

3-D PRINTED STRUCTURAL ELEMENTS AND THEIR MODELING FOR AEROSPACE USAGE

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Abstract

This research aims to analyze how of the commonly used 3D printing filaments provided by the MakerSpace Lab to students, who partake in aerospace competitions, when varying infill density and printing orientation, and compared to traditionally used materials like wood, perform when subjected to tensile tests. After undergoing the tests, the specimens made from PLA, PETG, and Nylon of 50% and 20% infill densities and printed in both flat and side orientations showed that PLA of 50% infill density had the highest yield among the filaments. Filaments surpassed the Young's modulus of Basswood but not Balsawood. Out of all the filaments, Nylon proved to be the most elastic.

Introduction

Additive Manufacturing (AM) technologies and its advancements have progressed exponentially and have become integrated in many industries. An article states that according to the Wohlers Report 2017, Boeing manufactured more than 20,000 parts using AM technologies, an example of its prevalence in the aerospace industry (Alami et al.,2023). Aerospace materials must be lightweight yet durable, and students often opt for a selection of wood or alloys. Unlike woods and alloys, 3D printing offers customization such as print orientation, layer height, infill density, and infill pattern. This research aims to provide insight into which amongst the students' commonly used 3d printing filaments can have their structural elements tailored, and will prove to be more effective than traditionally used materials when tensile testing is applied, and if these can prove beyond prototyping to be used for aerospace applications and student competitions.

Objectives

To produce and compare data from tensile testing and Young's Modulus between various specimens made from commonly used 3D printer filaments provided to students in the University's Makerspace Lab, such as PLA, PETG, and Nylon, and varying infill density and printing orientation. To explore which of the materials can prove to be useful for aerospace applications and competitions, and if students can utilize these materials interchangeably with more traditional materials, like wood.

Methodology

The specimens were modeled in CAD programs, both in Autodesk Fusion and Creo Parametric, following the Standard Method for Tensile Properties of Plastics the ASTM D638-14 (Type I), which measured 7mm in thickness and 13mm in width of the narrow section. The materials available in the MakerSpace Lab were PLA, PETG, and Nylon. All specimens were printed using a Creality Ender 3D printer and triangle-shaped infill geometries. Each of the 6 layers of material to form the walls measured 0.2mm, making them 1.2mm thick overall. A total of 20 PLA specimens were printed in various batches, divided into infill density: 20% and 50%, and orientation: flat and side. An upright orientation was not used, as when printed, it would exceed the parameters of the printer bed. When performing tensile tests on the Applied Test Systems Universal Test Machine, there was slippage between the grips and the specimens, given the smoothness of the material's surface, which caused errors. Data could be extracted from only 4 specimens. For PETG, the variables were the same, except the printing number was reduced from 5 specimens per batch to 3, and 24 were printed in total. There was a reduction in testing availability for the number of specimens, so only 4 of the PETG were selected, and only one specimen of Nylon was observed. For better grip, PETG specimens were filed manually at the wide tabs with a 120-grit sandpaper sheet. Students provided Basswood and Balsawood Young's modulus data.

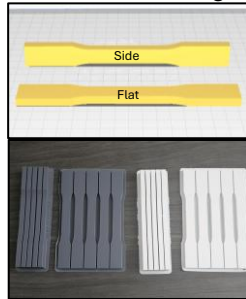


Figure 1: CAD Model (Top)

Figure 2: Example of Printed Specimens, PLA (Bottom)



Figure 3: 3D Printer



Figure 4: Universal Test Machine



Figure 5: Close-up of Test

Analysis of Results

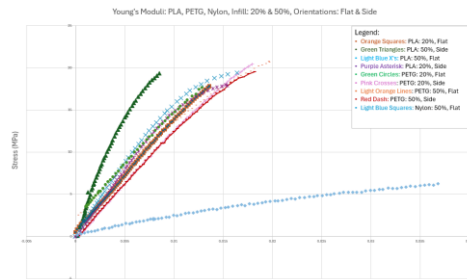


Figure 6: Young's Modulus Graphs & Data

Sample:	Modulus:
PLA: 20%, Flat	1376.7 MPa
PLA: 50%, Side	2651.3 MPa
PLA: 50%, Flat	1468.1 MPa
PLA: 20%, Side	1383.5 MPa
PETG: 20%, Flat	1512.1 MPa
PETG: 20%, Side	1205.1 MPa
PETG: 50%, Flat	1203.2 MPa
PETG: 50%, Side	1143.7 MPa
Nylon: 50%, Flat	190.99 MPa
Basswood	8.2MPa
Balsawood	3600MPa

Nylon: when load is/reaches until: 304.243 N. Nylon load until: 655.1904N

For each test the machine provided raw data of time(sec), displacement(in), load(lb), and strain(in/in) for each tested specimen. With the loads converted to Newtons and divided by the cross-sectional area (48.76 mm^2), Stress (N/mm^2) was found, which was divided by Strain and graphed to find the Young's Modulus.

Conclusions & Recommendations

PLA filaments of 50% infill density were more rigid than those of 20%. The one with the highest modulus of PETG was that of 20% infill density. Between PLA and PETG, the specimen titled "PLA: 50%, Side" demonstrated the highest modulus. Nylon had a modulus of 190.99 MPa, a low modulus, but considering that it is the value only up to a 304.243 N load, further than the fracture point of the other specimens, making it exceedingly elastic. Nylon did not break and reached the testing limit, but stretched until the load reached 655.1904N, and the test was concluded. Nylon's elastic nature may be suitable for other applications, but not those this study was aiming for, as an overly elastic material, when deforming, could pass on the load to other parts of a structure. Basswood's modulus is significantly smaller than PLA and PETG. Balsawood, which the closest to its modulus (3600MPa in the Young's modulus X direction), would be "PLA: 50%, Side, which reached 2651.3MPa. Still, considering the woods' low density, they may not be used interchangeably with the filaments. Accounting for the area, it was observed that the load, though applied to the entire specimens, the outer layers or walls exhibited a higher yield and took on the load more than the interior. The density serves more as a structural component. More prototyping and pre-testing should be done to ensure minimum error when graphing the stress-strain data and to minimize material waste. Another recommendation would be to gather the G-codes of each print to later reference when calculating the cross-sectional area.

References

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