ISSN 2355-0082

Optimization of Process Variables in 3D Printing on Dimensional Accuracy Using Nylon Filaments

Optimasi Variabel Proses Pada 3D Printing Terhadap Akurasi Dimensi Menggunakan Filamen Nylon

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Accepted 17 December 2021
Approved 06 April 2022

Abstract—Manufacturing process over the past 50 years has led to very rapid and continuous progress in the manufacturing industry, one of the manufacturing processes that has progressed is 3D printing technology. The type of filament used in this research is nylon filament. This study aims to obtain optimal process parameters for dimensional accuracy. The method used in this study is the Taguchi L_{27} OA method. The process parameters used are nozzle temperature, bad temperature, layer thickness, flowrate, printing speed, overlap, infill density, infill speed, wall thickness. The results showed that the optimal process parameters are nozzle temperature(256°C), bad temperature(96°C), layer thickness(0.2mm), flowrate(90%), printing speed(30mm/s), overlap (10%),

Keywords: 3D printing; Accuracy; Dimensions; Nylon; Parameter;

Over the last 50 years, the manufacturing process has resulted in rapid and continuous progress in the manufacturing industry [1]. One of the progressive manufacturing processes is 3D printing technology, which is rapidly developing in the manufacturing industry [2]. 3D printing has numerous applications, one of which is the production of finished products such as mugs and bowls of various shapes. However, it has a flaw in the product printing process that is related to dimensional accuracy in this case. As a result, the final product is still not in accordance with the desired design because the product's size has decreased or increased in comparison to the desired size. In connection with these shortcomings, it is necessary to have the right process parameters on a 3D printer to get a product or printout with good dimensional accuracy. [3].

Several studies on the process parameters of this 3D printer have been carried out by researchers. Research on the effect of process parameters on tensile strength and dimensional accuracy using nylon filament using the Taguchi L9 OA method shows that the most influential process parameter on dimensional accuracy is Layer thickness [4]. The best process parameters use a nozzle temperature of 90℃, bed temperature of 55℃, and a layer thickness of 0.2 mm [3]. Research on the effect of process parameters on dimensional accuracy using nylon filaments obtained the parameters that most affect the response to the dimensional accuracy of 3D printing nylon 6 products showing different results on the four dimensions, layer thickness parameter is the most influential factor on the response of LO and WO dimensions with the value of the percent contribution of 42.0802% and the value of the percent contribution of WO is 18.9439% while for the dimensions w and T the most influential parameters are generated by the nozzle temperature parameter with the contribution value of w of 60,1022% and the value of the contribution of T of 43.3853% [5]

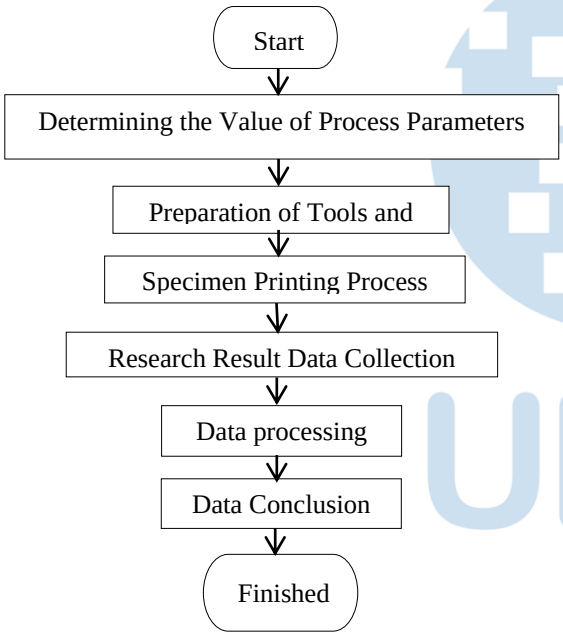
Research on the effect of process parameters on dimensional accuracy using PLA filaments shows that to achieve good dimensional accuracy, a smaller layer thickness is needed, a lower extrusion temperature and infill percentage, and a hexagonal infill patter [6]. Dimensional accuracy research using filament Eflex the most dominant parameter is layer thickness from parameter settings flowrate, layer thickness, nozzle temperature, printing speed, overlap, and fan speed [7].

According to the research, this study was carried out to optimize the 3D process parameters by focusing on nine process parameters, namely Nozzle

Temperature(°C), Bed Temperature(°C), Layer Thickness(mm), Wall Thickness (mm), Flowrate(percent), Print Speed(mm/s), overlap(percent), infill density(percent), infill speed(mm/s) with Taguchi L27 OA method using nylon filament for dimensional accuracy. Using predetermined process parameters, this study aims to obtain the most optimal process parameters for dimensional accuracy of nylon nylon filament

METHOD

This study uses nylon filament because it has the advantages of being strong and flexible, high impact resistance, does not cause unpleasant odors when printing, and has high abrasion resistance, so it will be very good if used for ready-to-use products. With the experimental method used to obtain the most optimal process parameters for dimensional accuracy. The stages of the research process are shown in the flow chart in Figure 1.



Picture 1 Research Flowchart

1.1 Determining Process Parameters

The process parameters consist of experimental factors and levels, the selection of these factors and levels is based on a literature review. The factors used in this research are Nozzle Temperature(°C), Bed Temperature(°C), Layer Thickness(mm), wall thickness (mm), Flow rate(%), Print Speed(mm/s), overlap(%), infill density (%), and infill speed (mm/s), as well as the level used can be seen in Table 1.

Table 1 Level Value and Process Parameter

Code	Factor	Level		
		1	2	3
A	Nozzle Temperature(°C)	256	258	260
B	Bed Temperature(°C)	95	98	100
C	Flowrate(%)	90	95	100
D	Printing Speed(mm/s)	25	30	35
E	Layer Thickness(mm)	0.2	0.24	0.28
F	Wall Thickness (mm)	0.8	1.0	1.2
G	Overlap(%)	5	10	15
H	Infill Density(%)	20	25	30
I	Infill Speed(mm/s)	20	25	30

After the level values and process parameters are determined, the next step is to design the factorial of the Taguchi L27 OA (Orthogonal Array) method using analysis software. The results of the factorial design are presented in Table 2.

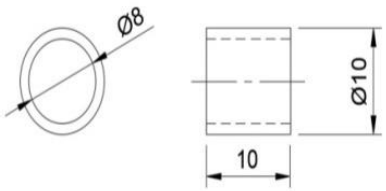
Table 2 Taguchi L27 OA Factorial Design

No	A	B	C	D	E	F	G	H	I
1	256	90	0.20	90	30	5	20	25	0.8
2	256	90	0.20	90	35	10	25	30	1.0
3	256	90	0.20	90	40	15	30	35	1.2
4	256	95	0.24	95	30	5	20	30	1.0
5	256	95	0.24	95	35	10	25	35	1.2
6	256	95	0.24	95	40	15	30	25	0.8
7	256	100	0.28	100	30	5	20	35	1.2
8	256	100	0.28	100	35	10	25	25	0.8
9	256	100	0.28	100	40	15	30	30	1.0
10	258	90	0.24	100	30	10	30	25	1.0
11	258	90	0.24	100	35	15	20	30	1.2
12	258	90	0.24	100	40	5	25	35	0.8
13	258	95	0.28	90	30	10	30	30	1.2
14	258	95	0.28	90	35	15	20	35	0.8
15	258	95	0.28	90	40	5	25	25	1.0
16	258	100	0.20	95	30	10	30	35	0.8
17	258	100	0.20	95	35	15	20	25	1.0
18	258	100	0.20	95	40	5	25	30	1.2
19	260	90	0.28	95	30	15	25	25	1.2
20	260	90	0.28	95	35	5	30	30	0.8
21	260	90	0.28	95	40	10	20	35	1.0
22	260	95	0.20	100	30	15	25	30	0.8
23	260	95	0.20	100	35	5	30	35	1.0
24	260	95	0.20	100	40	10	20	25	1.2
25	260	100	0.24	90	30	15	25	35	1.0
26	260	100	0.24	90	35	5	30	25	1.2
27	260	100	0.24	90	40	10	20	30	0.8

In Table 2 it is used for the G-code manufacturing process and then used for printing dimensional accuracy test specimens. This specimen will be printed with three replications for each specimen.

1.2 Preparation of Tools and Materials

The tools used in this research are the Anycubic 4max 3D Printing machine which is used to print test specimens, the Asus brand laptop which is used to run the software that will be used in the research, the slicing software to get the G-code, dry box filament is used to dry the filament during the experiment. the printing process, a micrometer with an accuracy of 0.001 mm was used to measure the test specimen, and the material used was nylon filament with a diameter of 1.75mm and black.



Picture 2 Dimensions and Shape of Test Specimen

1.3 Object of research

The object of research carried out on a 3D printer is a specimen with object dimensions10mm x 10mm as shown in Figure 2. Specimen Designusing CAD software in STL format then processed in slicing software to get G-code which will be saved to the SD card and then inserted into the 3D printer

1.4 Product Dimension Measurement

Printed specimens are measured to determine the dimensional accuracy of the finished product. Measurement of the dimensions of this specimen using a micrometer with an accuracy of 0.001 mm. The dimensions measured are the Outside Diameter of the Specimen with measurements at three different points.

2. RESULTS AND DISCUSSION

The results of printing specimens with three replications in each specimen using the Taguchi L27 OA factorial design method in Table 2 will be shown in Figure 3.

Figure 3 Printed Specimens

The specimen from this printing was measured for the accuracy of the dimensions of the outer diameter of the specimen, which was 10mm with the measurement positions at three different points using a micrometer with an accuracy of 0.001 and the results of the position measurements were averaged which will be shown in Table 3 which will then be processed in the analysis software.

Table 3 Results of Measurement of the Outside Diameter of the Specimen

EXP. No.	Outside Diameter			
	Preliminary data	Replication 1	Replication 2	Average
1	9,806	9,834	9,834	9,834
2	9,793	9,799	9,799	9,799
3	9,742	9,813	9,813	9,813
4	9,922	9,887	9,887	9,887
5	9,928	9,871	9,871	9,871
6	9,952	9,893	9,893	9,893
7	9,981	9,929	9,929	9,929
8	9,984	9,914	9,914	9,914
9	9,953	9,924	9,924	9,924
10	9,958	9,967	9,967	9,967
11	9,971	9,968	9,968	9,968
12	9,982	9,962	9,962	9,962
13	9,985	9,991	9,991	9,991
14	9,986	9,982	9,982	9,982
15	9,911	9,985	9,985	9,985
16	9,965	9,977	9,977	9,977
17	9,975	9,967	9,967	9,967
18	9,966	9,976	9,976	9,976
19	9,976	9,986	9,986	9,986
20	9,985	9,972	9,972	9,972
21	9,943	9,970	9,970	9,970
22	9,944	9,978	9,978	9,978
23	9,927	9,972	9,972	9,972
24	9,950	9,969	9,969	9,969

25	9,988	9,974	9,974	9,974
26	9,966	9,956	9,956	9,956
27	9,979	9,967	9,967	9,967

The Taguchi method is used to process measurement data in order to obtain optimal process parameters that affect the dimensional accuracy test results. The data is processed using analysis software in which the values in Table 3 are entered, and the measurement data is entered into the analysis software to obtain the Mean Plot and S/N Ratio results with "smaller is better" quality because the smaller the deviation, the better the dimensional accuracy.

Figure 4 and Table 4 show the results of the analysis software calculation on the accuracy of the dimensions of the outside diameter of the specimen, while Figure 5 and Table 5 show the S/N Ratio.

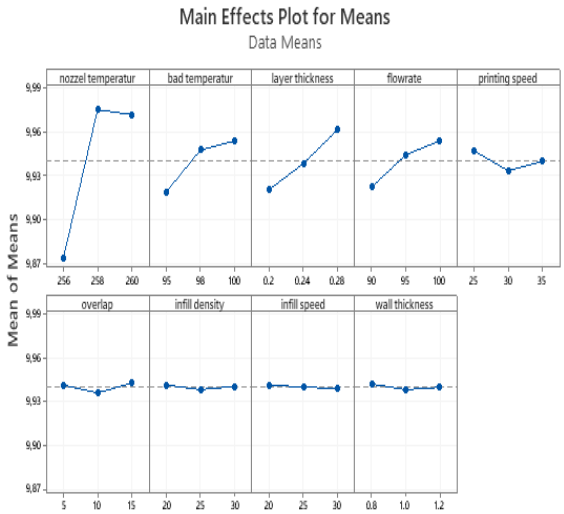


Figure 4 Graph of the Mean Plot Outer Diameter of the Specimen

Table 4 Results Mean Plot Outside Diameter of Specimen

Response Table For Mean					
Factor	Level			Delta	Rank
	1	2	3		
A	9,874	9,975	9,972	0.101	1
B	9,919	9,948	9,954	0.035	3
C	9,921	9,938	9,961	0.041	2
D	9,922	9,944	9,954	0.031	4
E	9,947	9,933	9,940	0.014	5
F	9,941	9,936	9,943	0.007	6
G	9,941	9,938	9,941	0.003	8
H	9,941	9,940	9,939	0.002	9
I	9,942	9,938	9,940	0.004	7

Figure 5 Graph of S/N Ratio of Specimen Outside Diameter

Table 5 S/N Ratio Outside Diameter of Specimen

Respons Table For Signal to Noise Ratios					
Factor	Level			Delta	Rank
	1	2	3		
A	-19.89	-19.98	-19.98	0.09	1
B	-19.93	-19.95	-19.96	0.03	3
C	-19.93	-19.95	-19.97	0.04	2
D	-19.93	-19.95	-19.96	0.03	4
E	-19.95	-19.94	-19.95	0.01	5
F	-19.95	-19.94	-19.95	0.01	6
G	-19.95	-19.95	-19.95	0.00	8
H	-19.95	-19.95	-19.95	0.00	9
I	-19.95	-19.95	-19.95	0.00	7

Based on Figure 6 and Table 5 the value of the S/N Ratio with “smaller is better” quality indicates that the optimal parameter values and successively affect the accuracy of the dimensions of the outer diameter of the printed object specimen, namely nozzle temperature (256°C), layer thick ness(0.2mm), bad temperature(96°C), flowrate(90%), printing speed(30mm/s), overlap(10%), wall thickness (1.0mm), infill density(25%), and Infill speed(30mm/s).

3. CONCLUSION

Based on the results of the measurement of the outer diameter of the printed object specimen in Table 3 and the results of the analysis software data processing, it can be concluded that the optimal process parameter values for the accuracy of the dimensions of the outer diameter of the specimen are nozzle temperature (256°C), bad temperature (96°C), layer thickness(0.2mm), flowrate(90%), printing speed(30mm/s), overlap(10%), infill density(25%),

and Infill speed(30mm/s), and wall thickness (1.0mm).

For further research, it can be added or used more process parameters and levels, because the more parameters or levels used, the optimal parameter values for dimensional accuracy found, the better.

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