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Mechanical properties of commercial PLA filament as 3D printed parts utilizing fused filament fabrication

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Abstract. In the field of Additive Manufacturing, Fused Filament Fabrication (FFF) is one of the methods used for prototyping and production applications. However, the performance of the printed parts produced can be affected by the various parameters used. The purpose of this research is to evaluate the bonding between layers of 3D printed parts from 3D printer by using Polylactic Acid (PLA) with printing parameters, namely printing temperature, printing speed and raster angle. The specimens were printed by using Monoprice Maker Select 3D printer. Compression test and fatigue test were carried out to determine the behavior of true stress-strain and the lifespan of sample subjected to cycling loading. The influence of printing temperature, printing speed and raster angle is determined by using Analysis of Variance (ANOVA). The results show that printing temperature affect the bonding between layers of samples more than the printing speed and raster angle.

1. Introduction

Manufacturing has dependably been tied in with handling crude material into segments or parts that can be collected into utilitarian products. Different inquiries about have been done to additionally enhance the numerous parts of ordinary assembling, for example, materials, feasibility, process optimization, and sustainability [1]-[4]. Fused Filament Fabrication (FFF) is an additive manufacturing which combined individual layer of extruded thermoplastic filament into a 3D geometry form [5]-[8]. It is a complex process with a large number of processing parameters. The combination of these parameters which influence product quality and material properties is difficult to understand [9, 10]

Polylactic Acid (PLA) will be utilized for the technique that specifically manage a thermoplastic polymer through spout since Polylactic acid is other printable material besides has mechanical properties altogether greater than utmost different plastics [11], [12] and it is appropriate eco-accommodating choices of effectively existing polymers and in addition growing amazing failure rate polymers which have aggressive execution things from feed stocks that are accessible from inexhaustible stock properties [13]. Generally, the bonding molten polymer is controlled by a diffusion progression which is reliant on the temperature also contact pressure in the bonding zone, as well as time allowed for diffusion to take place. Given that bonding in the FFF method happens on ambient pressure, it acts which printing is major influence evolving bond strength. On the other hand, temperature difference too shows a foremost character. Therefore, this study on printing parameter in example printing temperature, printing speed and raster angle is conducted to investigate their effect on the mechanical properties of the printed parts.”



2. Methodology

The material that used is polylactic acid (PLA). Polylactic acid is a thermoplastic, which means can be transform into molten in its melting point of 150°C to 160°C . Monoprice Maker Select 3D printer is used to print out the samples which are 18 samples of Model 1 and 54 samples of Model 2. Figure 1 shows the sample of Model 1 and Figure 2 shows the sample of Model 2. Before printing, CATIA v5 software is used to draw the models of the sample and converted into STL files.

Model 1 is for compression test with diameter of 1 mm and height of 2 mm. The purpose of compression test is to determine the true stress-strain. Model 2 is for fatigue test with total length of 115 mm and 0.02 mm of thickness. The purpose of fatigue test is to determine the total number of cycles that sample can be subjected to under a single loading scheme.



Figure 1: Specimen for compression test



Figure 2: Specimen for fatigue test .

3. Result and discussion

3.1. Compression Strength

A force of 10 kN and speed of 1.5 mm/s are applied and data obtained from the test is the data of force (kN) and stroke (mm). Figure 3 shows the deformation sample of Model 1. From the data obtained, stress and strain are calculated. Figure 4 shows the graph of stress versus strain.

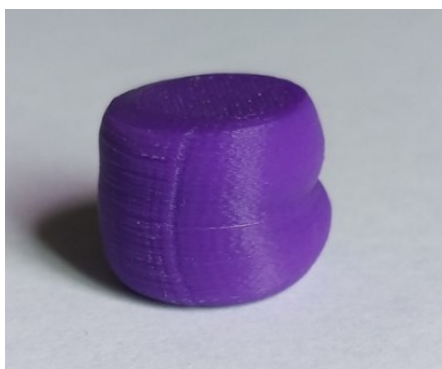


Figure 3: Specimen deformation after compression test

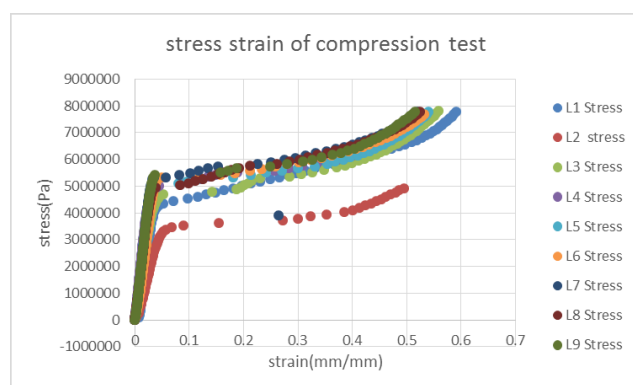


Figure 4: Graph of stress vs strain for compression test .

S/N ratio is calculated to maximize the response, so the larger is better. Figure 5 shows the graph mean of S/N ratio obtained. Table 1 shows the response table of printing parameters.

Table 1. Response Table of Printing Parameters

Level	Temperature A (dB)	Printing Speed B (dB)	Printing Angle C (dB)
1	130.6	132.2	132.2
2	132.6	131.4	131.6
3	133.1	132.7	132.5

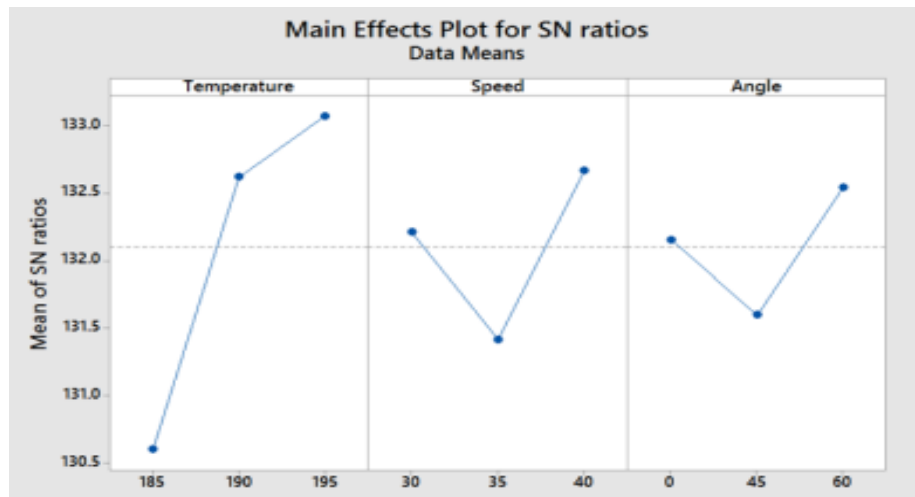


Figure 5: Graph mean of S/N ratio vs level of each printing parameters

3.2. Fatigue strength

A 50% from value of UTS is applied to conduct the fatigue test. Figure 6 shows the graph mean of S/N ratio and Table 2 shows the response table of printing parameters.

Table 2. Response table of printing parameters

Level	Temperature A (dB)	Printing Speed B (dB)	Printing Angle C (dB)
1	88.10	99.20	95.06
2	88.00	103.25	97.45
3	109.69	83.34	92.38

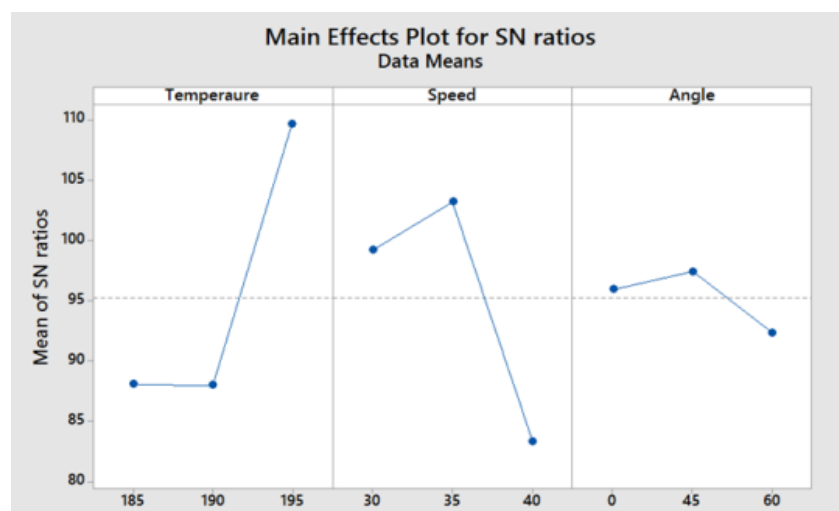


Figure 6: Graph mean of S/N ratio vs level of each printing parameters

3.3. Analysis of Variances (ANOVA)

Analysis of variance (ANOVA) is a collection of statistical models and associated estimation procedures used to analyze the differences among group means in a sample. The values are obtained based on the S/N ratio. Table 3 and 4 show the ANOVA table analysis form compression test and fatigue test.

Table 3. ANOVA for compression test

Printing Parameter	Factor	DOF f_n	Sum of Square S_n	Variance V_n	F-value	P-value	Contribution %
Printing Temperature	A	2	10.4070	5.2035	11.63	0.079	69.02
Printing Speed	B	2	2.4069	1.2035	2.69	0.271	15.96
Raster Angle	C	2	1.3686	0.6843	1.53	0.395	9.08
Error	e	2	0.8948	0.4474			5.93
Total		8	15.0774				100

Table 4. ANOVA for fatigue test

Printing Parameter	Factor	DOF f_n	Sum of Square S_n	Variance V_n	F-value	P-value	Contribution %
Printing Temperature	A	2	936.72	468.36	2.20	0.313	45.30
Printing Speed	B	2	664.51	332.25	1.56	0.391	32.13
Raster Angle	C	2	40.71	20.36	0.10	0.913	1.97
Error	e	2	426.09	213.05			20.60
Total		8	2068.03				100

4. Conclusion

In this research, the effect of printing temperature, printing speed and raster angle on mechanical properties of compression test and fatigue test are examined for PLA. These are conclusions from this study:

- All the experiment results showed that the printing temperature, printing speed and raster angle have a marked effect on compression test and fatigue test.
- Compression and fatigue test revealed that the printing temperature is the most effect on the samples compared to printing speed and raster angle.
- The significant parameters for compression test 195°C of printing parameter, 40 mm/s of printing speed and 60° of raster angle and for fatigue test is 195 °C of printing temperature, 35 mm/s of printing speed and 45° of raster angle.

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