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Compression Strength Characteristics of ABS and PLA Materials Affected by Layer Thickness on FDM

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Compression Strength Characteristics of ABS and PLA Materials Affected by Layer Thickness on FDM

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Abstract. This study aims to determine the compression strength of the Fused Deposition Material (FDM) additive manufacturing with the parameters in different layer thicknesses between 0.10 – 0.35 mm. The specimen manufacturing process refers to ASTM D695 Standards with ABS (acrylonitrile butadiene styrene) and PLA (polylactic acid) materials. Based on the test results, the highest compression strength is found in 0.15 mm layer thickness PLA material with a yield strength value of 66.78 MPa. The lowest compression strength is found in 0.35 mm of layer thickness ABS material with a yield strength value of 33.41 MPa. The value of compression strength on ABS and PLA materials varies with each layer thickness change.

1. Introduction

FDM is one of the more popular and widely known additive manufacturing methods in the community. This method allows three-dimensional models drawn with computer-aided designs to be presented as products quickly. FDM deposits semi-liquid polymeric materials using an extruder head on the printed part. At the printing stage, the nozzle will move on the X-axis and Y-axis planes, while the platform will move on the Z-axis according to the printing parameters layer by layer [1]. Printing parameters are given according to the desired specifications of the part to be produced. Printing parameters will affect the mechanical properties of the resulting part, this occurs in ABS and PLA materials used as filaments [2]. Parameters such as layer thickness and printing direction of ABS material affect the tensile strength of 3D printing [3]. Likewise, the angle of the printing orientation and the thickness of the 3D printing layer of ABS material affect the surface roughness [1]. ABS and PLA materials are the most widely used in FDM technology today because they have different printability and mechanical properties [4, 5]. he added value of PLA is that it is a material derived from nature which is biodegradable, therefore concern for environmental protection clearly separates PLA from ABS material for future use plans [4]. How the layer thickness parameter influences the compressive strength of ABS and PLA materials is something that needs to be known from this research.

The compression strength of FDM products is an important topic in its influence on mechanical properties. Research on the effect of infill variations on the compression strength of PLA materials with the FDM process has been carried out, where fourteen infill patterns produce variations in compression strength [6]. Two different polymeric materials, ABS and PLA, have been subjected to compression tests which show that the compression strength properties of ABS and PLA are highly dependent on the filling density [7, 8]. Compression tests on additive manufacturing based on fabricated filament composites (CFF) have been carried out to determine the effect of reinforcement pattern, reinforcement distribution, print orientation, and fiber percentage on compression strength [9]. Likewise, changes in compression behavior occur in variations of PETG composites [10]. The layer thickness parameter is also very important in influencing the mechanical properties of tensile strength [3]. How to layer thickness affects the compression strength of ABS and PLA filaments is an interesting study of this research. ABS filament is a filament of one form of thermoplastic and amorphous polymer which has excellent heat response properties [11]. While PLA filament is one of the bioplastic materials from renewable energy sources that supports a better level of consumption from an economic [11, 12]. These two materials are excellent for 3D printing in the manufacture of many products with a very wide range of applications with excellent physical and mechanical properties.

In this study, the effect of layer thickness on the compressive strength of the FDM process using ABS and PLA filaments will be discussed. This will be a consideration when making ABS and PLA products quickly using a 3D Printer.

2. Material and Method

In this study, the specimen for testing was in accordance with the ASTM D695 standard [6]. Specimen design for the printing process can be seen in Figure 1. Meanwhile, the ABS and PLA filament materials are from UP fila.

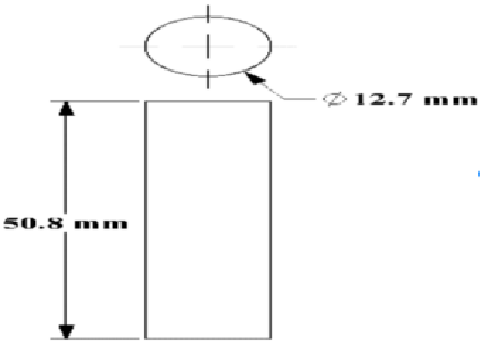

Figure 1. Specimen of compression test (ASTM D695)

Specimens are designed with CAD software and then the file is converted into stl format, so that it can be applied to the UP Studio three-dimensional object slicing software. Then the file is sent to the UPBox printer to be printed into a specimen test. Printing parameters are given with layer thickness variations such as Table 1. The filament material and layer thickness in specimen printing are varied. Each variation of the test in Table 1 is made of 5 samples. Other parameters such as infill 100%, and quality normal is applied. The position of the printing specimen and the variation in the shape of the printed specimen can be seen in Figure 2. Compression test with the TN20ND Controlab Machine under normal conditions and room temperature. This test is to determine the value of maximum compressive strength, yield compressive strength, and reduction in length at maximum force. Specimens that are ready to be tested can be seen in Figure 3.

Table 1. Various of specimen test

Specimen	Filament material	Layer thickness (mm)
C1	ABS	0.15
C2	ABS	0.25
C3	ABS	0.35
C4	PLA	0.15
C5	PLA	0.25
C6	PLA	0.35

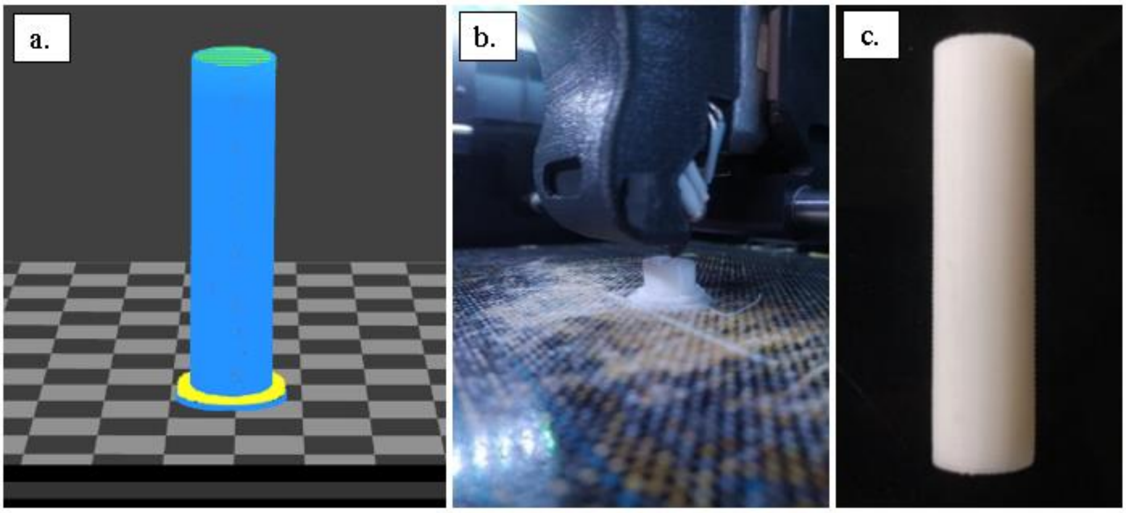

Figure 2. (a) Orientation position of printing, (b) printing process, (c) printing result

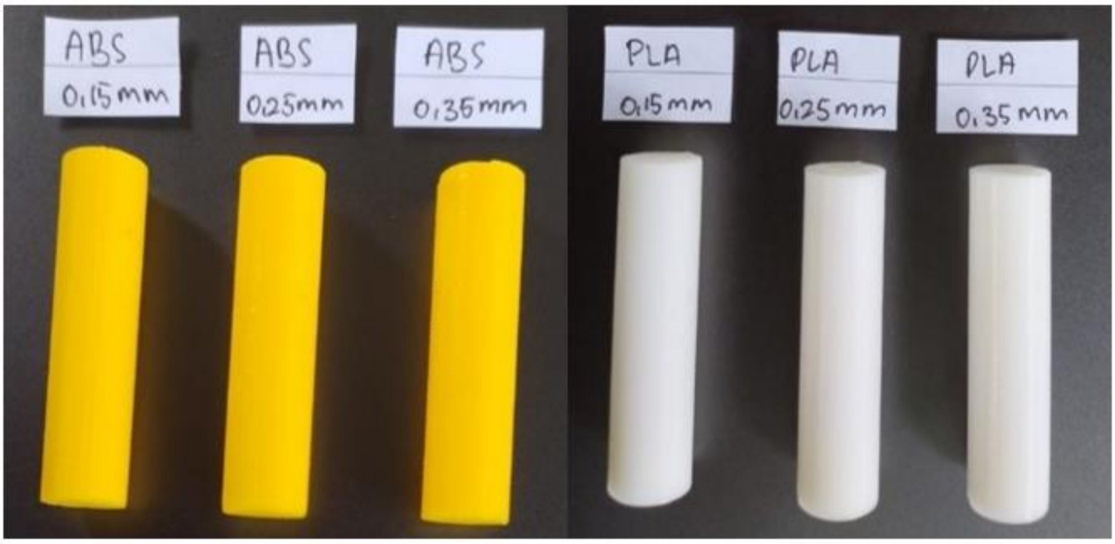

Figure 3. Specimen ABS (yellow) and PLA (white) for compression test

3. Results and Discussion

The results of the compression strength test obtained from the study are presented in Table 2 statistically. It can be seen that the PLA material has a higher compression strength value than the ABS material. This is due to the fact that the bond imparted between the layers in the sample-making process is better for the PLA material samples than for the ABS material samples. The cause of differences in the molecular structure of ABS and PLA materials also affects the strength value. The difference in the number of branches and functional groups of polymers, PLA has substituted for CH_3 and O_2 groups in the material [7]. This affects the chain entanglement in PLA material and increases the glass transition temperature. In addition, as the layer thickness increased in the ABS and PLA materials, it was observed that the samples were stacked and shortened in the longitudinal section without spreading in the cross-section as a result of the compression test. The shape of the fracture shown in Figure 4 shows that the strain on ABS material is greater than that of PLA material. The ABS material appears to breakage for all samples at all layer thicknesses. The PLA material appears for 0.15 mm and 0.25 mm of layer thickness showed breakage, and at 0.35 mm of layer thickness, the PLA material was only deformed.

In Figure 5, as the layer thickness increases, the compression strength of ABS and PLA materials varies. However, the ductility of ABS material shows a higher strain value as its resistance to elastic stretching. As shown in Figure 6 the ABS strain value is higher than PLA and the value also varies with changes in layer thickness. Several studies have reported that the compressive strength value for PLA material is higher than ABS for a constant layer thickness [7, 13]. Compressive strength values reported by Abeykon et al are 25 MPa and 32 MPa for ABS and PLA materials, respectively. The % strain values are also obtained from 17% for ABS and 6% for PLA. Ozsoy et al investigated that compressive strength values are 22 MPa and 32 MPa for ABS and PLA materials, respectively. The % strain values are also obtained from 23% for ABS and 5% for PLA. The yield strength is higher than the results of the study [7, 13] because it is influenced by different types of filament materials and infill methods.

Table 2. Results of compression tests of ABS and PLA material

ABS Sample	Max Strength (MPa)	Yield Strength (MPa)	Strain (%)	PLA Sample	Max Strength (MPa	Yield Strength (MPa)	Strain (%)
C1 -01	39.73	34.60	5.51	C4 -01	66.51	64.15	2.40
-02	41.23	38.62	5.20	-02	72.19	70.34	2.46
-03	37.52	33.40	4.33	-03	71.08	70.03	1.59
-04	40.36	37.74	4.13	-04	67.29	65.18	3.19
-05	40.12	37.52	4.57	-05	65.79	64.21	2.48
Average	39.79	36.38	4.75	Average	68.57	66.78	2.43
STDEV	1.38	2.25	0.59	STDEV	2.87	3.14	0.57
C2 -01	42.57	39.18	4.33	C5 -01	67.68	65.84	2.72
-02	39.80	37.19	4.59	-02	63.58	62.79	1.61
-03	38.70	35.04	5.67	-03	66.42	65.11	2.40
-04	40.04	37.44	6.95	-04	66.18	65.14	1.59
-05	38.30	36.73	4.11	-05	65.71	65.18	1.59
Average	39.88	37.12	5.13	Average	65.91	64.81	1.98
STDEV	1.67	1.49	1.18	STDEV	1.49	1.17	0.54
C3 -01	37.51	34.11	4.86	C6 -01	70.92	70.13	2.01
-02	36.17	33.07	5.02	-02	67.92	67.13	2.40
-03	36.56	33.96	4.98	-03	68.16	66.59	4.00
-04	35.22	31.78	4.51	-04	67.61	66.82	2.46
-05	37.51	34.11	5.22	-05	67.53	66.74	3.82
Average	36.59	33.41	4.92	Average	68.43	67.48	2.94
STDEV	0.97	1.01	0.26	STDEV	1.42	1.49	0.91

Figure 4 The shape of the Spesimen fracture ABS (yellow) and PLA (white)

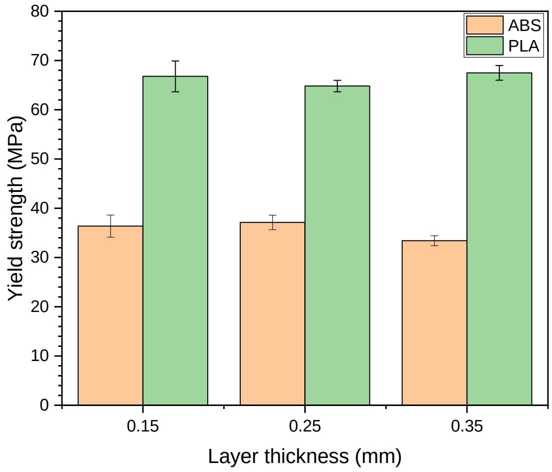

Figure 5. Yield strength of ABS and PLA materials

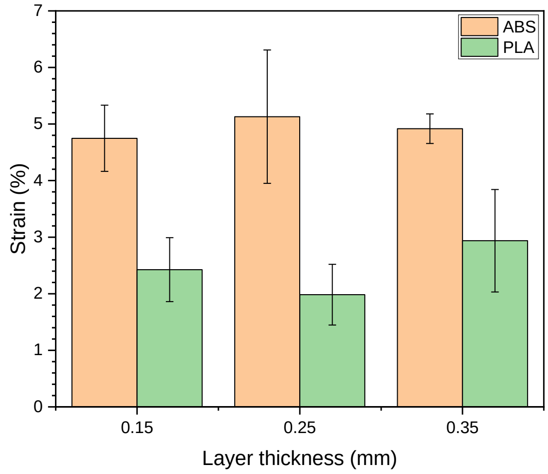

Figure 6. Maximum strain of ABS and PLA materials

4. Conclusion
Based on the results of this study, shows that the samples printed with PLA material filaments have a higher yield strength value than ABS materials so PLA materials are more able to accept compression loads than ABS. However, in contrast, the strain of ABS material is higher than that of PLA material. The value of compression strength and strain value varies with increasing layer thickness, this is influenced by the direction of the compression force that is perpendicular to the surface of the layer where the sample is stacked and shortened in the longitudinal section without spreading in the cross-section as a result of the compression test. Therefore, the layer thickness affects the compression strength of ABS and PLA materials on FDM.

5. Acknowledgments
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