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Biaxial Stress–Strain Response and Strain Localization in 3D-Printed PLA and TPU Thin Sheets

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Scientific context

Uniaxial tests and global force–displacement curves cannot resolve the multiaxial deformation of additively manufactured thin sheets [1]. In PLA (polylactic acid) and TPU (thermoplastic polyurethane), printing-induced anisotropy, interlayer heterogeneity, surface roughening, and out-of-plane waviness promote strain localization and failure. Measurements are therefore required at both macroscale and damage scale.

Objective

Relate biaxial force response to full-field strain localization and damage evolution in 3D-printed PLA and TPU sheets using an open-hardware biaxial testing platform powered by computer vision algorithms.

Experimental

Biaxial Loading — Four independent stages load the cruciform specimen; two load cells measure orthogonal forces.

Synchronized Multiscale Imaging — A wide-field camera records DIC sequences, while optical-flow feedback keeps the selected microscopic region centered under reflected-light microscopy [3].

Digital Image Correlation (DIC) — The unloaded frame defines the homography and L_0. In fiducial-grid mode, fiducials anchor global strain and the IC-GN grid provides the displacement-field shape. Displacement gradients yield ε_{xx}, ε_{yy} and γ_{xy} maps [2].

Validity — Low correlation, high residuals, or marker loss exclude frames. For large TPU strains, grid-only magnitudes require independent validation.

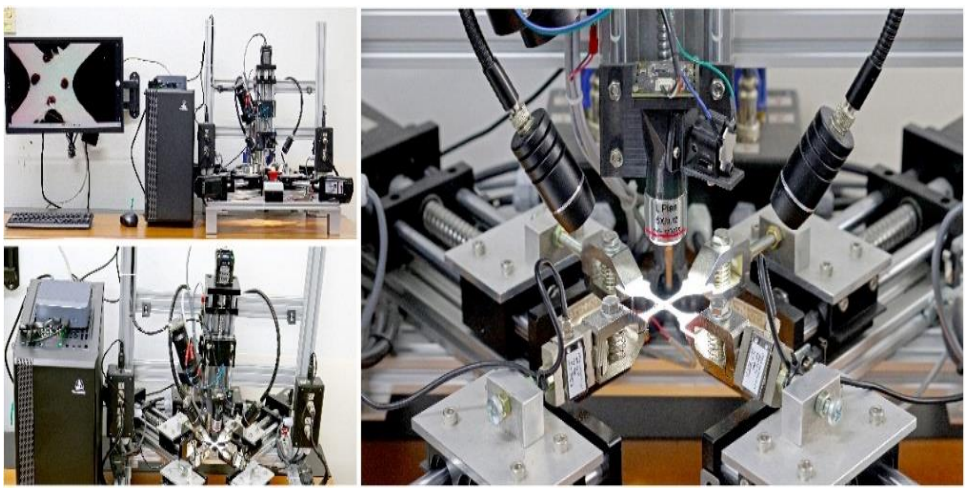


Figure 1. Open-hardware biaxial tensile testing platform and multiscale optical system.

Results and discussion

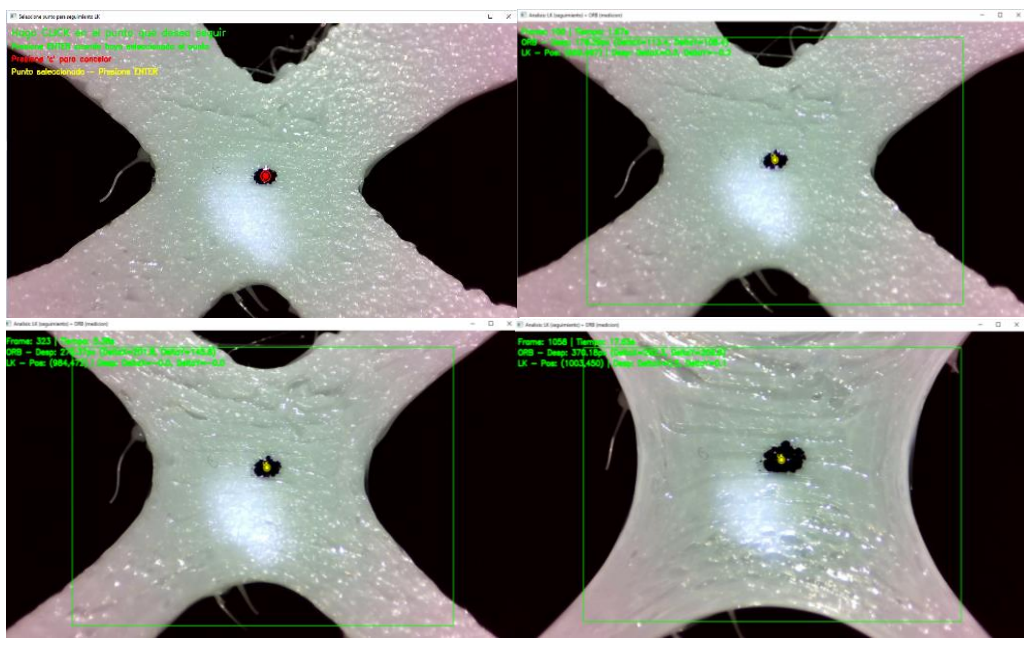


Figure 2 Optical-flow tracking point environment, for a TPU sample.

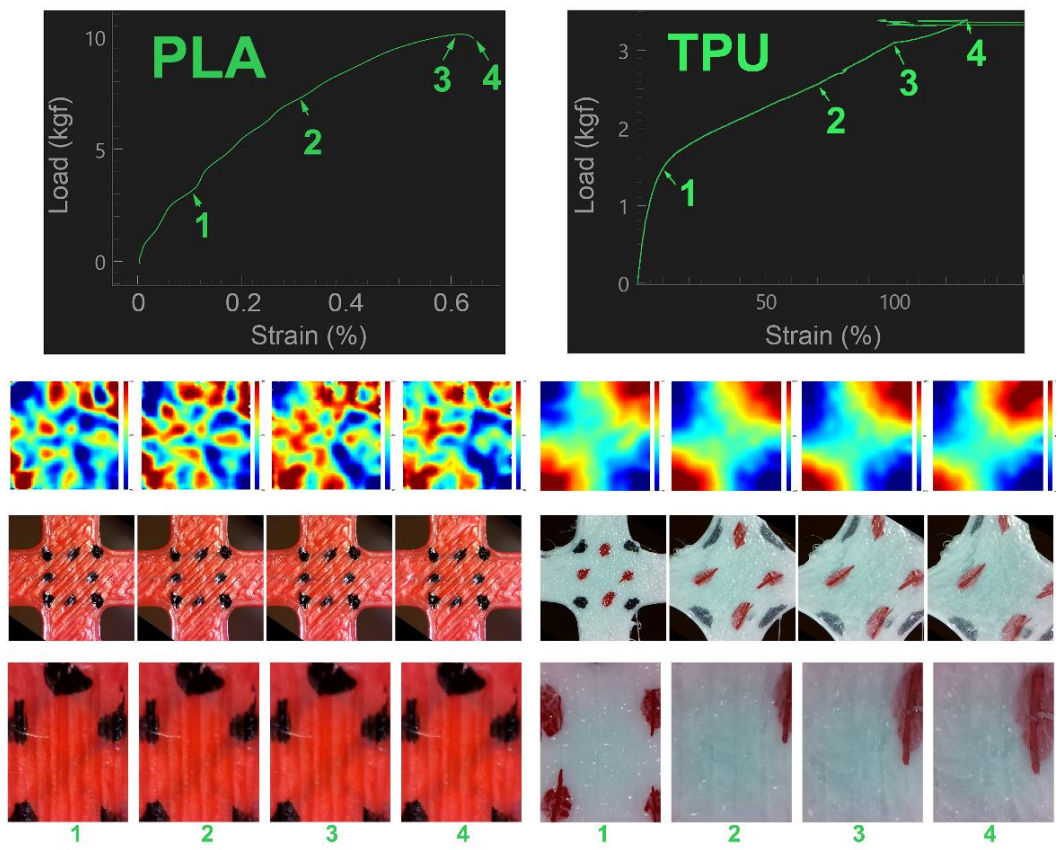


Figure 3 PLA/TPU stress–strain response, shear-strain maps, and global/detail micrographs.

Conclusions

PLA and TPU followed distinct strain-localization pathways, strongly influenced by sheet thickness.

Full-field maps revealed strain partitioning and localization absent from force–displacement curves.

Catastrophic damage initiation was material-dependent, occurring at high-shear external surfaces in TPU and at interbead regions in PLA.

The open hardware pipeline's computer vision algorithms enable low-cost testing of high-heterogeneous materials.

References and acknowledgments

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