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Layer Height, Temperature Nozzle, Infill Geometry and Printing Speed Effect on Accuracy 3D Printing PETG

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***Abstract**. The manufacturing industry has grown rapidly in the last few decades. 3D printing is one of the technologies of manufacturing, this technology makes products by adding filaments that are stacked systematically to become a finished product. PETG filament is a polymer with the name polyester but with glycol modification. This study aims to determine and understand the effect of the process parameters layer height, nozzle temperature, infill geometry and printing speed. This research method uses the Taguchi method with L16 and various parameters; layer height 0.12 mm; 0.16 mm; 0.2 mm; 0.28 mm, infill geometry cross; cubic; tri-hexagonal; triangles, nozzle temperature 220 ºC; 230 ºC; 240 ºC; 250 ºC and printing speed 40 mm/s; 50 mm/s; 60 mm/s; 70 mm/s. After testing, it can be concluded that the most influential parameters are sequentially; layer height, nozzle temperature, printing speed, and infill geometry with layer height parameters have the dominant influence, nozzle temperature and printing speed parameters have a balanced influence and infill geometry parameters have the least influence.*

***Keywords** - Additive manufacturing; FDM; Taguchi's DO; Rapid prototypin; Design-for-manufacturing.*

INTRODUCTION

Additive manufacturing (AM) or rapid prototyping (RP) is a direct conversion technique from three-dimensional data such as computer aided design (CAD) into a physical prototype. RP was first described in 1986 by Charles Hull and commercialized in 1990. This technology makes an object or product by adding material techniques instead of throwing away materials to reduce waste while obtaining satisfactory quality goods [1-3].

Accuracy is the closeness of a measurement to the actual size of the quantity being measured. Each parameter will give its own influence on a product. Parameters such as layer height, nozzle temperature, fan speed, and so on are set to help reduce the deviation of the specimen dimensions [4-6].

Research on the accuracy of specimens on PLA and ABS materials has been widely carried out. The dimensional deviation of the PLA filament was lowest at low printing speeds and high extrusion temperatures [4]. Filament and found that the most influential parameters for accuracy were temperature and layer height [7, 8]. Same filament in the case of this study as PLA has very different dimensional responses and in that study the high level of accuracy of the PETG filament makes PETG a suitable choice for dimensional control [9, 10].

Low deviations in the dimensional accuracy quality of the PLA filament were found in specimens using low print speed and high extrusion temperature parameters [4]. Study on the dimensional accuracy of nylon filaments and concluded that the layer thickness or layer height process parameters have a significant effect [11, 12]. PLA filaments for dimensional accuracy and they concluded that the infill pattern or infill geometry parameters had a high influence [13, 14]. Therefore, is important to study the influence of different parameters for better quality of dimensional accuracy from addictive manufacture especially at fused deposition modeling.

METHODS

The preparation is in the form of tools, materials, how to process data and so on. This design is based on previous research by Santana et al (2017) and Liu et al (2018) which used cuboidal and slab-shaped specimens. The keyboard keycap puller design will also be used as a comparison of the accuracy of the PETG 3D printing. In this study PETG (solid grey 1,75mm filament size) was used from Esun. 3D printer, Creality Ender 3 V2 and we also used enclosure to better controlling the room temperature. The design is made using the 2017 version of the Inventor application then extracted to STL format. Then the STL format converted to G-Code and set the parameters helped by UltimakerCura softwere. We used digital caliper from Insize for measured the accuracy dimension. Measurements were taken in the morning of about 8-10 am, this was done to reduce the effect of the difference in measurement time. Te following is the design of the dimensional accuracy specimen to determine the effect of layer height, nozzle temperature, infill geometry, and printing speed, we used the Taguchi method to get maximum results with minimum expenditure. We use L16 because the variables used are 4 parameters and 4 levels with orthogonal array calculations and for each experiment for the variable shown at table 3.

Generally, fdm technology not so good at very high speed, therefore we selected 4 low print speed at 40mm/s, 50mm/s, 60mm/s and 70 mm/s. As PETG has temperature nozzle range at 220 °C – 250 ºC, therefor we selected temperature nozzle at 220 ºC, 230 ºC, 240 ºC and 250 ºC. In previous research layer height was observed that has high impact on quality of accuracy dimension, therefore we selected 4 level at 0,12 mm, 0,16 mm, 0,20 mm and 0,24 mm. Infill geometry has unique effect on printed part, certain pattern gave different effect. Based on that we selected 4 level infill geometry that is triangles, cross, cubic, tri-hexagonal. These parameters is shown at table 1. Design that used for this research is 2 type, first is cube that can be see at figure 1 and second is keyboard keycap puller or key puller at figure 2. All the other parameter such as infill density, temperature enclosure or room, bed temperature is fixed at table 2.

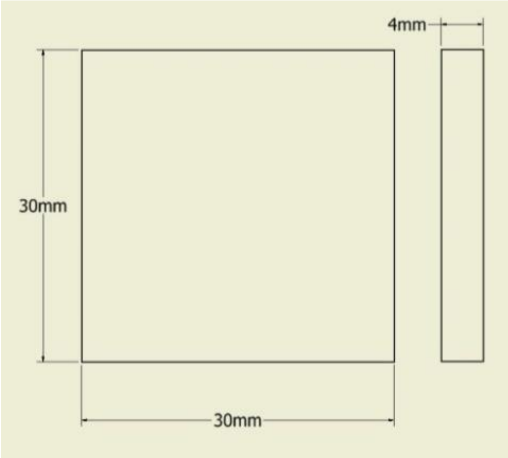

Figure 1. 2D plate design.

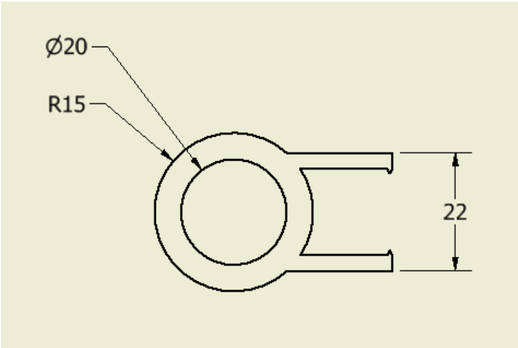

Figure 2. 2D design key puller.

Table 1. 3D printing process parameters along with their levels.

Parameter and level	1	2	3	4
Layer height (mm)	0.12	0.16	0.2	0.24 mm
Infill geometry	Triangles	Cross	Cubic	Tri-Hexagonal
Temperature nozzle (ºC)	220	230	240	250
Print speed (mm/s)	40	50	60	70

Table 2. Fixed parameters.

Parameter	Set value
Temperature enclosure	40ºC
Infill density	50%
Bed temperature	80ºC

Table 3. Experiment based on Taguchi L16.

Eksperimen	**Layer height (mm)**	**Infill geometry**	**Temperature nozzle (ºC)**	**Printing speed (mm/s)**
1	0.12	Triangles	220	40
2	0.12	Cross	230	50
3	0.12	Cubic	240	60
4	0.12	Tri-Hexagonal	250	70
5	0.16	Triangles	230	60
6	0.16	Cross	220	70
7	0.16	Cubic	250	40
8	0.16	Tri-Hexagonal	240	50
9	0.2	Triangles	240	70
10	0.2	Cross	250	60
11	0.2	Cubic	220	50
12	0.2	Tri-Hexagonal	230	40
13	0.24	Triangles	250	50
14	0.24	Cross	240	40
15	0.24	Cubic	230	70
16	0.24	Tri-Hexagonal	220	60

RESULTS DAN DISCUSSION

In this study Minitab application was used for analyze data that have been collected. The effect of parameters is shown at table below. The results of printing plate design specimens, key puller designs and the calculation process can be seen in Figure 3, Figure 4 and Figure 5. After analyzing the results from minitab, it was observed that layer height, nozzle temperature, infill geometry and printing speed give influence to quality of accuracy dimension. Parameter that has the most influenced for quality of accuracy dimensional is layer height. Lower dimensional deviation was found at lower layer height, infill geometry cross, higher nozzle temperature and lower printing speed.

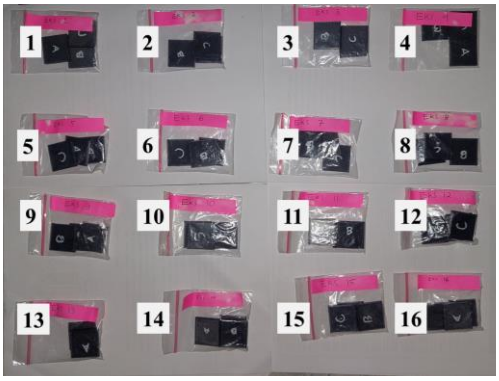

Figure 3. Plate design specimen printing results.

Figure 4. Key puller design printing results.

Figure 5. Dimensional Accuracy Measurement.

Based on the figure 6, the layer height process parameter is the most influential parameter on the dimensional accuracy of the X side specimen. The data can also be concluded that the optimization of dimensional accuracy parameters in succession from the most influential is layer height (0.12 mm), printing speed (40 mm/s), nozzle temperature (240 °C), and infill geometry (cross). Based on the figure 7, the layer height process parameter is the most influential parameter on the dimensional accuracy of the Y side specimen. The data can also be concluded that the optimization of dimensional accuracy parameters in succession from the most influential is layer height (0.12 mm), printing speed (40 mm /s), nozzle temperature (240 °C), and infill geometry (cross). Based on the figure 8, the layer height process parameter is the most influential parameter on the dimensional accuracy of the key puller specimen. The data can also be concluded that the optimization of dimensional accuracy parameters in succession from the most influential is layer height (0.12 mm) printing speed (50 mm/s), nozzle temperature (250 ºC) and infill geometry (cross).

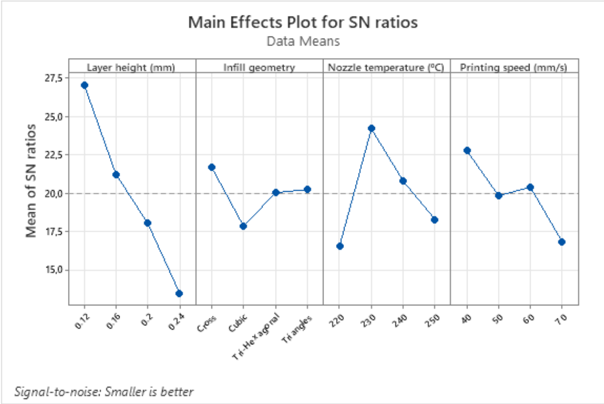

Figure 6. Graph of S/N Ratio of X side specimen.

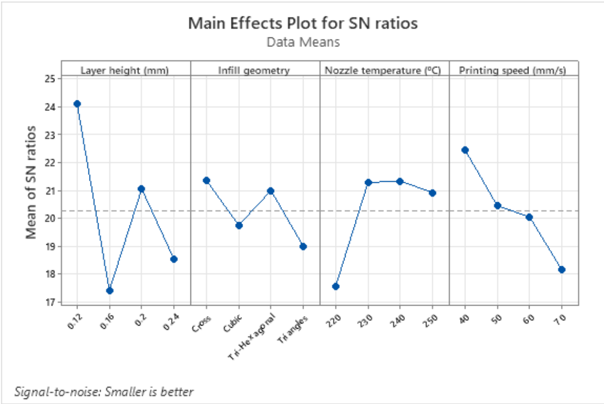

Figure 7. Graph of S/N Ratio of Y side specimen.

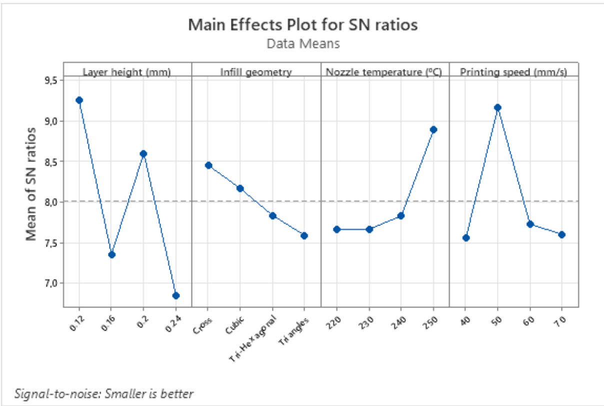

Figure 8. Graph of S/N Ratio of key puller specimen.

The effect of the layer height parameter on dimensional accuracy is that if the layer height used is low, the resulting extrusion diameter will be small, it can reduce the empty space on each side of the specimen which will affect the density of the specimen. The nozzle temperature parameter affects accuracy because the heat of the nozzle will determine whether the filament will melt completely or not, which results in the complete attachment and freezing of the filament on the bed. Temperature nozzle for more complicated designs requires a hotter temperature, the more complex the design, the hotter the nozzle temperature. Printing speed regulates the consistency of the printing process, with low speed the filament can stick to the bed more perfectly.

Infill geometry or infill pattern is one of the parameters found in the Cura application which functions to regulate the shape of the content and empty space that will be received in the center of the specimen. Infill geometry is a bit more unique in terms of its uniqueness than other parameters, because the use of the infill type depends on the design and parameters used.

The cross design is the best in this accuracy test because the cross design is a design used for flexible filaments with low infill density. The resulting pattern does not have a long horizontal straight line, causing flexibility in the horizontal section. The infill density used in this study is 50%, which is normally low.

Infill geometry triangles are an alternative to a grid design with the same level of contribution to the specimen load as the grid. The Tri-hexagon, grid, and Triangles designs are suitable for everyday printing because the load contribution is quite evenly distributed. Tri-hexagon uses three parallel lines, is a mixture of small triangles and large hexagons. Cubic and Tri-hexagon are suitable for designs that require rigidity in every part.

CONCLUSION

The higher the layer height, the lower the level of dimensional accuracy. Infill geometry is the parameter with the lowest influence compared to other parameters. The temperature nozzle tends to be the higher the temperature, the more accurate the dimensional accuracy. The lower the printing speed, the higher the level of dimensional accuracy.

The optimal parameters for the X-sided plate design from the most influential are layer height (0.24 mm), printing speed (40 mm/s), nozzle temperature (230 ºC) and infill geometry cross. The optimal values for the Y-side plate from the most influential are layer height (0.24 mm), nozzle temperature (240 ºC) printing speed (40 mm/s), and infill geometry cross. The optimal values for the key puller design from the most influential are layer height (0.24 mm), printing speed (40 mm/s), nozzle temperature (250 ºC) and infill geometry cross.

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REFERENCES

[1] Alsoufi, M. S., El-Sayed, A., & Elsayed, A. E. (2017). How Surface Roughness Performance of Printed Parts Manufactured by Desktop FDM 3D Printer with PLA+ is Influenced by Measuring Direction Environmental sustainability and energy conservation during machining processes View project How Surface Roughness Performance of Printed Parts Manufactured by Desktop FDM 3D Printer with PLA+ is Influenced by Measuring Direction. American Journal of Mechanical Engineering, 5(5), 211–222. https://doi.org/10.12691/ajme-5-5-4.

[2] Aloyaydi B, Sivasankaran S, Mustafa A. Investigation of infill-patterns on mechanical response of 3D printed poly-lactic-acid. Polymer Testing. 2020 Jul;87:106557.

[3] Rismalia M, Hidajat SC, Permana IGR, Hadisujoto B, Muslimin M, Triawan F. Infill pattern and density effects on the tensile properties of 3D printed PLA material. Journal of Physics: Conference Series. 2019 Dec;1402:044041.

[4] Ansari, A. A., & Kamil, M. (2021). Effect of print speed and extrusion temperature on properties of 3D printed PLA using fused deposition modeling process. Materials Today: Proceedings, 45, 5462–5468. https://doi.org/10.1016/j.matpr.2021.02.137.

[5] Durgashyam, K., Indra Reddy, M., Balakrishna, A., & Satyanarayana, K. (2019). Experimental investigation on mechanical properties of PETG material processed by fused deposition modeling method. Materials Today: Proceedings, 18, 2052–2059. https://doi.org/10.1016/j.matpr.2019.06.082.

[6] Panjaitan, J. H., Tampubolon, M., Sihombing, F., & Simanjuntak, J. (2021). *Pengaruh Kecepatan, temperature dan Infill Terhadap Kualitas dan Kekasaran Kotak Relay Lampu Sign Sepedamotor Hasil dari 3D Printing*. *2*(2).

[7] Polak, R., Sedlacek, F., & Raz, K. (2017). Determination of fdmprinter settings with regard to geometrical accuracy. Annals of DAAAM and Proceedings of the International DAAAM Symposium, 561–566. https://doi.org/10.2507/28th.daaam.proceedings.079.

[8] Zharylkassyn, B., Perveen, A., & Talamona, D. (2021). Effect of process parameters and materials on the dimensional accuracy of FDM parts. *Materials Today: Proceedings*, *44*, 1307–1311. https://doi.org/10.1016/j.matpr.2020.11.332.

[9] Santana, L., Horst, D., & Alves, J. L. (2020). DIMENSIONAL ANALYSIS OF PLA AND PETG PARTS BUILT BY OPEN SOURCE EXTRUSION-BASED 3D PRINTING Charact erizat ion of t he Mechanical

Propert ies of FFF St ruct ures and Mat erials: A Review on … Enrique Cuan-Urquizo 3D-Print ed Conduct ive Filamen s Based on Carbon Nanost ruct ures Embedded in a Polymer Mat rix: A … DIMENSIONAL ANALYSIS OF PLA AND PETG PARTS BUILT BY OPEN SOURCE EXTRUSION-BASED 3D PRINTING.

[10] Saputra, O. A. (2019). *PENGOPERASIAN MESIN CETAK 3D* (1st ed.). Wade Group.

[11] Basavaraj, C. K., & Vishwas, M. (2016). Studies on Effect of Fused Deposition Modelling Process Parameters on Ultimate Tensile Strength and Dimensional Accuracy of Nylon. IOP Conference Series: Materials Science and Engineering, 149(1). https://doi.org/10.1088/1757-899X/149/1/012035.

[12] Soejanto, I. (2019). Desain eksperimen dengan metode Taguchi (1st ed., Vol. 1). Graha Ilmu.

[13] Alafaghani, A., & Qattawi, A. (2018). Investigating the effect of fused deposition modeling processing parameters using Taguchi design of experiment method. Journal of Manufacturing Processes, 36, 164–174. https://doi.org/10.1016/j.jmapro.2018.09.025

[14] Mohamed, O. A., Masood, S. H., & Bhowmik, J. L. (2016). Optimization of *fused deposition modeling* process parameters for dimensional accuracy using I-optimality criterion. *Measurement: Journal of the International Measurement Confederation*, *81*, 174–196. https://doi.org/10.1016/j.measurement.2015.12.011.

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