RESEARCH OF 3D PRINTED OBJECT DIMENSIONS INFLUENCE ON SURFACE PRECISION

Verbickaitė E., Sviackevičius P., Jurkonis E.
Vilnius Gediminas Technical University

Abstract
3D printing becomes more popular not only in arts, entertainment but also in production of industrial objects. Wider use of this technology needs quality of final product to be foreseen more accurately and effectively. While analyzing 3D printed object's relative measurements of 2D objects are taken into consideration. Main goal is to analyze influence of 3D printed object's size to its precision, prototype printing and evaluation. During analyze difference of whole project and printed model parameters and representation faults of a single fragment were evaluated. During research, ABS and PETG polymer were used. Experiment's step flow chart was created, variables of printing parameters were chosen and evaluation criteria were foreseen. Prepared 3D model is converted into STL file format. While generating operating G-code of a print-head, the same layer generating criteria were used for all printed models. All printed models were measured and according to gathered data charts of faults and deviations were created. Results and conclusions are presented. Notable, that major fault repeatability in 3D printed objects is noticeable along Z axis.
Key words: *3D printing, ABS, PETG, polymers, precision, G-code*

Introduction

3D Printing era has begun. It is one of the most potential industries over the last years. Currently, 3D printing technology is widely utilized in manufacturing of fully functioning prototypes. This technology lets us shorten design to manufacture cycles, thus reducing the cost of product and increasing competitiveness in the market. 3D printing becomes more popular not only in industry but also in arts, entertainment. Wider use of this technology needs quality of its final product to be foreseen more accurately and effectively. It is, however, remarkable how the question of accuracy is carefully

avoided.[1] There is a significant lack of published data on the FDM process characteristics and printing precision. This research was conducted in order to partially fill this gap and provide much needed information about accuracy. Other publications give only a superficial view on the matter without a proper scientifically founded in-depth analysis of the accuracy problem. There are some applications where question of accuracy is irrelevant, but compared with the biggest amount of applications the question of (guaranteed) accuracy is of prime importance.[1] The research was undertaken to characterize FDM technology and its processes in term of the achievable dimensional and geometrical accuracy. FDM is the most used technology of rapid prototyping with great potential towards rapid manufacturing. Designers need to know the capability profile of the process they are going to use. Used dimensional accuracy model was chosen in such way to represent characteristics needing to be investigated. Parts were printed from different polymers which have different shrinkage percentage. The main parameters that could cause dimensional deviations were: Layer Thickness, Infill, Extrusion multiplier, Part positioning on the platform. Current study investigates the effects of process parameters upon the dimensional accuracy of parts fabricated using Mass Portal delta printer.

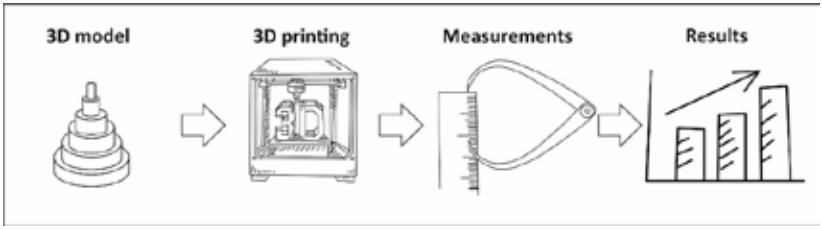

Figure 1. Experimental Process Flow Chart

Experiments and results

1. Experimental Software, Parameters, Materials

Slic3r (version 1.2.9) – G-code generator for 3D printers.
Repetier Host (version 1.6.0.) – Printing operating program.
Main chosen parameters of accuracy test prints:

- nominal dimensions of object – 30 mm, 20 mm, 10 mm;
- geometric features – circular;
- infill – 100% ;
- layer height – 0,2 mm, 0,1 mm;
- extrusion multiplier – 0,9;

- cooling – min 0, max 100%;
- printing speed – 30–45 mm/s.[4]

Materials used:

- white ABS 1,75 mm: Print temperature 220–260 ℃; First layer temperature 235 ℃;Print base material; Acrylic/ABS [2].
- blue PETG 1,75 mm :Extrusion Temperatures: 240–260 ℃; High strength filament; Dimensional Accuracy: ±0.05 mm;

2. Experimental Model

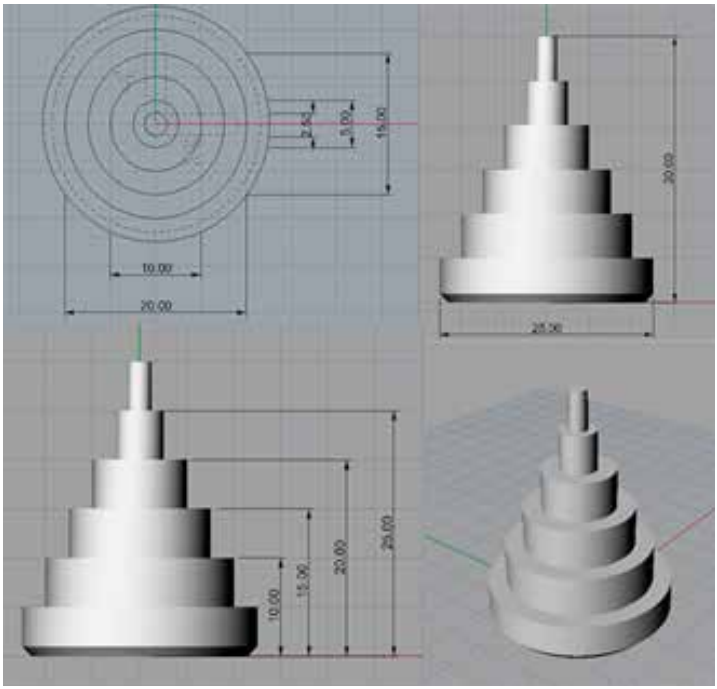

Figure 2 Digital 3D model of printed objects

4. Experimental instruments

3D delta printer MassPortal – Print speed: 30 mm/s – 300 mm/s Experimental materials: ABS, PET; Plastic filament diameter: 1.75 mm; Heated glass print bed — up to 120 °C; Nozzle diameter: 0.4 mm. [3]

For measurements: digital caliper. Resolution: 0.01 mm, Accuracy: 0.02 mm

Results

Table 1. Measurement results of printed object original size

Experiment No1. ABS white 30 mm					
Parameter	Layer height	0,2 mm			0,1 mm
Measure	Dimensions	1	2	3	4
Linear	Z_1	4,9	5	4,9	4,9
	Z_2	9,9	10	9,9	9,9
	Z_3	14,8	14,9	14,8	14,9
	Z_4	19,8	19,9	19,8	19,9
	Z_5	24,8	24,8	24,8	24,9
	Z	30	29,9	29,9	30,3
Diametric	D_1	2,3	2,3	2,3	2,5
	D_2	4,75	4,75	4,85	4,8
	D_3	9,8	9,75	9,75	9,8
	D_4	14,6	14,6	14,6	14,6
	D_5	19,6	19,6	19,6	19,6
	D_6	24,5	24,5	24,6	24,5

Table 2. Measurement results of printed object scaled 0.6

Experiment No2. ABS white 20mm					
Parameter	Layer height	0,1 mm			0,2 mm
Measure	Dimensions	1	2	3	4
Linear	Z_1	3,2	3,3	3,3	3,3
	Z_2	6,7	6,6	6,6	6,5
	Z_3	9,8	9,9	9,9	9,9
	Z_4	13,3	13,3	13,2	13,2
	Z_5	16,6	16,6	16,6	16,5
	Z	19,9	20,0	19,6	19,9
Diametric	D_1	1,45	1,5	1,5	1,45
	D_2	3,15	3,1	3,1	3,1
	D_3	6,5	6,5	6,5	6,5
	D_4	9,8	9,8	9,8	9,75
	D_5	13,05	13,05	13,0	13,05
	D_6	16,35	16,3	16,3	16,2

Table 3. Measurement results of printed object scaled 0.3

Experiment No3. ABS white 10 mm					
Parameter	Layer height	0,1 mm			0,2 mm
Measure	Dimensions	1	2	3	4
Linear	Z_1	1,7	1,6	1,7	1,6
	Z_2	3,3	3,3	3,3	3,3
	Z_3	5,3	5,0	4,9	4,9
	Z_4	6,8	6,7	6,7	6,5
	Z_5	8,5	8,3	8,3	8,4
	Z	10,0	10,0	10,0	10,0
Diametric	D_1	0,8	0,8	0,9	0,9
	D_2	1,6	1,6	1,7	1,7
	D_3	3,1	3,1	3,1	3,2
	D_4	4,7	4,75	4,7	4,8
	D_5	6,45	6,45	6,4	6,4
	D_6	8,2	8,1	8,1	8,0

Table 4. Measurement results of printed object (PETG material)

Experiment No4. PETG Blue				
Parameter	Layer height	0,2mm		
Measure	Dimensions	1	2	3
Linear	Z_1	5,0	3,3	1,8
	Z_2	10,0	6,7	3,4
	Z_3	15,0	10,2	5,2
	Z_4	20,0	13,5	6,8
	Z_5	25,0	16,9	8,5
	Z	30,2	20,5	10,3
Diametric	D_1	2,2	1,8	0,9
	D_2	4,8	3,2	1,5
	D_3	9,9	6,5	3,1
	D_4	14,8	10,0	4,8
	D_5	19,9	13,3	6,5
	D_6	24,9	16,6	8,2

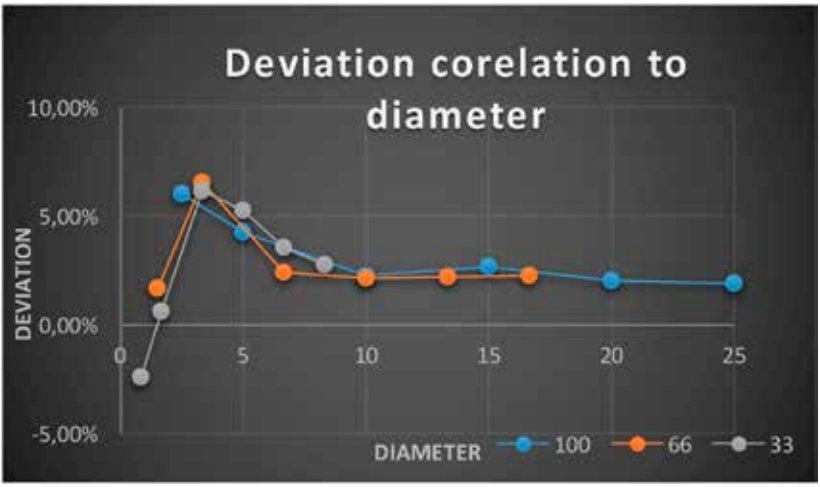

Figure 3. Deviation corelation to diameter

Conclusions

Linear and Diametric dimensions have been selected as quality indicators for the MassPortal printer. Parameters selected in Slic3r program had an affect for dimensional accurasy of printed objects. Investigation for geometric accuracy is based on the linear and diametric deviations between printed physical object and its' digital model. The experimental results indicate that:

- The average shrinkage of ABS polymer can be defined between 2–3%.
- In Fig.3 visible data spike can be treated as an error of printer machanics. Thus, should not be taken into consideration.

References

1. D. Dimitrov W. van Wijck K. Schreve N. de Beer, (2006),"Investigating the achievable accuracy of three dimensional printing", Rapid Prototyping Journal, Vol. 12 Iss 1 pp. 42 - 52
2. Materials [žiūrėta 2016-03-16] Prieiga per internetą: http://www.esun3d.net/cpxx.aspx?id=138&TypeId=10
3. MassPortal printers [žiūrėta 2016-03-15] Prieiga per internetą: http://massportal.com/en/shop/3dprinters
4. J. Kechagias*1, P. Stavropoulos2, A. Koutsomichalis3, I. Ntintakis4 and N. Vaxevanidis5 "Dimensional Accuracy Optimization of Prototypes produced by PolyJet Direct 3D Printing Technology",(2014) p. 61-65 ISBN: 978-1-61804-241-5