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The Effect of 3D Printing Filament Heat on Surface Roughness and Dimensional Accuracy

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Abstract - The application of advanced 3D printer technology makes it easy for designers and concept development teams to produce components and concept models using a 3D printer. 3D Printing is a tool that can process the creation of a series of objects by placing thin layers that are formed sequentially according to the desired shape. FDM is a 3D Printing technique for printing products using filament as a material. FDM (Fused Deposition Modeling) technology is a technology for creating 3D objects. 3D printing is often referred to as the newest technology that can change the world. However, FDM technology has a weakness because this technology uses a building process per layer, making the resulting surface appear to have lines that indicate the boundaries between layers, thereby affecting the roughness of the specimen surface. In this discussion, the researcher uses the Taguchi Method experimental design with the L9 Orthogonal Array design plan with three factors and three levels. Signal to Noise Ratio SNR analysis to determine optimal parameters for Dimensional Accuracy and Surface Roughness of ABS filament. The process parameters that will be used in this research are nozzle temperature (°C), print speed (mm/s), bed temperature (°C). The optimal parameters in terms of accuracy are nozzle temperature (237°C), print speed (42mm). /s), Bed Temperature (92°C). And in surface roughness the optimal parameters are Nozzle Temperature (240°C), Print Speed (45mm/s), Bed Temperature (105°C).

Keywords: *3D printing; Acrylonitrile Butidine Styrene (ABS); Dimensional Accuracy And Surface Roughness; Fused Deposition Modeling (FDM), Taguchi Method*

Abstrak - Aplikasi kemajuan teknologi printer 3D membagikan kemudahan untuk *designer* serta regu pengembangan konsep untuk memproduksi komponen serta model konsep memakai printer 3D. 3D *Printing* adalah alat yang dapat memproses pembuatan serangkaian objek dengan menempatkan lapisan-lapisan tipis yang dibentuk secara berurutan sesuai dengan bentuk yang diinginkan. FDM merupakan teknik 3D *Printing* untuk mencetak produk menggunakan filamen sebagai material. Teknologi FDM (*Fused Deposition Modelling*) merupakan salah satu teknologi untuk membuat objek 3D. 3D printing sering disebut sebagai teknologi terbaru yang akan mampu mengubah dunia. Namun teknologi FDM memiliki kelemahan karena teknologi ini menggunakan proses bangunan per lapis membuat permukaan yang dihasilkan terlihat memiliki garis yang menunjukan batas antar *layer* sehingga mempengaruhi kekasaran padapermukaan spesimen. Dalam pembahasan ini peneliti menggunakan desain eksperimen Metode Taguchi dengan rancangan desain L9 *Orthogonal Array* dengan tiga faktor dan tiga level. Analisis *Signal to Noise Ratio* SNR untuk mengetahui parameter yang optimum pada Akurasi Dimensi Dan Kekasaran Permukaan filamen ABS. Parameter proses yang akan digunakan dalam penelitian ini yaitu Suhu *Nozzle* (°C), Kecepatan *Print* (mm/s),Suhu *Bed* (°C).Paramater yang optimal dalam akurasi dimensi yaitu Suhu *Nozzle (*237°C), Kecepatan *Print* (42mm/s), Suhu *Bed* (92°C).Dan di Kekasaran Permukaan Parameter yang optimal yaitu Suhu *Nozzle (*240°C), Kecepatan *Print* (45mm/s), Suhu *Bed* (105°C).

Kata Kunci: *3D Printing; Acrylonitrile Butadine Styrene (ABS); Akurasi Dimensi dan Kekasaran Permukaan; Fused Deposition Modelling (FDM); Metode Taguchi*

I. Introduction

3D Printing is a tool that can process the creation of a series of objects by placing thin layers that are formed sequentially according to the desired shape. The 3D printing process is a process where a solid object is produced from a digital file. The process of making three-dimensional objects is part of the Additive Manufacturing Process[1]. For further information, there are various Additive Manufacturing (AM) technologies that have been used by both large industries and home industries,

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including Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS), Direct Metal Deposition (DMD), and Inkjet Modeling (IJM)[2].

One of the most effective and well-known methods used in Additive Manufacturing (AM) technology is Fused Deposition Modeling (FDM) where products produced through this process have the potential to compete with conventional manufacturing methods (Injection Molding). To date, FDM technology has been widely used in the 3D printing process because it is easy to use, lower costs, environmentally friendly and easier in the product development process. Of the many developments in FDM technology, this can be seen in various fields such as making automotive spare parts, manufacturing industry, health, food, fashion, architecture and many more in various fields.[3].

3D printer technology makes it easy for designers and concept development teams to produce components and concept models using 3D printers. To produce an object, it is necessary to move a set of 3D models/objects, or draw using a three-dimensional design program such as*AutoCAD, Cura Ultimaker, 3dsMax, SketchUp*, and many other types. Digital 3D models are generally stored in STL (Standard Triangle Language) format and then sent to the printer using an SD card. The STL file needs to be processed by an application called a “Slicer” which converts the model into a series of thin layers and creates a G-code file containing instructions tailored to the specific type of 3D printer. Then this G-code file can be printed using the 3D Printing application (which loads the G-code and uses it so that it can still instruct the 3D printer throughout the 3D printing process).

With FDM technology, duplicate products from thermoplastic materials can be made with the same shape and dimensions of a sample product.by Satyanarayana & Prakash [7].For a product that has been produced using thermoplastic material, it is important to know its tensile strength. Process efficiency and accuracy or material strength of a product are very important concerns, this is due to very tight competition in the manufacturing industry. Therefore, to be able to obtain quality products with an efficient process, this matter has a very significant influence. Before printing or making a finished product, a prototype is needed to identify its shape and dimensions. Fast prototyping and using a 3-dimensional printer machine.

However, FDM (Fused Deposition Modeling) technology has a weakness because this technology uses a building process per layer so that the resulting surface appears to have lines that indicate the boundaries between layers. The lines or boundaries per layer are influenced by the speed of movement of the printer to create the pattern (Print Speed), the thickness per layer (Layer Thickness), the flow rate (Flow Rate) of the liquid plastic texture caused by the printing temperature (Nozzle Temperature), cooling speed (Cooling Speed) and position (Orientation).

On the other hand, there is a parameter point of view on a 3D Printing machine, which is a reference used to control a value on the machine so that it can produce the desired results while it is being processed. When 3D Printing parameters are entered through slicer software to produce a program language, namely G-code, it will then be read by the machine as a command for the printing process. The parameters available on the 3D Printing machine are; Nozzle Temperature, Layer Thickness, Temperature based Plate, Print Speed, Infill Pattern and others.

From research that has been carried out [5] regarding "The influence of nozzle and base plate temperature on ABS material on the density and surface roughness values of the product on the leapfrog creater 3D printer machine". In this research, nozzle temperatures were used, namely 190˚C, 205˚C, 220˚C and base plate temperatures of 30˚C, 50˚C. From this research, the surface roughness results in this research were found at a nozzle temperature of 190˚C and a base plate temperature of 30˚C using glue of 5,709 µm.

From the research that has been carried out[2], conducted research on "The Effect of Printing Speed on the Level of Surface Roughness of Additive Manufacturing Results with Polylactic Acid Filament". In this study, printing speed was varied with values of 50% (1st specimen), 100% (2nd specimen) and 150% (3rd specimen). From this research, it was found that the average value of the surface roughness measurement results tends to increase (get rougher) if the printing speed is increased.

From the research that has been carried out[4] conducted research on "Optimization of Fused Deposition Modeling (FDM) Machine Parameters on Product Surface Roughness Using the Taguchi

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Method". In this research, the Taguchi method was used using the parameters printing speed, printing temperature and layer height. From this research, the results showed that layer height had the largest contribution, printing temperature was in second place and print speed was third.

From the research that has been carried out[6] conducted research on "Study of Nozzle and Base Plate Temperature Parameters on ABS Material as 3D Printer Raw Material on Surface Smoothness. In this research, three nozzle setting temperature parameters were used, namely 240˚C, 250˚C and 260˚C (single nozzle and dual nozzle), base plate temperature 30˚C and 100˚C and adhesive type with glue or without glue. From this research, the results showed that the best temperature for printing is a nozzle temperature of 240˚c and a base plate of 30˚c.

Based on the background and the four studies that have been carried out by predecessors, this research is to look at the influence of parameters on surface roughness and dimensional accuracy on 3D printing objects using the FDM principle. The process parameter used is temperature*Nozzles*, Print Speed, Bed Temperature. The material used is ABS filament. The method used is the Taguchi method experimental design.

II. The Proposed Method

The research stages carried out follow the flow diagram shown in Figure 2.1.

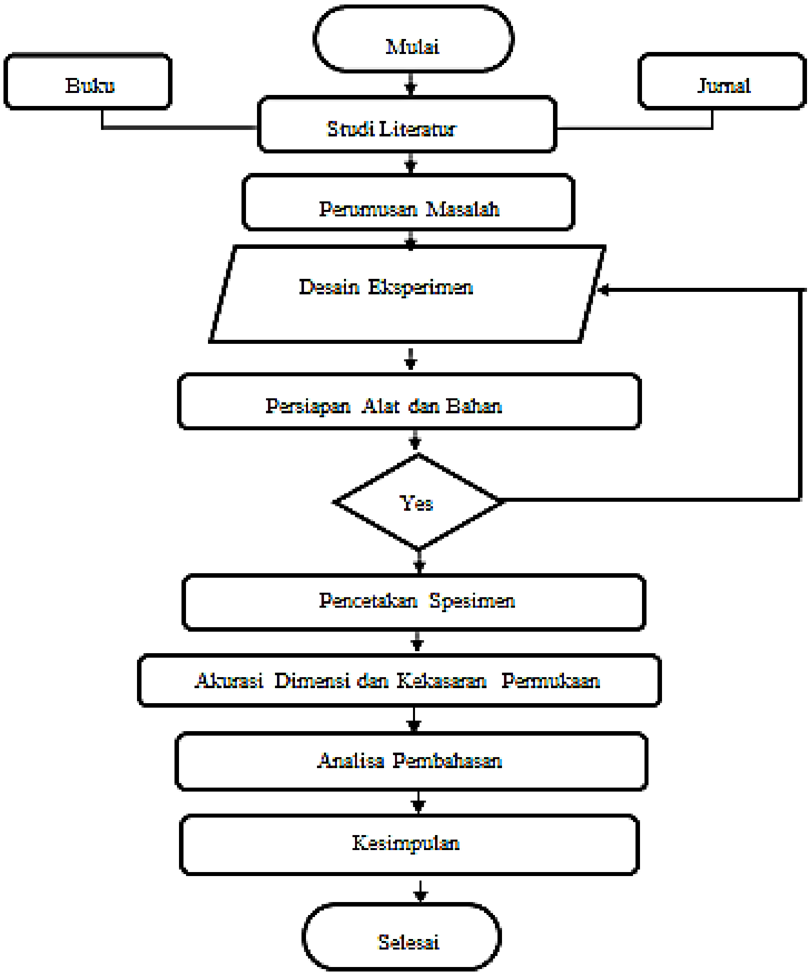

Figure 2.1 Research Flow Diagram

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III. Method

A. Literature Study

Literature study is a series of activities related to methods of collecting data by taking notes, reviewing literature or reading.

B. Place and Time of Research

a. The following is the place and time of research:
   1. The place where the research was carried out was in the Laboratory of the Department of Mechanical Engineering, Faculty of Engineering and Computers, Harapan University, Medan.
   2. The duration of the research is planned for six months starting from February to August 2023.

C. Research Materials and Tools

a. Research Materials. In this research the materials used are:

   1. SUNLU ABS plastic material with a diameter of 1.75 mm. Shows the specifications of the filament used in the research. ABS Filament (*Acrylonitrile Butadiene Styrene) is one of the most widely used materials for 3D printer filaments. The choice of this material is not without reason, firstly because it is stable against temperature and exposure to chemicals. In addition, it is very durable and can be easily cleaned by evaporation of acetone.*

b. Research Tools. In this research, the tools used in making specimens were:

   1. The 3D Printer machine used is a Creality Ender 3 V2 Printer with an XYZ priting area of 235×235×250 mm. This type of printer is FDM (Fused Deposition Modeling) whose process is capable of printing objects that are exactly the same as the image that has been designed.

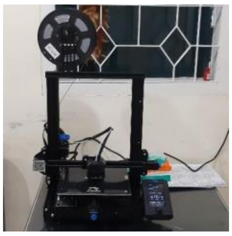

Figure 3.1 Creality Ender 3 V2 3D Printing Machine

   2. The laptop used is an ASUS X441M model used to run Auto CAD software, Creality Slicer and data analysis software.

   3. Dimensional Accuracy Test Equipment. This tool refers to dimensional accuracy in 3D printing.

   4. Surface Roughness Test Equipment. This tool is a tool for measuring specimen surface roughness. The roughness test tool used is the Mitutoyo SJ-210 surface roughness tester.

   5. *AutoCAD 2020 Software. Software*it is used to design the specimen to be printed and tested. How to use this software so that it can be read by Crelity Slicer software by moving the AutoCAD Drawing file format (Dwg) to the destination file format, namely STL (StereoLithography). After transferring the file, the 3D object can be read by Crelity Slicer software.

   6. *Creality Slicer Software 4.2.8. Software*This is used to enter

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parameters and get G-code and run the 3D Printing machine.

7. *Minitab Analysis Software. Software*This is used to determine variations in parameters and factors that can influence variables in the Design of Experiment (DOE) method.

D. Experimental Design

a. Response Parameters. Response parameters are parameters that are influenced by process parameters during the experiment. The response parameter in this research is the tensile strength of the printed specimen expressed in Mpa.

b. Process Parameters. The process parameters that will be used in this research are Nozzle Temperature (237,240,245°C), Print Speed (42,45,50mm/s), Bed Temperature (92,100,105°C). The selection of process parameters in the form of factors and experimental levels was based on previous researchers who in this study used PLA (Polylactic Acid) filaments (BW Kurniawan., 2022). This research used a different type of filament material, namely ABS (Acrylonitrile Butadine Styrene) filament and used the Taguchi L9 design. Orthogonal Array with three factors and three levels. The parameter values and levels that have been determined and shown in Table 3.1 are as follows.

Table 3.1 Parameter Values and Levels

Factor	Parameter	Levels		
		1	**2**	**3**
A	Nozzle Temperature (°C)	237	240	245
B	Print Speed (mm/s)	42	45	50
C	Bed Temperature (°C)	92	100	105

E. Orthogonal Array (OA) Selection

Based on the number of process parameters and the number of levels used in this research, it is shown in Table 3.2. So you can determine the Orthogonal Array matrix used. The selection of an appropriate orthogonal matrix depends on the factor values and the number of level values for each level. Determining the number of factors and levels of factors will influence the total number of degrees of freedom used to determine the type of Orthogonal Array selected. The factorial design in this research was created using software. This research uses the Taguchi L9 Orthogonal Array (OA) method with 3 parameters and 3 levels.

Table 3.2 Orthogonal Arrays

Exp.	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1

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7	3	1	3
8	3	2	1
9	3	3	2

The experimental design that will be carried out can be seen in table 3.3

Table 3.3 Experimental Design

Exp.	Nozzle Temperature (°C)	Print Speed (mm/s)	Bed Temperature (°C)
1	237	42	92
2	237	45	100
3	237	50	105
4	240	42	100
5	240	45	105
6	240	50	92
7	245	42	105
8	245	45	92
9	245	50	100

F. Research Process

Figure 3.2 Research Process Diagram

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IV. Results and Discussion

A. Collection of Experimental Results Data

Data collection for this research was carried out by combining the process parameters found on the FDM 3D printing machine. The process parameters that are considered to influence the dimensional accuracy response are nozzle temperature (°C), print speed (mm/s), and bed temperature (°C). Table 4.1 shows the results of dimensional accuracy and surface roughness tests.

Table 4.1 Test results of cube dimensional accuracy and cube surface roughness

Exp.	Nozzle Temperature (°C)	Print Speed (mm/s)	Bed Temperature (°C)	Cube Dimensional Accuracy Test Value (mm)	Cube Surface Roughness Test Value (uM)
Specimen 1	237	42	92	20.06	1,717
Specimen 2	237	45	100	19.53	1,809
Specimen 3	237	50	105	19.62	2,955
Specimen 4	240	42	100	19.48	1,709
Specimen 5	240	45	105	19.54	1,726
Specimen 6	240	50	92	20.02	1,674
Specimen7	245	42	105	19.73	2,441
Specimen 8	245	45	92	19.62	2,159
Specimen 9	245	50	100	19.70	1,905

Based on table 4.1, it can be seen that the most optimal parameters for cube dimensional accuracy are specimen 1, in the initial parameters that have been tested from 9 specimens that are specimen 1 cube at nozzle temperature (237°C), print speed (42 mm/s), and at bed temperature (92°C) Obtaining dimensional accuracy test results (20.06mm), it can be concluded that specimen 1 obtained good cube dimensional accuracy test results. Meanwhile, looking at the parameter that has the most influence on the surface roughness of the cube, namely specimen 6, the initial parameters that have been tested from 9 specimens are specimen 3 cubes at nozzle temperature (240°C), print speed (50mm/s), and bed temperature (92° C) Obtaining Surface Roughness results (1.674 uM), it can be concluded that specimen 6 obtained optimal Surface Roughness test results.

Table 4.2 Hollow dimensional accuracy test results and hollow surface roughness

Exp.	Nozzle Temperature (°C)	Print Speed (mm/s)	Bed Temperature (°C)	Hol Dimensional Accuracy Test Value (mm)	Hollow Surface Roughness Test Value (uM)
Specimen 1	237	42	92	19.88	2,628
Specimen 2	237	45	100	19.92	2,831
Specimen 3	237	50	105	19.89	2,997
Specimen 4	240	42	100	19.90	2,943
Specimen 5	240	45	105	19.92	3,596

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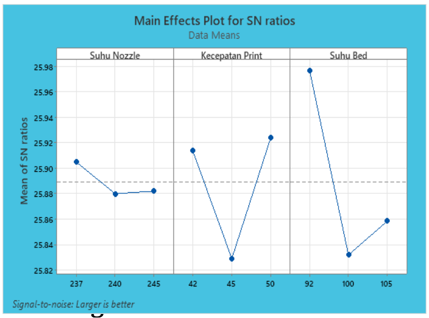
Specimen 6	240	50	92	19.95	3,186
Specimen7	245	42	105	19.93	3,551
Specimen 8	245	45	92	19.94	2,388
Specimen 9	245	50	100	19.94	3,068

Based on table 4.2, it can be seen that the most optimal parameters for Hollow dimensional accuracy are in specimen 6, nozzle temperature (240°C), print speed (50mm/s), and bed temperature (92°C). Based on the initial parameters that were tested from 9 specimens, the dimensional accuracy test results were obtained (19.95 mm), it can be concluded that specimen 6 obtained the optimal dimensional accuracy value. Meanwhile, looking at the parameters that have the most influence on Hollow surface roughness, namely specimen 8, in the initial parameters that have been tested from 9 specimens, specimen 5 Hollow is at nozzle temperature (245°C), print speed (45mm/s), and at bed temperature (92° C) obtained Surface Roughness results (2.388 uM), it can be concluded that specimen 8 obtained optimal Surface Roughness test results.

B. Calculation of S/N Ratio for Response



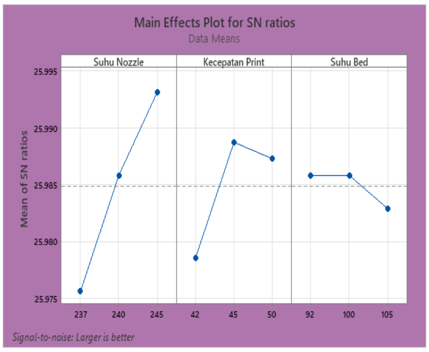


Figure 4.2.S/N Ratio Chart

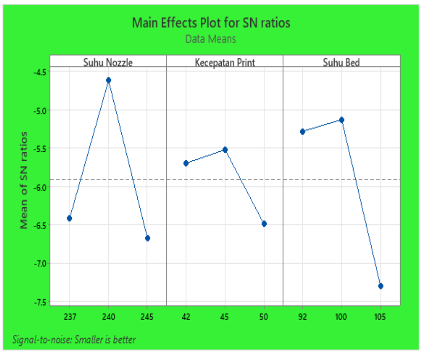


Figure 4.3. S/N Ratio Chart

Based on Figure 4.1, it can be seen that the most optimal parameters for dimensional accuracy are bed temperature (92°C), print speed (50mm/s), nozzle temperature (237°C), while the initial parameters that have been tested from 9 specimens are close to the parameters. This optimal is in the 7th specimen which has a dimensional accuracy of 19.73 (mm). The only parameters that differentiate are print speed and nozzle temperature. Meanwhile, the lowest parameter occurred in the 4th specimen with a dimensional accuracy value of 19.48 mm.

Based on Figure 4.2, it can be seen that the most optimal parameters for dimensional accuracy are Nozzle Temperature (245°C), Print Speed (45mm/s), bed temperature (92-100°), Meanwhile the initial parameters that have been tested from 9 specimens are close to This optimal parameter is in the 8th specimen which has a dimensional accuracy of 19.94 (mm). The only parameters that differentiate are print speed and bed temperature. Meanwhile, the lowest parameter occurred in the 1st specimen with a dimensional accuracy value of 19.88 mm.

Based on Figure 4.3, it can be seen that the most optimal parameters for dimensional accuracy are Nozzle Temperature (245°C), Print Speed (45mm/s), bed temperature (92-100°), Meanwhile the initial parameters that have been tested from 9 specimens are close to This optimal parameter is in the 8th specimen which has a dimensional accuracy of 19.94 (mm). The only parameters that differentiate are print speed and bed temperature. Meanwhile, the lowest parameter occurred in the 1st specimen with a dimensional accuracy value of 19.88 mm.

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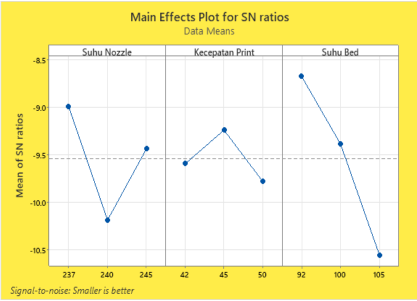

Figure 4.4. S/N Ratio Chart

Based on Figure 4.4, it can be seen that the most optimal parameters for surface roughness are bed temperature (92°C), print speed (45mm/s), nozzle temperature (237°C), while the initial parameters that have been tested from 9 specimens are close to the parameters. This optimum is in the 8th specimen which has a surface roughness of (2.388uM).

C. Data Confirmation/Verification Test

Table 4.3 Initial Combination

Initial Combination	Cube Dimensional Accuracy (mm)
Specimen 6	19.73

Table 4.4 Optimal Combination

Optimal Combination	Cube Dimensional Accuracy (mm)
Confirmation Test Specimen	19.68

Table 4.5 Initial Combination

Initial Combination	Hollow Dimensional Accuracy (mm)
Specimen 6	19.94

Table 4.6 Optimal Combination

Optimal Combination	Hollow Dimensional Accuracy (mm)
Confirmation Test Specimen	19.92

Based on tables 4.3 and 4.4, it shows that the dimensional accuracy value for the cube specimen in the initial combination is 19.73 mm and the optimal combination is 19.68 mm. there was a decrease in the optimal combination with a difference of 0.05 mm compared to the initial combination. And tables 4.5 and 4.6 show the results of dimensional accuracy for hollow specimens with the initial combination being 19.94, with the optimal combination being 19.92 mm, there is a decrease in the optimal combination with a difference of 0.02 mm compared to the initial combination. This decrease in the optimal combination is suspected to be due to temperature instability in the room during the process of printing the initial combination specimen with the optimal combination specimen.

Table 4.7 Initial Combination

Initial Combination	Cube Surface Roughness (uM)
Specimen 6	1,674

Table 4.8 Optimal Combination

Optimal Combination	Cube Surface Roughness (uM)
Confirmation	2,128

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Test Specimen

Table 4.9 Initial Combination

Initial Combination	Hollow Surface Roughness (uM)
Specimen 8	2,388

Table 4.10 Optimal Combination

Optimal Combination	Hollow Surface Roughness (uM)
Confirmation Test Specimen	2,483

Based on tables 4.7 and 4.8, it shows that the surface roughness value for the cube specimen in the initial combination is 1.674 uM and the optimal combination is 2.128. There was an increase in the optimal combination with a difference of 0.454 uM compared to the initial combination. And in tables 4.9 and 4.10, the surface roughness results for hollow specimens with the initial combination are 2.388 uM, with the optimal combination being 2.483, there is an increase in the optimal combination with a difference of 0.02 mm compared to the initial combination. 0.095 uM. This increase in the optimal combination is suspected to be due to temperature instability in the room during the process of printing the initial combination specimen with the optimal combination specimen.

V. Conclusion

From the results of experiments that have been carried out to obtain an optimization process using the Taguchi Method, in the research entitled "The Effect of 3D Printing Filament Heat on Surface Roughness and Dimensional Accuracy" it can be concluded that:

- The results of experiments using the Taguchi Method obtained optimal process parameter values for dimensional accuracy using ABS filament, namely Nozzle Temperature (245°C), Print Speed (50 mm/s), Bed Temperature (92°C).
- The parameters that have the greatest influence on dimensional accuracy using ABS filament are Nozzle Temperature (240°C), Print Speed (50 mm/s) and Bed Temperature (92°C). Meanwhile, for surface roughness, the parameters that have the greatest influence are Nozzle Temperature (245°C), Print Speed (50mm/s), and Bed Temperature (92°C).

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References

[1] Mahamood, S., Khader, M. A., & Ali, H. (2016). Applications of 3-D Printing in Orthodontics. A Review. D Printing, 3 (11) 4.
[2] Mohamed, O.A., Masood, S.H., & Bhowmik, J.L. (2015). Optimization of Fused Deposition Modeling Process Parameters: A Review of current research and future prospects. Advances in Manufacturing, 3(1), 42-53. http://doi.org/10.1007/s40436-014-0097-7.
[3] Taufik, I., Budiono, HS, Herianto, H., & Andriyansyah, D. (2020). The Effect of Printing Speed on the Surface Roughness Level of Additive Manufacturing Results with Polylactic Acid Filament. Journal of Mechanical Engineering, 4(2). https://doi.org/10.31002/.v4i2.3412.
[4] Karuniawan, BW, Rachman, F. & Setiawan, AA, (2019). Optimization of Fused Machine Parameters DepositionModeling (FDM) of Product Surface Roughness UseMethod Taguchi. Techno Bahari, 6(2), pp. 23-29.

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DOI:https://doi.org/10.35447/jitekh.v1i1

[5] Sahputra, B., Hakim, R. & Saputra, I., 2018. Study of Nozzle and Base Temperature Parameters Plates on ABS Material as Raw Material for 3D Printers on Smoothness Surface. pp. 1-10.
[6] Pristiansyah, P., Hasdiansyah, H., & Sugiyarto, S. (2019). Optimization of FDM 3D Printing Process Parameters for Dimensional Accuracy Using Eflex Filament. Manutech: Journal of Manufacturing Technology, 11(01), 33-40. https://doi.org/10.33504/manutech.v11i01.98.
[7] Kumar, S., Panda, A. K., & Singh, R. K. (2011). A Review on Tertiary Recycling of High-Density Polyethylene to Fuel. Resources, Conservation and Recycling Vol. 55 893-910.
[8] (Kuswanto, 2017) & Basavaraj, CK, and Vishwas, M. (2016). Zailani Hamzah1 , Pristiansyah2, Dedy Ramdhani3 1,2,3 Department of Mechanical Engineering, Manufacturing Polytechnic Bangka Belitung State zhyhamzah9@gmail.com.
[9] Achillas, C. A. (2014). A methodological framework for the inclusion of modern additive manufacturing into the production portfolio of a focused factory. Journal of Manufacturing Systems.
[10] Andy , O. S. (2019). 3D Printing Machine Operation. Surakarta: Indonusa Surakarta Polytechnic.
[11] Craftcloud. (2022, December 10). Dimensional accuracy. Retrieved July 23, 2023, from https://all3dp.com/2/3d-printer-dimensional-accuracy/.
[12] Nugroho, A., & Ardiansyah, R. (2018). Making LSU (Lapan Surveillance Uav) Components Using a 3D Printer. Aerospace News.
[13] Russianto, T., Saiful, H., & Hary, W. (2019). Types and Printing of 3D Printing for Prototyping. Journal of the AKPRIND Yogyakarta Institute of Science & Technology, 12 (1), 14-21. https://ejournal.akprind.ac.id/index.php/jurtek/artice/view/2156.
[14] Ross, P. J. (2008). Taguchi Techniques for Quality Engineering. Taiwan: McGraw-Hill Companies. Inc.
[15] Saputra, TH, Hutama, AS, Ningsih, A. and Pamasaria, HA (2022) "Analysis 3D Printing Parameters Fdm Type on Dimensional Accuracy with Filament Made from Recycled Low Density Plastic Polyethylene (LDPE) and Polypropylene (PP)",*Sebatik*, 26(1), pp. 9-16. doi:https://doi.org/10.46984/sebatik.v26i1.1682.
[16] Shears, A. (2016). 3D Printer Raised Relief/Topographic Maps: A Cartographically Sound Method.
[17] Soejanto, I. (2009). Experimental Design with the Taguchi Method. Yogyakarta: Graha Ilmu.
[18] Sarah , S. (2018). Reducing High Porosity and Impairing Sealing Properties in Extrusion-Bed 3D Printing. Science & Technology.
[19] Sunyapa, B., 2016. CNC milling process variance analysis of steel surface roughness 41with the Taguchi method. jember: university of jember
[20] Ultimaker. (2017). Ultimaker 3 Installation and User Manual.