Tensile Behavior of Vacuum Infiltrated Fused Deposition Modeling Sandwich Structure Composites

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INTRODUCTION

Additive manufacturing (AM) is transforming the methods by which prostheses are built today. However, the strength of AM materials was identified by [1] as a major limiting factor to large scale clinical adoption. This research explores vacuum infiltration of AM composites to determine if this method is promising for increasing the ultimate tensile strength (UTS) of the AM materials, and reducing anisotropy inherent in AM materials.

Figure 1: ASTM D638 tensile samples and test configuration

MATERIALS & METHODS

Infiltrating AM materials was identified by [2] as a promising internal reinforcement strategy to improve mechanical properties. In this research, we create sandwich structure composites of 3 filament materials (PLA, CF-PLA, CF-PETG), 2 resin infiltrating materials (Epoxy, Urethane), and in 2 print directions (0°, 90°). These samples were tested using the ASTM D638 test methods [3] to determine mechanical properties (**Figure 1**).

RESULTS

In **Figure 2** and **Figure 3** we can notice that for CF-PLA and CF-PETG filament materials, creating vacuum infiltrated composites increased the transverse UTS and reduced anisotropy (especially in urethane composites.) However, due to porosity in the infiltrated samples (**Figure 4**), many of the mechanical properties did not reach their theoretical potential strength.

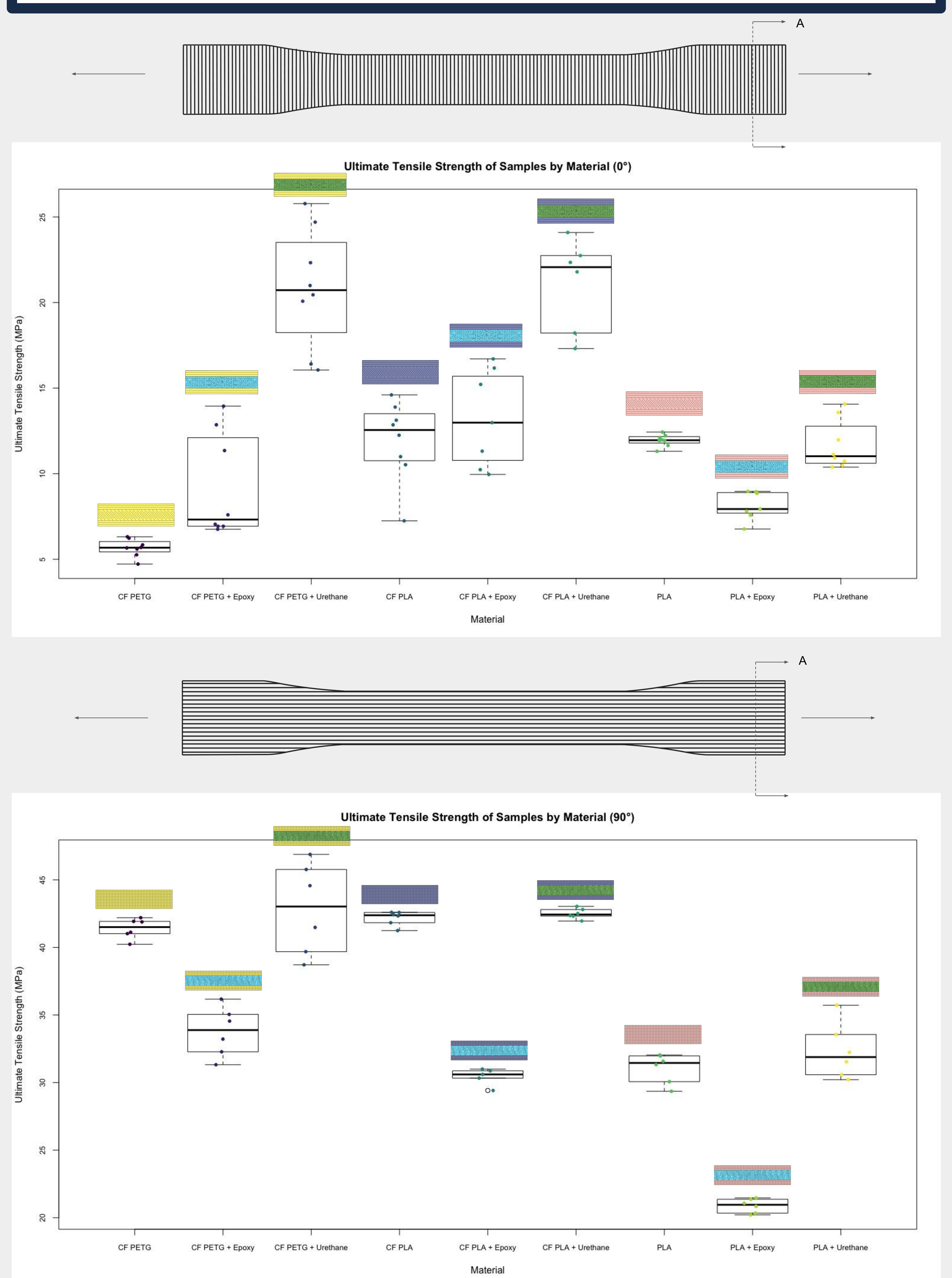

Figure 2: Ultimate tensile strength by material and loading configuration

CONCLUSIONS & FUTURE WORK

Due to porosity in the manufacturing process of the AM vacuum infiltrated composites, the mechanical properties measured by these experiments are not as high as theoretically possible. However, despite these defects, we do see an increase in UTS and a reduction of anisotropy in many of our materials. These results mean that this manufacturing method is a promising technology for creating stronger prostheses with AM materials.

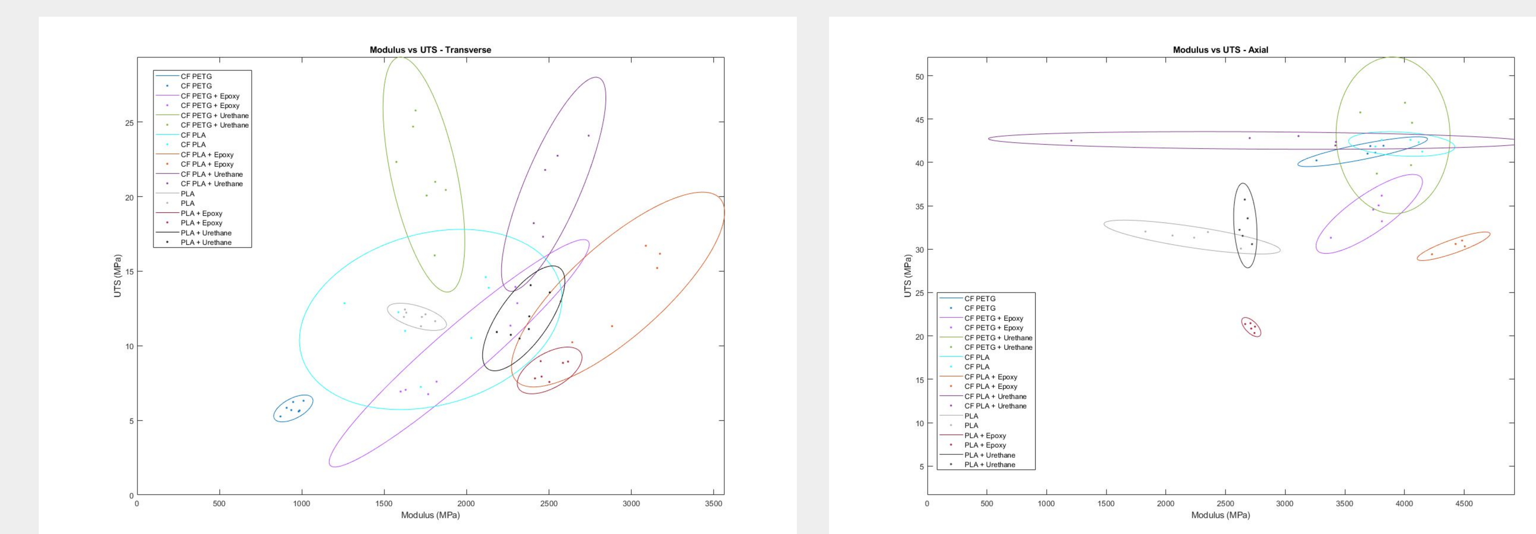

Figure 3: Ashby plots: Stiffness vs Ultimate Tensile Strength

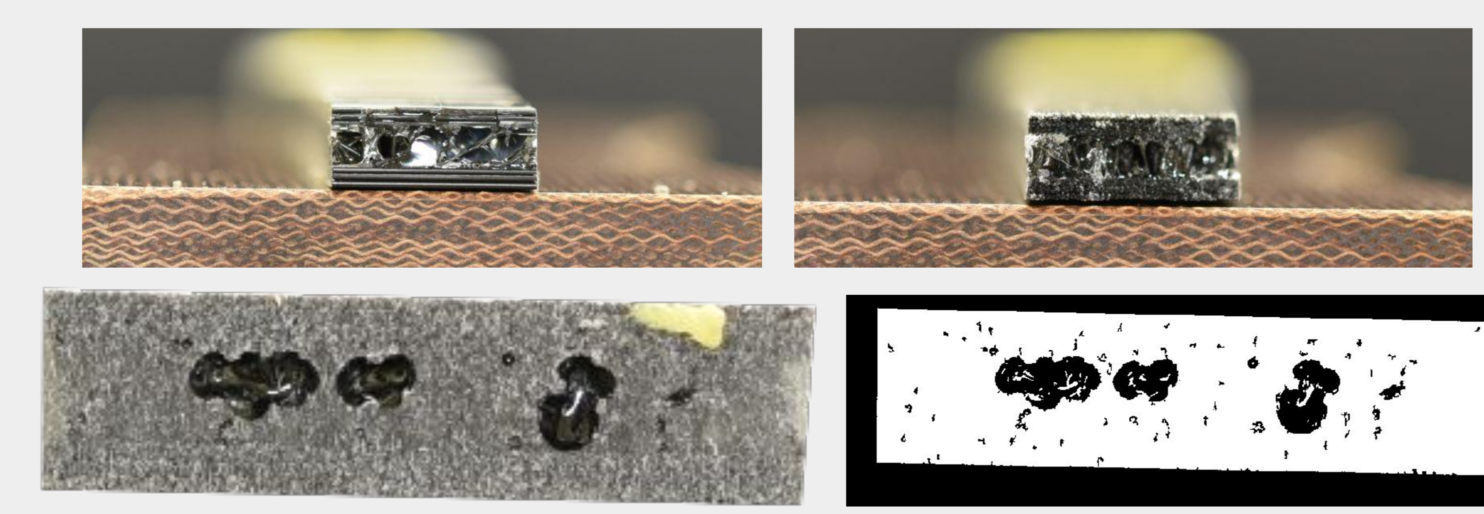

Figure 4: Fracture surfaces and evidence of porosity

REFERENCES

[1]I. A. Cabrera, T. C. Pike, J. M. McKittrick, M. A. Meyers, R. R. Rao, and A. Y. Lin, "Digital healthcare technologies: Modern tools to transform prosthetic care," Expert Review of Medical Devices, pp. 1–16, Oct. 2021, doi: 10.1080/17434440.2021.1991309.
[2] J. T. Belter and A. M. Dollar, "Strengthening of 3D Printed Fused Deposition Manufactured Parts Using the Fill Compositing Technique," PLoS ONE, vol. 10, no. 4, p. e0122915, Apr. 2015, doi: 10.1371/journal.pone.0122915.
[3] D20 Committee, "Test Method for Tensile Properties of Plastics," ASTM International. doi: 10.1520/D0638-14.

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