Mechanical Strength of PLA Fabricated by FDM as a Function of Layer Orientation

J. Atonal-Sánchez, K.M. Ortiz-Morales, A. Reyes-Cruz, L.E. Alvarado-Ochoa, V.D. Rodríguez-Gaspar.

Introduction

Polylactic acid (PLA) is widely used in Fused Deposition Modeling (FDM) due to its ease of processing and good mechanical performance. However, the layer-by-layer deposition process generates anisotropic behavior, where the mechanical response depends on the orientation of the printed layers relative to the applied load [1-3]. Therefore, evaluating the influence of layer orientation on the tensile strength of PLA is essential for improving the structural performance of additively manufactured components.

Objective

To evaluate the influence of layer orientation on the tensile strength of PLA manufactured by FDM through mechanical testing in accordance with ASTM D638 Type V specimen [1], in order to identify the configuration with the highest structural performance.

Methodology

Fig. 1 Experimental procedure for PLA tensile testing.

Layer Orientations

3D Printing: FDM

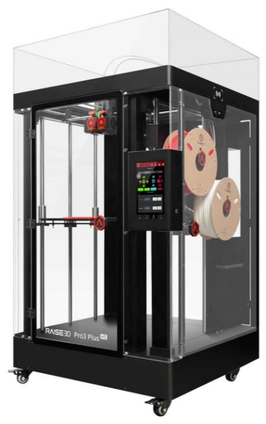

Fig. 2 Raise3D Pro3.

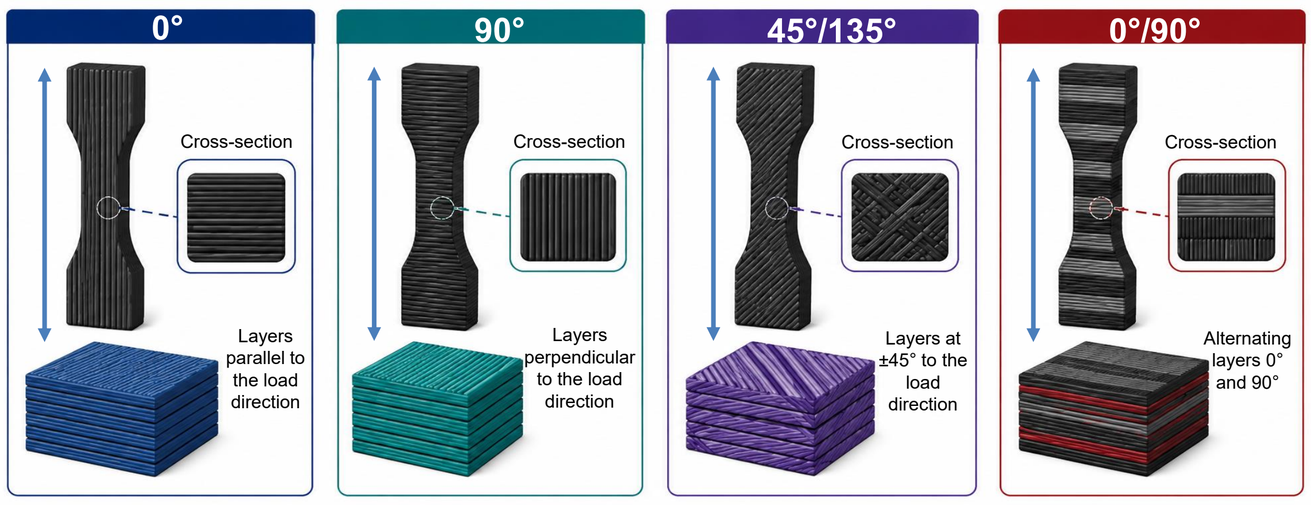

Fig. 3 Layer orientation configurations used in PLA specimens.

Material:	PLA
Layer height:	0.2 mm
Infill:	50%
Nozzle temp.:	215 °C
Bed temp.:	60 °C
Printing speed:	50 mm/s

Table 1. PLA printing parameters.

Experimental Results

Tensile tests were performed on multiple specimens for each layer orientation configuration (0°, 90°, 45°/135°, and 0°/90°). The experimental results were obtained by averaging the tensile strength values measured during the tests, allowing comparison of the mechanical behavior associated with each printing orientation.

Layer Orientation	Results
0°	Filaments aligned with the loading direction promote efficient stress transfer and stable tensile response.
90°	Load applied perpendicular to layers causes premature interlayer failure and brittle behavior.
45°/135°	Combined shear and normal stresses result in intermediate mechanical performance between 0° and 90°.
0°/90°	Cross-ply configuration provides better structural balance, improved crack arrest, and the highest tensile strength.

Table 2. Mechanical behavior associated with each layer orientation.

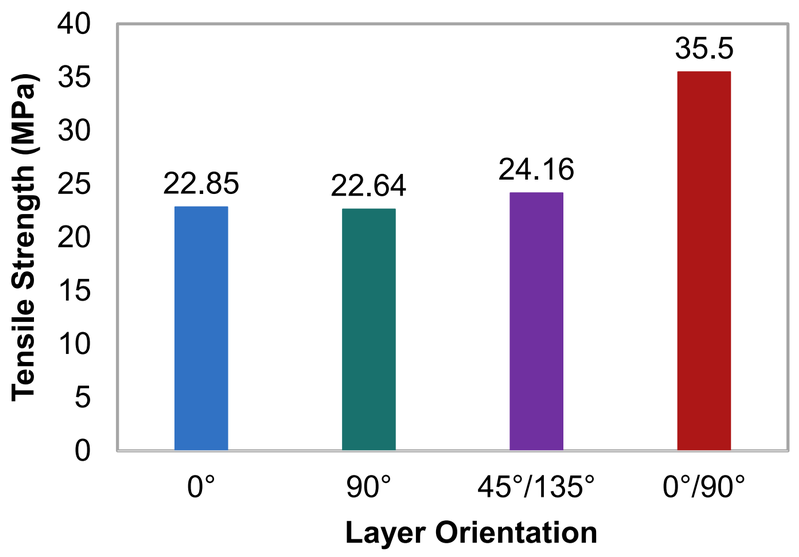

Fig. 4 Experimental tensile strength of PLA specimens.

Conclusions

- The 0°/90° cross-layer configuration achieved the highest strength, reaching an average value of **35.5 MPa.**
- The 90° orientation showed lower structural performance due to premature interlayer failure.
- The experimental results confirmed the anisotropic behavior of PLA manufactured through layer-by-layer deposition.
- Layer orientation significantly influences stress transfer and structural integrity in FDM-manufactured PLA components.

Acknowledgments

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References

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[3] Singh, R., Kumar, A., Patel, S. Investigation of mechanical properties in PLA parts fabricated by FDM technology. Scientific Reports, 2024.

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Instituto Politécnico Nacional, Escuela Superior de Ingeniería Mecánica y Eléctrica, Unidad Azcapotzalco, Av. de las Granjas 682, Santa Catarina, Azcapotzalco, 02550, Ciudad de México.
jatonals@ipn.mx

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