EMBRY-RIDDLE Aeronautical University
Mechanical Engineering
Discovery Day Poster Session

Tensile Testing Quantification of Fused Deposition Modeled printed Thermoplastic Polyurethane

Background

Fused Deposition Modeling, commonly known as FDM, has become one of the most widespread additive manufacturing (AM) methods available to consumers and industry. It is a fast, reliable, and inexpensive method to produce strong, large, and affordable parts. Its primary limitations include issues with printer resolution, tolerancing, and anisotropy. This anisotropy of FDM printed parts is larger than the anisotropy in other AM methods. The layer lines in FDM show that the optimal method to destroy the part is to apply a force orthogonal to the layer lines and thus separate the part layers. FDM has a wide variety of compatible materials for printing use. While these materials have been designed to print, the actual material characteristics of an end-use part rely more on the gcode slicer settings and the quality of the n printer.

Printer slicer settings define everything about how the printer will form the part and are as detailed as CNC settings. Slicer settings control everything about the printing process, such as the nozzle temperature, infill pattern, perimeter count, and extrusion rate.

Methodology

The tensile testing was performed in accordance with ASTM Standard D638-22 with reference to ASTM F2971 and D883-00 [1-4]. From the standard, the Type IV samples were printed using the following equipment and specifications—additional information regarding the methodology available upon request.

Table 1: Equipment List

Material/Equipment List	Item
Tensile Testing Machine	MTS Criterion w extended height model 43.504
FDM Printer	Ultimaker S5
Filament	Ultimaker White TPU 95A
Load Cell	5kN

Table 2: Print Settings

Printer Settings	Values
Nozzle Temperature	225°C
Print Speed	25mm/s
Bed Temperature	60°C
Chamber Temp	27°C
Infill Pattern	Gyroid
Fan Speed	20%
Nozzle Type	AA Core

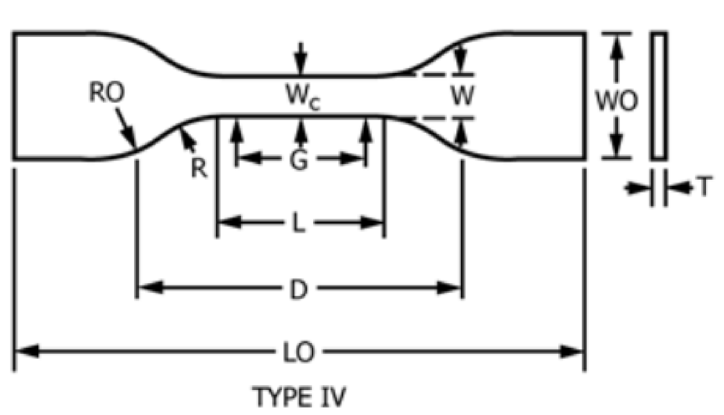

Figure 1: Test Sample 2D Drawing

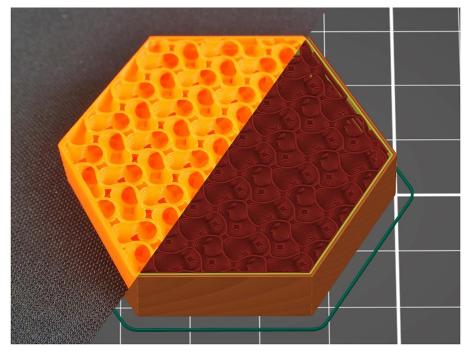

Figure 2: Gyroid Infill

Table 3: Test Sample Dimensions

Dimension Variables	Dimension mm
Width (W)	6.0 ± 0.50
Cross Sectional Width (Wc)	6.0 +0.00 -0.100
Length (L)	33.0 ± 0.50
Outer Width (WO)	19.0 + 6.40 -0.00
Outer Length (LO)	115 no max
Gauge Length (G)	25 ± 0.13
Grip Distance (D)	65 ± 5.00
Inner Radius (R)	14 ± 1.00
Outer Radius (RO)	25 ± 1.00
Thickness (T)	3.2 ±0.40

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ABSTRACT

With the advent of additive manufacturing (AM), understanding the effects of changing 3D printing settings is critical for engineering pursuits. One of the most widespread methods, known as Fused Deposition Modeling (FDM), has been well-researched by consumer hobbyists and members of the general public. However, an empirical analysis is needed for scientific research and projects, and few have been performed to prove the relationship between a printing setting and material strength quantitatively. This lack of literature is partly due to the breadth of printers and factors that can affect an FDM model's printability. This project tensile tested one Thermoplastic Polyurethane (TPU) brand at various infills. It analyzed the effects of infill percentage on the tensile strength and moduli of elasticity. Additionally, it interprets the data and details further testing to validate a hypothesis formed from the study results. The data used will also be showcased with another group who will use it to help validate their study. This study aims to clearly show that the process of printing a part is as imperative to the success of a project as creating a design and choosing materials.

Testing Procedure

Figure 3: Ultimaker s5

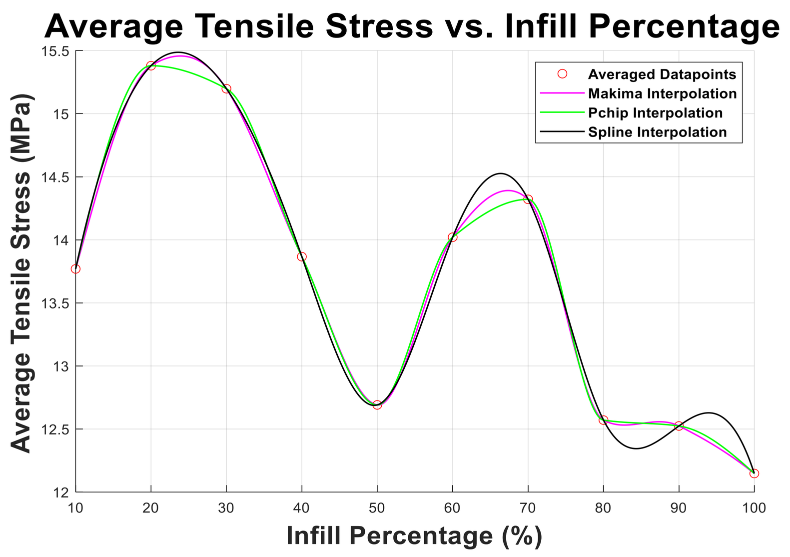
Figure 4: Test Coupons

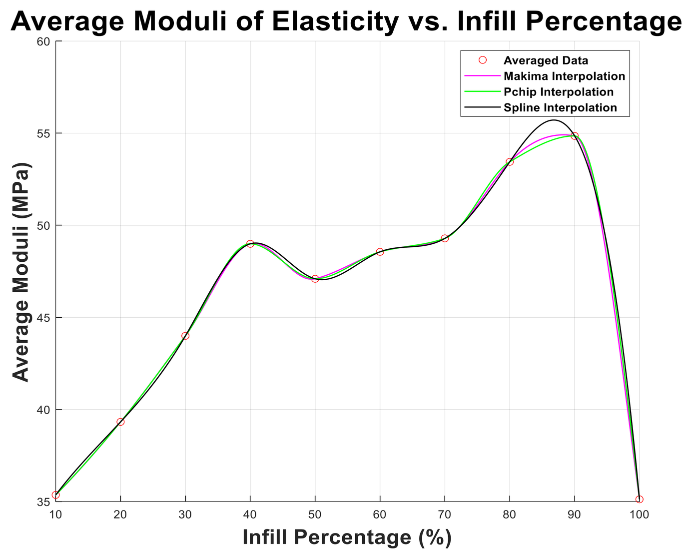
Figure 5: Testing Machine

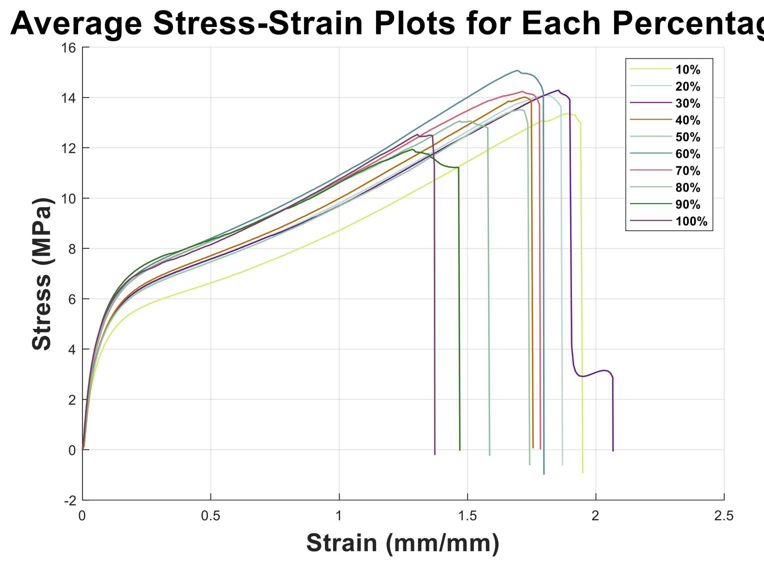
Figure 6: Tested Samples

Results

The primary information trends that were being investigated included understanding how the tensile strength and moduli of elasticity changed with respect to the infill percentage. As seen in Figure 6, the trend shows that the average tensile strength decreased as the infill percentage increased. At the same time, the moduli of elasticity increased with infill percentage until the part was 100% solid.







Conclusions

TPU is closely related to rubbers and behaves similarly. Several articles have shown that when combining TPU through traditional manufacturing, the tensile strength has decreased significantly with increases in TPU wt% [2-4]. Additionally, a phenomenon of rubber-like materials known as rubber toughening decreases the tensile strength of materials in exchange for increasing their toughness when subjected to temperatures above the glass transition temperature. This could be confirmed by baking the printed samples at a uniform temperature prior to testing.

References

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