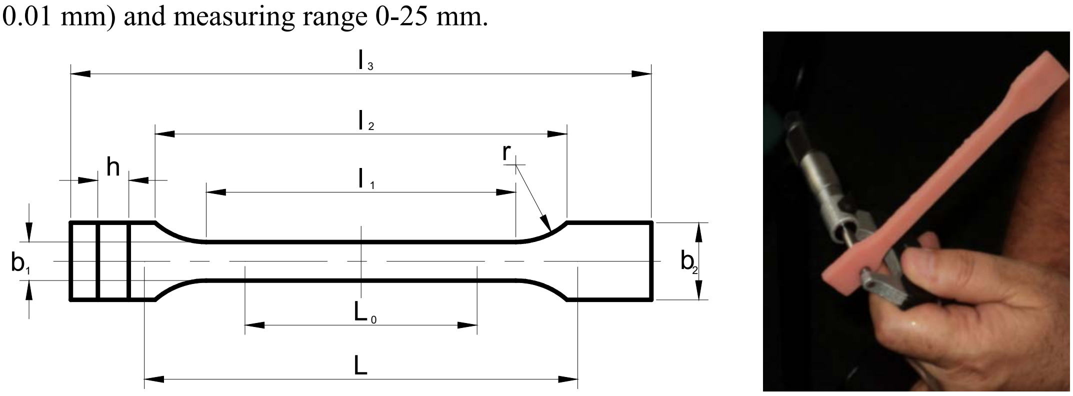


Figure 5. The shape of the specimen and measuring the dimensions h

After the measurements we carried out statistical analyzes. Table 1. shows the results of the RTV method for all three dimensions.

Table 1. Results of measurements for RTV method

	x	*y*	*z*
The default size of the 3D model	*150*	*20*	*4*
$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$	*149.68*	*20.459*	*4.3882*
$\bar{x} + t_p \frac{s}{\sqrt{n}}$ *(confidence level 95%)*	*150.4358*	*20.76393*	*4.783904*
$\bar{x} - t_p \frac{s}{\sqrt{n}}$ *(confidence level 95%)*	*148.9242*	*20.15407*	*3.992496*
$\bar{x} \pm t_p \frac{s}{\sqrt{n}}$ *(confidence level 95%)*	*149,68±0,755*	*20.459±0,305*	*4.3882±0,396*
The relative uncertainty	*0,50%*	*1,49%*	*9,02%*

It is obtained the mean deviation for all three measured dimensions for all three methods in this study. Then we approach the comparative analysis of results. The comparative presentation of the results is given in Table 2.

Table 2. Comparative presentation of the results of statistical data processing for all three methods

methods		x	y	z
RTV	The mean deviation [mm]	0,755	0,305	0,396
	The relative uncertainty [%]	0,50	1,49	9,02
Zcorp (3DP)	The mean deviation [mm]	0,233	0,060	0,310
	The relative uncertainty [%]	0,38	0,23	0,91
Cube 3D	The mean deviation [mm]	0,130	0,166	0,240
	The relative uncertainty [%]	0,112	0,871	5,104

Based on Table 2, taking into account all the directions of building, we see that the greatest dimensional accuracy is achieved by ZCorp method. **T**he smallest dimensional accuracy of all three methods is achieved in the direction of z axis. Therefore, the workpiece should be oriented so that the dimension with the highest tolerances are in the direction of z axis.

6. CONCLUSION

In general we can conclude that these procedures do not have high accuracy, so that 3D printing processes we can use in cases when the speed and price have priority over the dimensional accuracy. By performing comparative analysis of RTV, Cube 3D and ZCorp rapid prototyping process, it is best to use ZCorp method if the dimensional accuracy is paramount. ZCorp method gives the smallest deviations. Cube 3D procedure is the second of obtained dimensions accuracy. RTV method has the greatest deviations, because the error of dimension includes: error in model making, error in mold making and error in making the cast in the mold.

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