Aleksija Đurić
Ranka Gojković [1]
Biljana Marković
Slaviša Moljević
Jelica Anić

LAYER THICKNESS INFLUENCE OF MACRO- AND MICROSTRUCTURE QUALITY OF 3D PRINTED PARTS

Abstract: *In this paper will be analyzed the influence of the layer thickness on the micro and macro structure of the parts obtained by 3D printing, i.e. fused filament fabrication (FFF) technology. Specimens for analysis will be printed on the 3D printer Zotrax M 200, and the macro and microstructure will be done on the VHX 6000 microscope. It will be shown in the paper that by increasing the thickness of the layer, the time required for the production of the part will be significantly reduced, but also the quality of the surface is also significantly affected.*

Keywords: *3D printing, Fused filament fabrication, layer thickness*

1. Introduction

Fused filament fabrication (FFF) is an additive manufacturing technique which is suitable to produce parts with intricate internal shapes. An FFF printer is essentially a computer numerically controlled (CNC) gantry machine, equipped with one or multi-extruder nozzle head. In FFF technique, parts are manufactured by melting and extruding polymeric filament through a heated nozzle in a prearranged pattern onto a base plate. (Goh, G. D., et al., 2019) (Stansbury & Idacavage, 2016)

Multi material FFF components have begun to demonstrate added multi-functionality in manufactured parts that are desirable for a range of applications. (Allen & Trask, 2015) (Leigh et al., 2012)

The FFF process illustration is shown on figure 1.

Factors affecting the part quality and mechanical properties of the FFF-fabricated thermoplastic parts are shown in figure 2. The focus of this research will be on the influence of layer thickness on microstructure surface quality.

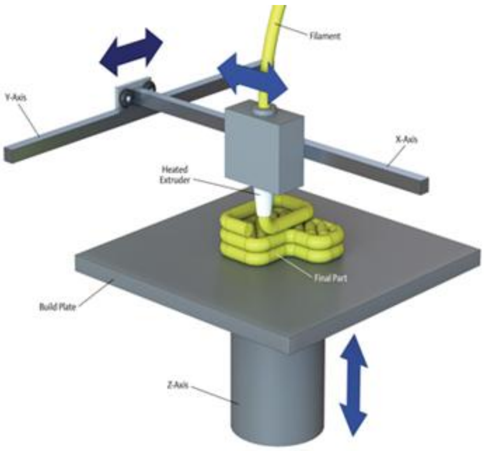

Figure 1. Illustration of FFF process.

The layer thickness and printing direction have a significant effect on the scaffolds compressive strength of scaffolds, they have only a minor effect on the structural properties of scaffolds for 3D printed parts (1). In this research (2), the significant effects of layer thickness and binder

[1] Corresponding author: Ranka Gojković
Email: active rankagojkovic@gmail.com

saturation level on the mechanical properties, integrity, and dimensional accuracy of the 3D printing the process has been experimentally studied. After this research is concluded that the under the same binder saturation, a decrease in layer thickness from 0.1 to 0.087 mm increased the tensile strength in specimens and decreased the flexural strength while. From an analysis of Wu, W. at all. (2015) it was to investigate the effects of raster angle and layer thickness on mechanical properties of 3D-printed speciment. The experiments confirmed that raster angle and layer thickness both have a marked effect on tensile, compressive and three-point bending properties. Author Fernandez-Vicente, M, and others conclude in the research that the change in the fill density determines mainly the tensile strength, and the stiffness, especially between 20% and 50% (Fernandez-Vicente at all., 2016).

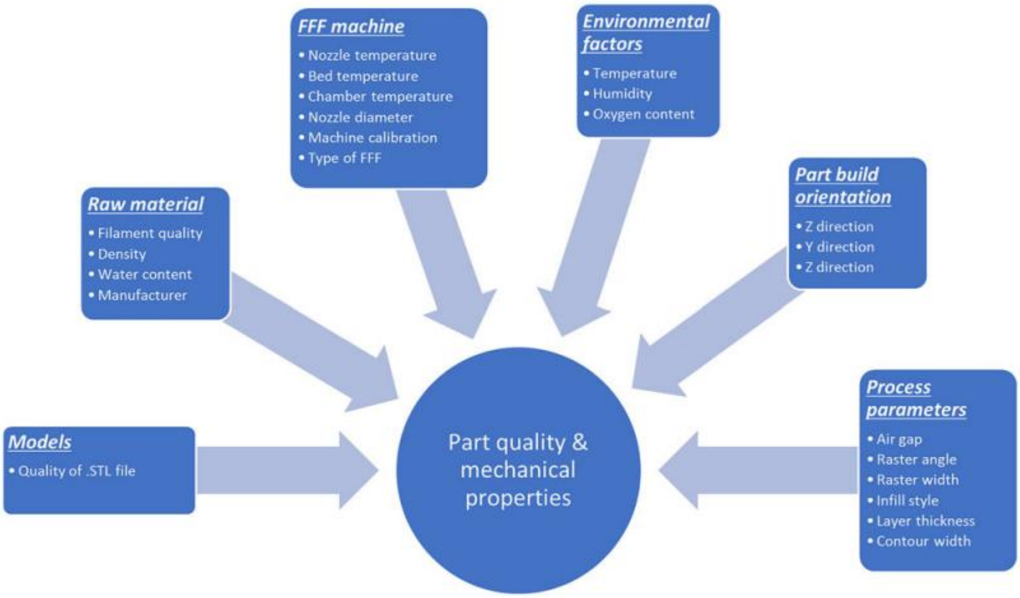

Figure 2. Factors affecting the part quality and mechanical properties of the FFF-fabricated thermoplastic parts.

2. Experimental set-up

For this research was used 3D printer Zotrax M200 (figure 3a). The dimension of the printed parts was φ10x20 mm and they are produced with material Z-ULTRAT. This material is ABS combined with polycarbonate.

Z-ULTRAT is a versatile material suitable for printing many different types of models. It is ideal for prototyping models with the features similar to the products manufactured in the injection molding technology. It is also suitable for mechanical and chemical post-processing. The objects 3D printed by Z-ULTRAT are strong, stable and resistant to creep. Properties of the material are suitable for evaluation of parts before production (Mild & Morovič, 2016) (Z-ULTRA- Material_Data).

Four specimens were produced (figure 3b), printed with different layer thickness as is shown in table 1. In this table are shows also other parameters for 3D printing. All specimens are printed with normal quality under the same working conditions.

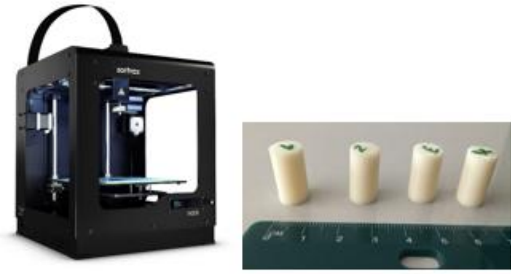

Figure 3. (a) 3D printer Zotrax M200; (b) Specimens

Table 1. Parametars for 3D printing

Parameters, units	Value			
Speciment marks	1	2	3	4
Layer thickness, mm	0.09	0,14	0,19	0,29
Nozzle diameter,	0,4			
Infill angle, °	20			
Infill, %	90			
Nozzle temperature, °C	221			
Platform temperature, °C	59,6			

The Z-Suite software was used to prepare 3d printing of specimens. The interface of this software with parameters for specimen marked as 1, is shown in Figure 4.

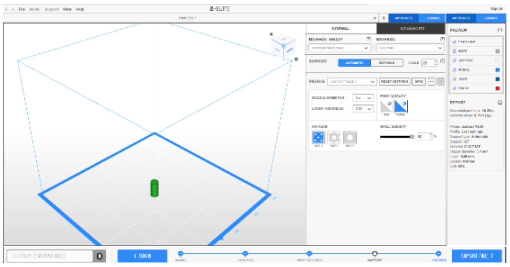

Figure 4. Interface of Z-SUITE software

The temperature of nozzle and platform was determined using thermography camera and the thermographic picture are shown in figure 5.

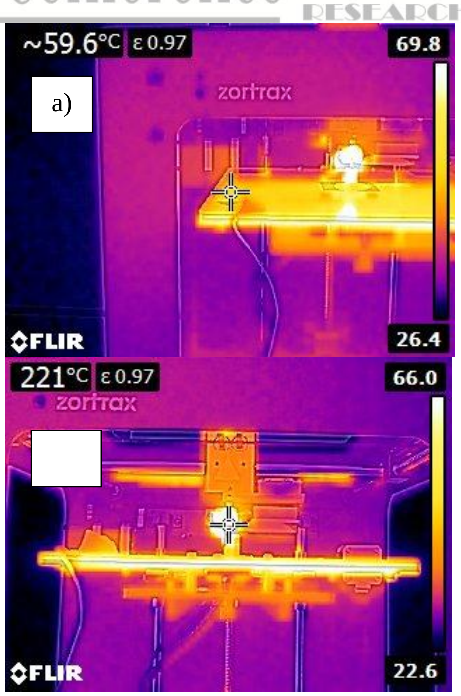

Figure 5. IR images of (a) nozzle; (b) Platform

3. Results and Discussion

The thickness of the layer directly affects the time needed to create the model. The effect of the layer size on time is shown in Figure 6.

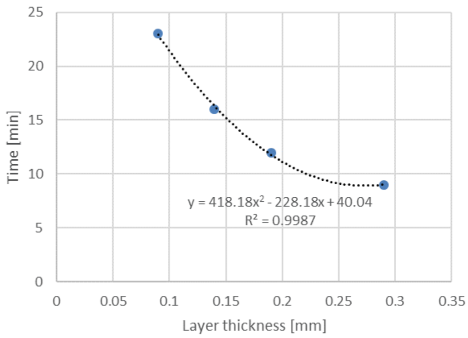

Figure 6. Diagram of dependence between 3D printing time and layer thickness

It can easily be concluded from the figure 6 that increasing the thickness of the layer significantly reduces the time required to create the model. For example, with a

magnification of the layer thickness from 0.09 mm to 0.29 mm, the time is reduced from 23 min to 9 minutes.
Measurement of specimen diameter was on the VHX 6000 microscope. The picture of the measurement of specimens 1 and 4 are in figure 7.

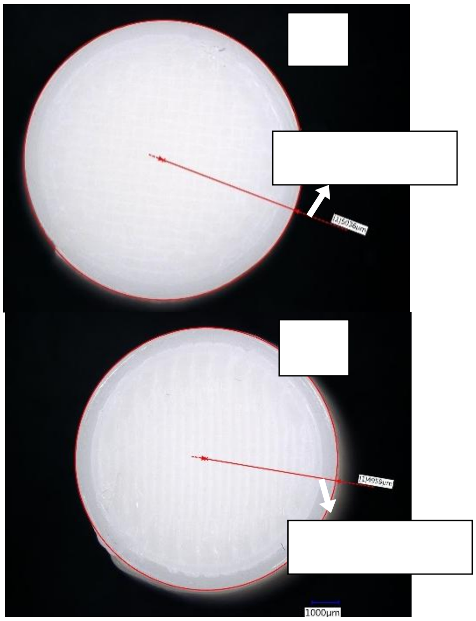

Figure 7. Measurment of diameter for (a) specimen 1; (b) specimen 4

The display of the diameter of all four specimens is given in Table 2 together with the deviation from the ideal diameter (5 mm).

Table 2. Specimen diameter measurement

No.	Layer thick. [mm]	Ideal diameter [mm]	Measured diameter [mm]	Deviation [%]
1	0.09	5	5.036	0,72
2	0.14		5.038	0,76
3	0.19		5.04	0,8
4	0.29		4.959	0,82

The deviations from the ideal diameter shown in the previous table are very small for all four samples, which means that the accuracy of 3D parts is slightly dependent on the layer thickness.

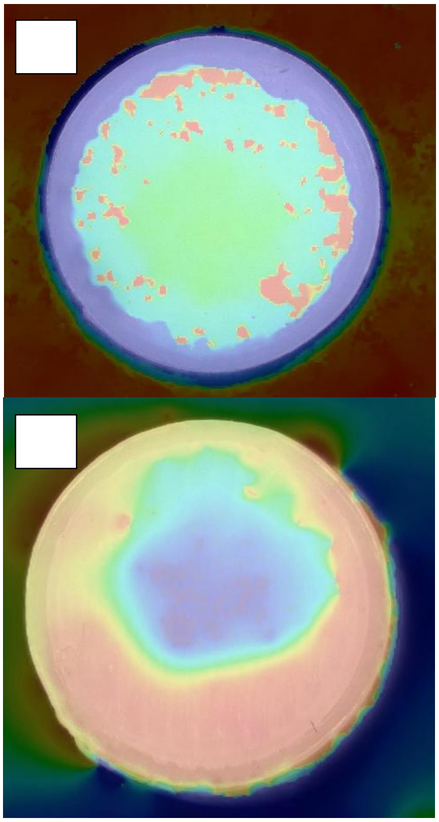

Figure 8. Indicating height in color for the (a) specimen 1; (b) specimen 4.

The quality surface of the specimen dependents heavily on the thickness of the layer thickness. This is proved in Figure 8, where is shown indicating height in color for the 3rd and 4th samples.
The microstructure of the surface of the specimens also shows the dependence heavily of the layer thickness. The surface microstructures of specimens 1 and 4 are shown in Figure 9, where a significant difference is seen.

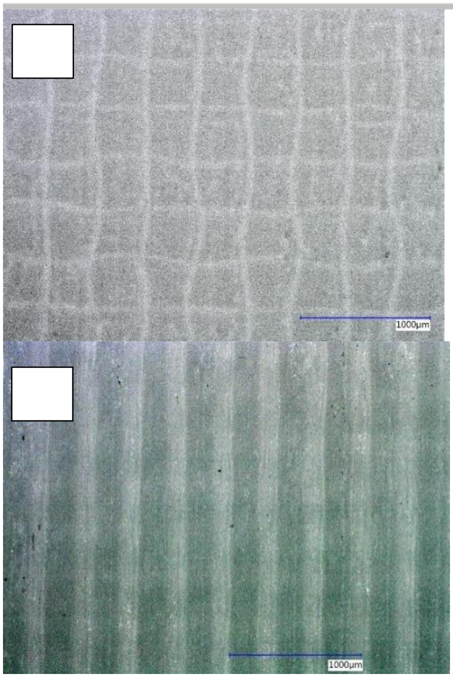

Figure 9. The surface microstructures of (a) specimen 1; (b) specimen 4.

4. Conclusion

After analyzing the influence of the layer thickness on the quality of the macro- and micro-structure, the following can be concluded:

- The thickness of the layer directly affects the time needed to create the model.
- The manufacturing accuracy of 3D parts on 3D printer Zotrax M200 is slightly dependent on the layer thickness.
- The surface quality and the surface microstructure of the specimen dependents heavily on the layer thickness.

Future research should focus on the optimization of all 3D printing parameters in order to match production time and the required quality of the obtained part

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References:

Allen, R. J. A., & Trask, R. S. (2015). An experimental demonstration of effective Curved Layer Fused Filament Fabrication utilising a parallel deposition robot. Additive Manufacturing, 8, 78–87. doi:10.1016/j.addma.2015.09.001

Arghavan, F., Mehran, S.-H., Mitra A.-E., Noor, A. and Abu, O. (2014) Effect of Layer Thickness and Printing Orientation on Mechanical Properties and Dimensional Accuracy of 3D Printed Porous Samples for Bone Tissue Engineering, PLOS ONE, 9 (9), pp. 1-14, https://doi.org/10.1371/journal.pone.0108252

Fernandez-Vicente, M., Calle, W., Ferrandiz, S., & Conejero, A. (2016). Effect of Infill Parameters on Tensile Mechanical Behavior in Desktop 3D Printing. 3D Printing and Additive Manufacturing, 3(3), 183–192. doi:10.1089/3dp.2015.0036

Goh, G. D., Yap, Y. L., Tan, H. K. J., Sing, S. L., Goh, G. L., & Yeong, W. Y. (2019). Process–Structure–Properties in Polymer Additive Manufacturing via Material Extrusion: A Review. Critical Reviews in Solid State and Materials Sciences, 1–21. https://doi:10.1080/10408436.2018.1549977

Leigh, S. J., Bradley, R. J., Purssell, C. P., Billson, D. R., & Hutchins, D. A. (2012). A Simple, Low-Cost Conductive Composite Material for 3D Printing of Electronic Sensors. PLoS ONE, 7(11), e49365. doi:10.1371/journal.pone.0049365

Milde, J., & Morovič, L. (2016). The Influence of Internal Structures in Fused Deposition Modeling Method on Dimensional Accuracy of Components. Research Papers Faculty of Materials Science and Technology Slovak University of Technology, 24(38), 73–80. doi:10.1515/rput-2016-0041

Stansbury, J. W., & Idacavage, M. J. (2016). 3D printing with polymers: Challenges among expanding options and opportunities. Dental Materials, 32(1), 54–64. doi:10.1016/j.dental.2015.09.018

Trevor, L. (2016) Ultrasonic welding 3D printed parts, Make parts fast, https://www.makepartsfast.com/how-to-ultrasonically-weld-3d-printed-parts /

Vaezi, M., and Chua, C.-K. (2011) Effects of layer thickness and binder saturation level parameters on 3D printing process, Int J Adv Manuf Technol, 53, pp. 275–284, https://doi.org/10.1007/s00170-010-2821-1

Wu, W., Geng, P., Li, G., Zhao, D., Zhang, H., & Zhao, J. (2015). Influence of Layer Thickness and Raster Angle on the Mechanical Properties of 3D-Printed PEEK and a Comparative Mechanical Study between PEEK and ABS. Materials, 8(9), 5834–5846. doi:10.3390/ma8095271

Z-ULTRAT_Material_Data_Sheet_eng.pdf, Zortrax Company, http://support.zortrax.com/.

Aleksija Đurić
University of East Sarajevo,
Faculty of Mechanical Engineering,
East Sarajevo,
Bosnia and Herzegovina
aleksijadjuric@gmail.com

Ranka Gojković
University of East Sarajevo,
Faculty of Mechanical Engineering,
East Sarajevo,
Bosnia and Herzegovina
rankagojkovic@gmail.com

Biljana Marković
University of East Sarajevo,
Faculty of Mechanical Engineering,
East Sarajevo,
Bosnia and Herzegovina
biljana46m@gmail.com

Slaviša Moljević
University of East Sarajevo,
Faculty of Mechanical Engineering,
East Sarajevo,
Bosnia and Herzegovina
slavisa.moljevic@gmail.com

Jelica Anić
University of East Sarajevo,
Faculty of Mechanical Engineering,
East Sarajevo,
Bosnia and Herzegovina
jelicaanic91@gmail.com