Journal of Engineering Technology and Applied Physics

Influence of Process Parameters on Rapid Prototype Part Using Response Surface Methodology

Chockalingam Palanisamy[1,*], Natarajan Chinnasamy[2] and Karthikeyan Muthu[3]
[1]*Faculty of Engineering and Technology, Multimedia University, 75450 Melaka, Malaysia.*
[2]*Department ofMechanical Engineering, Hindustan Institue of Technology, Coimbataore 641028, India.*
[3]*Department of Mechanical Engineering, Raja Rajeswari College of Engineering, Bangalore 560074, India.*
[*]palanisamy.chockalingam@mmu.edu.my
https://doi.org/10.33093/jetap.2019.1.1.2

***Abstract* - In this research the influencing process parameters on fused deposition modelling of Acrylonitrile Butadiene Styrene (ABS) parts were studied. The two process parameters, layer thickness and model interior fill style are studied. The specimens were built, tests carried out to find out the surface roughness quality of the specimens. The results analyzed using Response Surface Methodology (RSM). The result indicates that the specimen Type 1 with the 0.254 mm layer thickness and solid model interior fill style is the best specimen among the types of specimens tested.**

Keywords—Rapid prototyping, surface roughness, response surface methodology

I. Introduction

The rapid prototyping is commonly used today because it helps to reduce the time and cost on design and build of the prototype model and it becomes an alternative way that people prefer instead of other model production [1]. Fused Deposition Modelling (FDM) is solid-typed rapid prototyping system, it is an extrusion-based and widely used. Nowadays, appearance is apparently important to a product in order to attract customers [2]. Surface quality normally influences by the process parameters [3]. Therefore, surface roughness is one of the factors that might affect the appearance of a product. For a good surface finish of prototype, there is no or less post-processing stage needed in the building process. However, there are certain things that might influence the surface roughness of the prototype.

Anitha, *et. al.* [1] studied the effect of parameter towards the surface roughness of the prototype model such as signal and noise ratio, ANOVA analysis, correlation analysis, and regression analysis to get the result. They used three parameters as their inputs which are layer thickness, road width, and the speed. From the results, they concluded that the layer thickness is the factor that affects the most to the surface roughness. Nuneza *et. al.* [4] experimented the FDM using two parameters such as layer thickness and model interior fill style to determine the quality of the prototype model that made of ABS. From the experiment results, they concluded that the smaller layer thickness and the high density of the model interior fill style produced the best finishing surface of the prototype model.

Galantucci *et. al.* [5] studied FDM of prototype surface roughness by varying diameter, raster width and layer thickness and they concluded that the layer thickness is the main reason that affect the surface finish. According to Alberto Boschetto and Luana Bottini [6] the surface roughness of finishing barrel made by FDM by varying three process parameters namely, layer thickness, the deposition angle, and the material removed from the barrel finishing stage. There are several reasons such as layer thickness and model interior fill style that will affect the quality of the prototype part. Therefore, in this research different types of specimens with combination of process parameters such as layer thickness and model interior fill style. The specimens were tested for the quality of the specimens.

II. Material and Methodology

The Dimension 1200SST is used as the rapid prototyping machine. Figure 1 shows the Dimension SST1200es rapid prototyping machine. Table 1 shows the experiment plan designed using design of experiment response surface methodology. The design suggests 9 types of combination of parameters for specimen fabrication. The prototypes are fabricated in different run in order to avoid systematic error. The part is designed using Solidworks 3D modelling software, the file transferred into the Catalyst EX software to convert STL output for rapid prototyping. The RP machine made the prototype part with ABS material with the size of length of 20 mm, width of 15 mm and height of 10 mm. Parts are cleaned then using Mahr Surface Profilometer the surface roughness of the prototypes are measured. The data analyzed using Mintab15 software.

Published by MMU PRESS. URL: https://journals.mmupress.com/index.php/jetap/index

Fig. 1. Dimension SST 1200es Rapid Prototyping Machine.

Table 1. Process parameter for specimens.

Type	Layer thickness (mm)	Model Interior Fill style
1	0.254	Solid
2	0.254	Sparse high density
3	0.254	Sparse low density
4	0.292	Solid
5	0.292	Sparse high density
6	0.292	Sparse low density
7	0.33	Solid
8	0.33	Sparse high density
9	0.33	Sparse low density

III. Results and Discussion

The measured surface roughness of the specimens are given in Table 2 and Fig. 2 shows the results of surface roughness of the specimens. The contour graph consists of roughness average value (Ra), layer thickness and model interior fill style.

Table 2. Result of surface roughness testing.

Type	Layer Thickness (mm)	Model Interior Fill Type	Roughness Average (µm)
1	0.254	Solid	5.460
2	0.254	Sparse High Density	6.875
3	0.254	Sparse Low Density	8.323
4	0.292	Solid	9.310
5	0.292	Sparse High Density	9.510
6	0.292	Sparse Low Density	8.430
7	0.330	Solid	11.87
8	0.330	Sparse High Density	13.65
9	0.330	Sparse Low Density	9.530

From Table 2, those types with the same layer thickness but different model interior fill style were observed and compared. The specimen Type 1, 2, and 3 have the same layer thickness but different model interior style which are solid, sparse high density and sparse low density. From those 3 types of specimens, specimen Type 1 has the smoothest surface as it has the lowest value for roughness average which is 5.46 µm. However, the surface of specimen Type 3 has the roughest surface with the roughness average at 8.323 µm. From the result, it shows that the surface roughness of the specimen is depending on the model interior fill style. The higher value of the density of specimen with lower value of roughness average has smoother surface of specimens.

However, the result is not same for the specimens with layer thickness of 0.292 mm and 0.330 mm. The specimens Type 4, 5, and 6 have the same layer thickness value which is 0.292 mm but different model interior fill style. The specimen Type 6 with the sparse low density has the smoothest surface and the value of the roughness average is 8.43 µm. Specimen Type 5 with the sparse high density has the roughest surface and the value of roughness average of the specimen is 9.51 µm. Moreover, this result is same with the specimens that have layer thickness of 0.330 mm. The specimen Type 9 that has sparse low density has the smoothest surface among those three specimens. On top of that, the model interior fill style of specimen Type 8 that has the roughest surface is sparse high density. This situation might be causing by some reasons.

On top of that, the result was compared for the specimens that have the same model interior but different layer thickness. For the specimens Type 1, 4, and 7 have the same model interior fill style which is solid but they had different layer thickness values. From the result, it shows that the specimen Type 1 that with 0.254 mm has the smallest value of roughness average while the specimen Type 7 with 0.330 mm layer thickness has the highest value of roughness average. The data shows that the specimen with smaller layer thickness has smoother surface. This result is same with the group of specimens that have sparse high density and sparse low density.

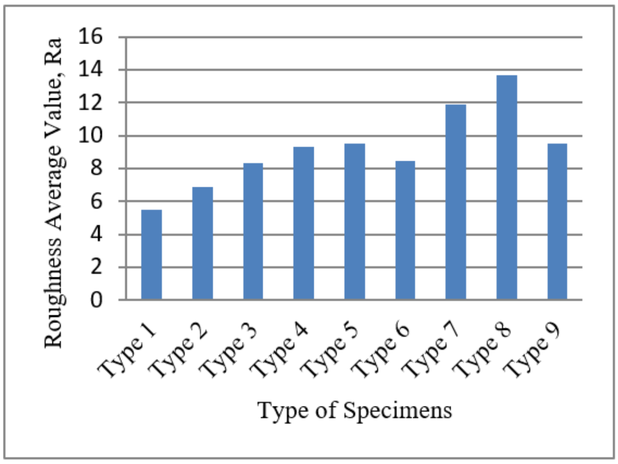

Fig. 2. Result of surface roughness.

A. Minitab Analysis

After the results are collected, the data are fed into the Minitab software to analysis the result. The Minitab helped to analysis the variance of the measured data and the relationship between two factors which are layer thickness and model interior fill style. Figure 3 is the contour graph which is a dimensional graph that consists of three experiment testing result. Minitab Analysis of Variance (ANOVA) is used to process results. Analysis of variance is a collection of statistical models used to analyze the differences among group means and their associated procedures [7]. Table 3 below is the table of Analysis of Variance for surface roughness testing.

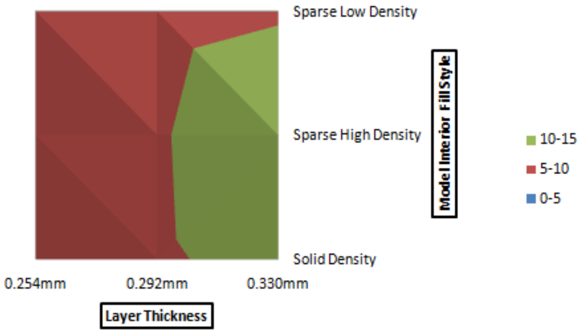

Fig. 3. Contour graph of surface roughness.

Table 3. Analysis of variance for surface roughness testing.

Source	Degree of Freedom	Sequence Sum of Square	Adjusted Sum of Square	Adjusted Mean Square	F	P-value
Regression	5	44.23	44.23	8.85	7.23	0.06
Linear	2	34.54	34.54	17.27	14.11	0.03
Square	2	2.92	2.92	1.46	1.19	0.42
Interaction	1	6.77	6.77	6.77	5.53	0.10
Residual Error	3	3.67	3.67	1.22		
Total	8	47.90				

From the Table 3, the P-value and α-value were to be considered and they are important to clarify the relationship of the two factors which are layer thickness and model interior fill style. The α-value was set 0.05 as the standard value.When P-value is less than or equal to the α-value, then the null hypothesis will be rejected, and the result is statistically significant. On the other hand, if the P-value is greater than α-value, then the null hypothesis will be accepted, and the result is statistically non-significant. For the linear, the P-value is smaller than α-value which meant that the two factors were affecting the result of the surface roughness testing. On top of that, the P-value for interaction is 0.1 which is greater than 0.05. This situation shows that the relationship between layer thickness and model interior fill style is independent and they did not affect each other.

Figure 4 shows the normal probability plot graph of surface roughness testing. The normal probability plot graph helps to determine whether the data is approximately normally distributed. When the data is normally distributed, the points of data should form an approximately straight line. From the Figure 4 above, the graph indicated the points form an approximately straight line. Therefore, the data is good and reliable.

Figure 5 shows that the residual versus fits graph of surface roughness testing. The residual versus fits graph is the graph that shows the distance of the 9 points and the theoretical straight line. For this graph, the 9 points must be inside the range of -3 and 3 for the standardized residual in order to count as reliable result that has fewer errors. From the Figure 5, it shows that, all the 9 points are in the range of -3 and 3 and they are count as reliable result. Next, the residual versus fits graph also indicates that the specimen Type 1 has the smoothest surface.

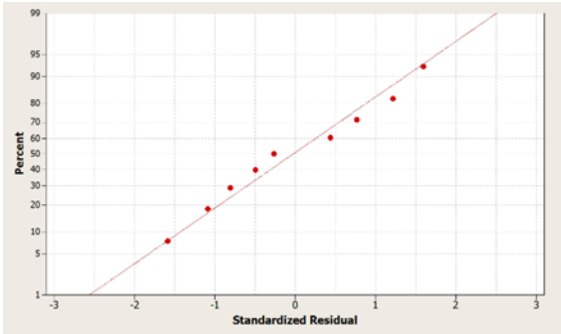

Fig. 4. Normal probability plot graph of surface roughness.

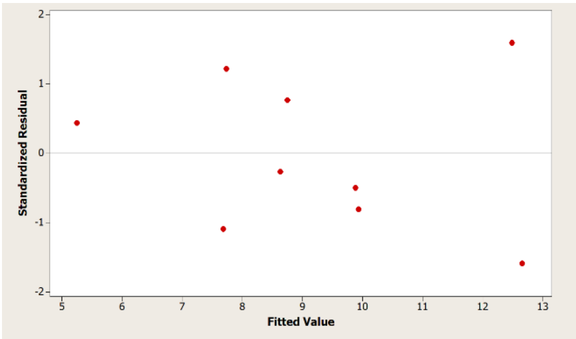

Fig. 5. Residual versus fit graph of surface roughness.

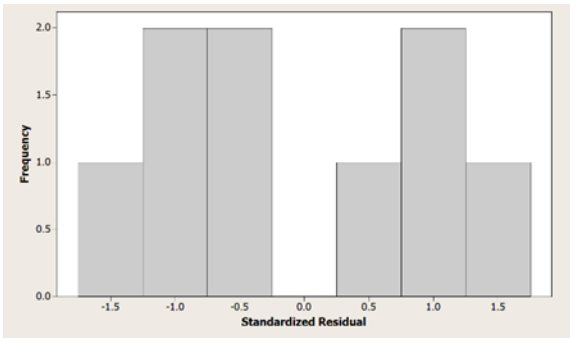

Fig. 6. Histogram chart of the surface roughness.

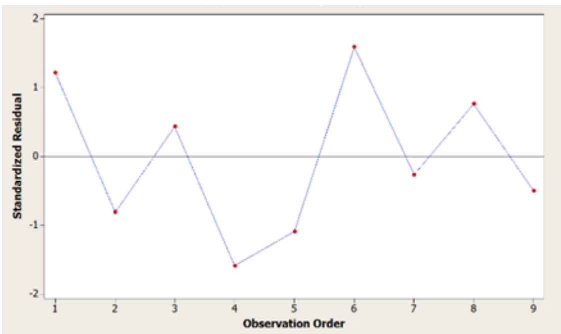

Fig. 7. Residual versus order chart of the surface roughness.

Figure 6 shows the histogram chart of the surface roughness testing. This graph is simply indicating that the amount of points in the range of the standardized residual of the versus fits graph. Figure 7 shows the residual versus order chart of the surface roughness testing. This graph indicate the order of types and the distance between the points and the theoretical line. From the graph, it shows that the specimens Type 7 has the shortest distance toward the theoretical line which means that it has the least error.

IV. Conclusion

Fused deposition modelling prototype made with varying process parameters is studied to determine the influencing process parameters that will affect the quality of the rapid prototype parts. Surface roughness of the prototype parts measured to test the quality of the specimens with influencing factors layer thickness and model interior fill style. The specimen Type 1 (0.254 mm and solid fill) has the smoothest surface with the lowest roughness average.

References

[1] R. Anitha, S. Arunachalam and P. Radhakrishnan, "Critical parameters influencing the quality of prototypes in fused deposition modelling," *J. Mater. Process. Technol.*, vol. 118, no. 1–3, pp. 385–388, 2001.

[2] A. Boschetto and L. Bottini, "Robotics and Computer-integrated Manufacturing Design for manufacturing of surfaces to improve accuracy in Fused Deposition Modeling," *Robot. Comput. Integr. Manuf.*, vol. 37, pp. 103–114, 2016.

[3] V. Mugendiran, A. Gnanavelbabu and R. Ramadoss, "Parameter optimization for surface roughness and wall thickness on AA5052 aluminium alloy by incremental forming using response surface methodology," *Procedia Eng.*, vol. 97, pp. 1991–2000, 2014.

[4] P. J. Nuñez, A. Rivas, E. García-Plaza, E. Beamud and A. Sanz-Lobera, "Dimensional and surface texture characterization in Fused Deposition Modelling (FDM) with ABS plus," *Procedia Eng.*, vol. 132, pp. 856–863, 2015.

[5] L. M. Galantucci, F. Lavecchia and G. Percoco, "Experimental study aiming to enhance the surface finish of fused deposition modeled parts," *CIRP Ann. - Manuf. Technol.*, vol. 58, no. 1, pp. 189–192, 2009.

[6] Boschetto and L. Bottini, "Roughness prediction in coupled operations of fused deposition modeling and barrel finishing," *Journal of Material Processing Technology*, vol. 219, pp. 181–192, 2015.

[7] P. Chockalingam, C. K. Kok, and T. R. Vijayaram, "Parametric study on grindability of GFRP laminates using different abrasives," *International Journal of Mechanical, Aerospace, Industrial and Mechatronics Engineering*, vol. 7, pp. 685-690, 2013.