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EXPERIMENTAL INVESTIGATION OF 3D PRINTER SPECIMEN PLA FILAMENT ON PRIMARY STRUCTURES OF SMALL UAV

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ABSTRACT

The use of additive production technology is becoming widespread in many areas. It is a frequently preferred method especially for rapid prototyping and functional parts (wing attachment) in small unmanned aerial vehicles (UAV). The determination of the mechanical properties of 3D printer specimens is of great importance. Therefore, the aim of this study is to determine mechanical properties of PLA 3D printer products and determined mechanical properties will use on primary structures of small UAVs. In order to determine the mechanical properties of PLA 3D printer specimen, tensile test was performed on ASTM D638 standard. Specimens were produced in three different orientations and no special internal structure was used. Although, specimens were produced separately for the accuracy of the test, same 3D printer properties were used for each specimens. Moreover, specimens were produced at 100% occupancy rate. The test results showed that 55 MPa was measured in the strongest strength with 0° *orientation. The specimens test results in the orientation of the* 45° *and* 90° *are also similar.*

INTRODUCTION

One of the areas where 3D printers are used is the UAV industry. So many UAV parts are produced using a 3D printer. The lack of knowledge of the mechanical properties of the produced parts is a major disadvantage for the user. With the determine of these features, 3D printer products will become more functional. Therefore, it was decided to carry out tensile tests on the specimens.

The mechanical properties of 3D printer products vary depending on the filament used. PLA (Poly Lactic Acid) and ABS (Acylonitrile Butadiene Styrene) are frequently used printing materials. These are thermoplastic materials so heat changes them as soften. Before cooling, you can sculpt and mold them into the shape that you want. This situation make easy to additive production. Next, nozzle of 3D printer start to build up the layers of created a CAM model.

ABS is an oil-based plastic. ABS has a high melting point and has the tendency to warp if cooled while printing. Therefore, ABS needs to be printed on a high heated bed. Because of amorphous property

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of ABS, it doesn't have definite melting point. However, the standard temperature of printing ABS is at $230°C$ and heated bed temperature is $105°C$ to $110°C$. For these, It must be special printer.

PLA is made from organic material. It features a far lower melting point than ABS. This material melts at a much lower temperature which is at $180°C$ to $220°C$ and heated bed temperature is $60°C$ to $65°C$. Also, PLA is easier and more convenient to use. Unlike ABS, it lays on the print bed with little to no shrinkage. PLA filaments have greater tensile strength and low ductility. Because, it does not wanted to high elongation break on spar of small UAV wing structure. When we consider cost, ease of production and tensile strength, PLA was selected.

The following table shows the properties of PLA and ABS filaments from [Tanikella, 2017] and [Price-compare, 2019];

Property	ABS2	PLA
Density (Mg/m^3)	1.00-1.22	1.24
Young's Module E (Gpa)	1.12-2.87	3.53
Elongation at Break (%)	3.00-75.00	6.05
Tensile Strength (Mpa)	25-50	36-55

Table 1: The properties of PLA and ABS filaments

The work presented here represents an expansion of the previous studies completed by [Letcher, 2014].

METHOD

Only tensile testing was performed on the specimens. The same brand PLA flament was used for the specimens. Each specimen was printed in only one direction and two layers of crust were used in each specimen. Specimens were produced at a 100% occupancy rate. All specimens were printed on a consumer level 3d-printer JGAURORA Magic. The conditions for the specimens are as follows;

- PLA material was extruded at $230°C$.
- Surface of heated bed is at $65°C$.
- Usage of PLA of 3D printer is $100mm/s$.
- Working condition of 3D printer is room temperature.

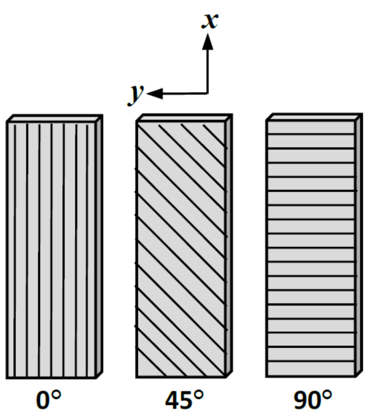

Figure 1: Orientation of specimens directions are $0°$, $45°$, and $90°$.

Specimens of each material were printed considering the ASTMD 638 [ASTM D638 , 2010]. Size of specimens were determined according to ASTM D 638 Standard Test Methods for Tensile Properties of Plastics [ASTM D638 , 2010]. The wedge grips were displaced at a rate of $5mm/min$ with data (force, grip displacement, and strain) collected at 100 Hz [Letcher, 2014]. The force measurement system was reset before the specimen was held at both ends [Tanikella, 2017]. 5 specimens were produced for each orientation. The types of orientation are $0°$, $45°$, and $90°$ as displayed in Figure 1. The tensile test was carried out at room temperature. Each specimen was checked with a $0.05mm$ precision caliper before the test. Each specimen was given a number. The sizes of specimens are shown in Figure 2 below.

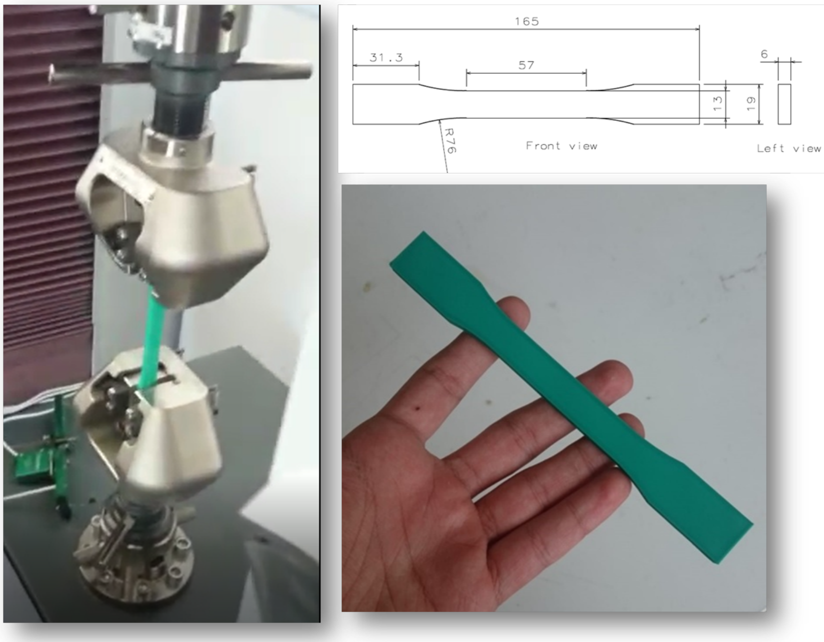

Figure 2: Tensile specimen dimension, production, and testing environment.

EXPERIMENTAL RESULTS

According to the results obtained, the strength is the strongest at $0°$ orientation (56.2761 Mpa) same as [Ziemian, 2014]. The strength results of the $45°$ and $90°$ orientations were similar. However, as expected, the strength at 45 degree is stronger than 90 degree. The highest strain value was measured in $90°$ orientation. Results of tensile test for 3 different raster orientation and summary of tensile testing are shown in Table 2 and Table 3 and lowest strain value measured in 0 orientation. According to the result elastic modulus values were close each other and strengths were different due to the difference between the filamnet orientation.

SIMULATION RESULTS

Structural analysis of unmanned aerial vehicle was performed with the data obtained from test result. Technical specifications of the unmanned aerial vehicle designed below are shown in the Table 4.

For analysis, load factor 3 was accepted and design factor 1.5 was accepted. In the analysis, maximum load to be exposed to the aircraft was taken. The forces obtained from the CFD data were applied to the UAV aerodynamic center. The printing thickness for the upper skin and the lower skin is 3 mm. The printing thickness for the front spar and rear spar is 4 mm. The printing thickness for root rib and tip rib is 4 mm. As a condition of analysis, frictionless surface was applied to the spar connection surfaces and root rib. Two degree of freedom support is applied to the pin holes. This means that the rotation around X-axis on the global axis and the movement along X-axis are free. Maximum stress

Orientation (Degree)	Actual Width (mm)	Actual Thickness (mm)	Ultimate Stress(Mpa)	Modulus of Elasticity (Gpa)	Elongation Break(%)
0	13.00	6.05	55.0486	3.586	2.44
0	13.05	6.00	55.4755	3.541	2.34
0	12.85	5.90	56.2731	3.588	2.48
0	12.90	6.00	54.9863	3.622	2.51
0	12.95	5.95	54.8646	3.542	2.38
45	13.10	5.80	39.0287	3.297	2.73
45	13.00	6.05	42.9420	3.411	2.89
45	12.85	5.90	39.0493	3.334	2.65
45	13.25	6.00	38.3827	3.262	2.76
45	12.95	6.15	40.3743	3.213	2.64
90	12.90	5.05	36.7880	3.114	3.74
90	13.05	6.05	37.4533	3.132	3.08
90	12.85	5.80	37.3357	3.016	3.63
90	13.15	5.90	37.5010	2.999	3.63
90	13.35	6.00	36.8860	3.276	3.94

Table 2: Results of tensile test for 3 different raster orientations

Orientation (Degree)	Avarage Ultimate Stress(Mpa)	Avarage Modulus of Elasticity (Gpa)	Avarage Elongation at Break(%)
0	55.3296	3.5758	2.430
45	39.9554	3.3034	2.734
90	36.1926	3.1074	3.540

Table 3: Summary of tensile testing result

UAV Weight	1 kg
Wing Span	1.177 m
Aspect Ratio	36.1926
Root Rib	0.1846 m
Tip Rib	0.12927 m
Stall Speed	8 m/s

Table 4: Technical specifications of UAV.

distribution and Von-Misses stress distribution are given on UAV wing in following visual.

CONCLUSION

The data obtained from the analysis showed that the UAV was based on the applied loads. Then, analyzed wing was produced from PLA. The body of UAV is also produced from PLA. During the ground and flight tests of the UAV, no damage occurred and the produced PLA parts were withstand applied loads. The use of PLA in UAV has been found to be more efficient, faster and cheaper than wood and foam materials.

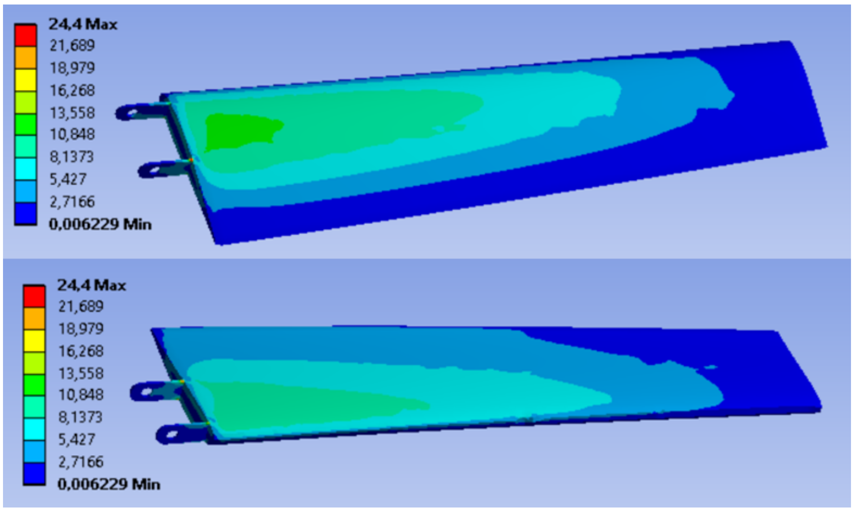

Figure 3: Maximum stress distribution (Mpa).

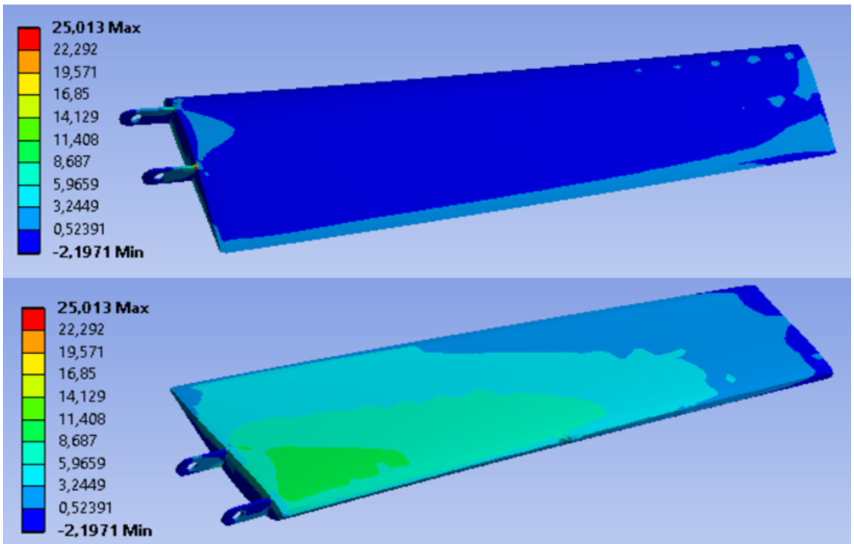

Figure 4: Von-Misses Stress distribution (Mpa).

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