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INVESTIGATING SHEAR PERFORMANCE OF PMCS

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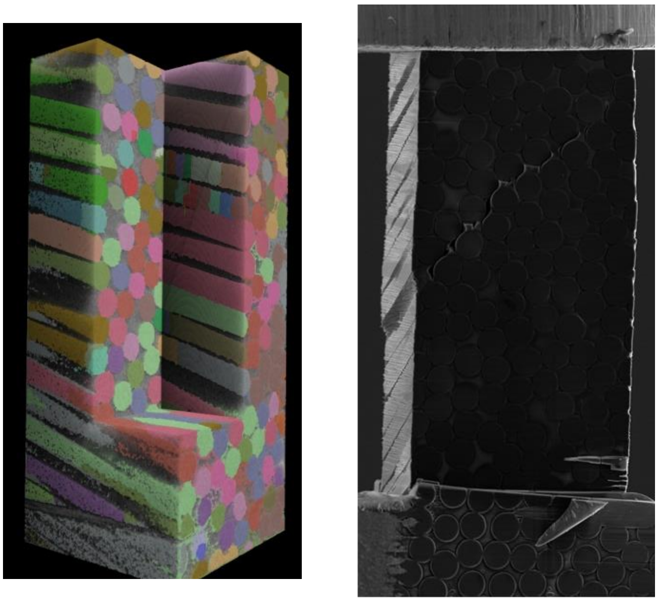
ABSTRACT

Understanding the shear performance of polymer matrix composites (PMCs) using a multiscale methodology requires novel in situ experimental techniques at each length scale. One limitation of the multiscale paradigm is inadequate experimentation at the microscale. In addition, limited investigation exists at the mesoscale to understand progressive damage phenomena. And lastly, although new experimental methods are required for in situ damage prognosis, many still need to provide the means of standardization. This study provides basic knowledge of microstructural instabilities, mesoscale damage prognosis, and the influence of size effects on PMCs while under shear loading.

Micromechanical experiments utilized transverse compressive approaches to investigate shear [1]. One subtle difference is that the fibers were purposefully angled (70°, 45°, 20°) during the fabrication process of the micropillar. A digital twin of the microstructure is reconstructed using X-ray ηCT, and progressive failure is captured using scanning electron microscopy (Figure 1). The experiment provides the capability to observe fiber/matrix debonds, axial matrix cracks, and instabilities (in the form of sliding) while under combined compression/shear loading mechanisms.



a) b)

Figure 1 a) Segmented X-ray nCT image of pristine microstructure showing angled fibers and b) in situ SEM image of microstructure prior to failure.

Mesoscale experimentation harnessed the power of shape optimization to capture failure phenomena using X-ray µCT analysis [2]. The novel modified butterfly notch geometry enables the assessment of damage states at different loading increments (50%, 75%, 90%) with minimal invasive fixturing.

Implementing AI/ML enables the characterization of damage initiation and progression. The experiment allows observing a quasi-static laminated sequence's matrix cracks, delamination, and fiber breakage under shear loading.

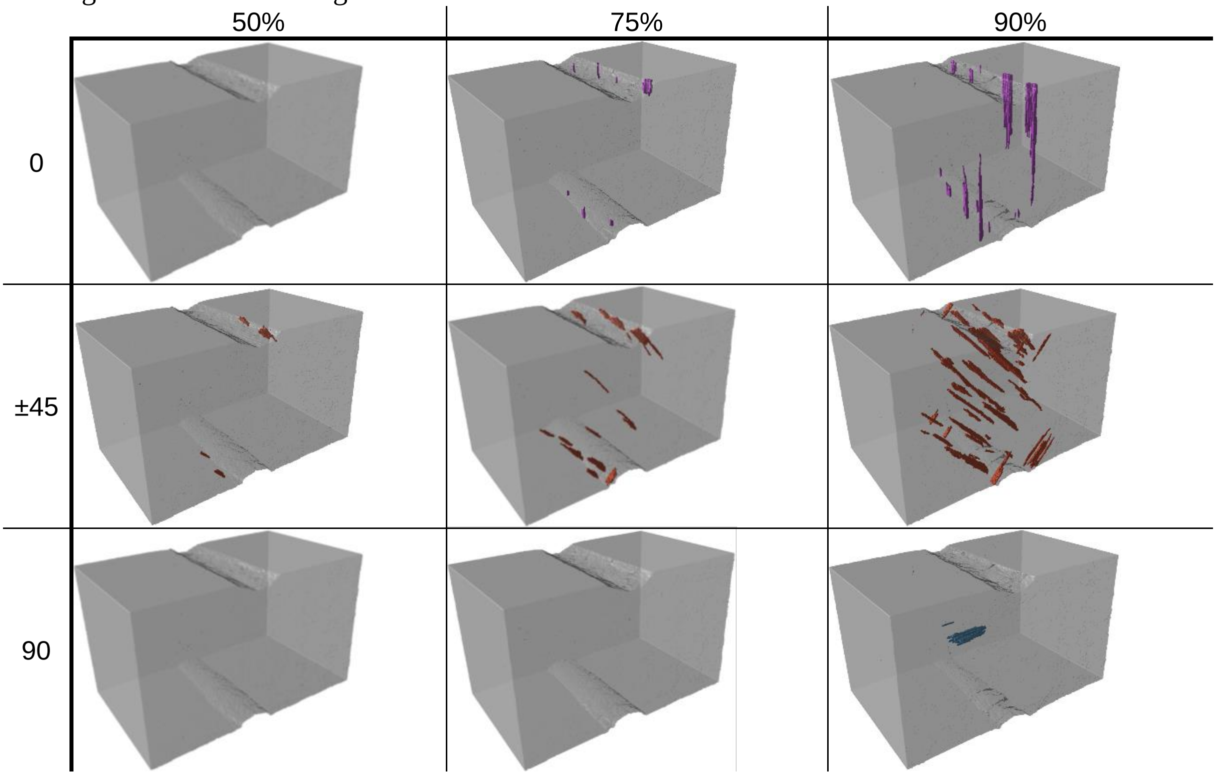
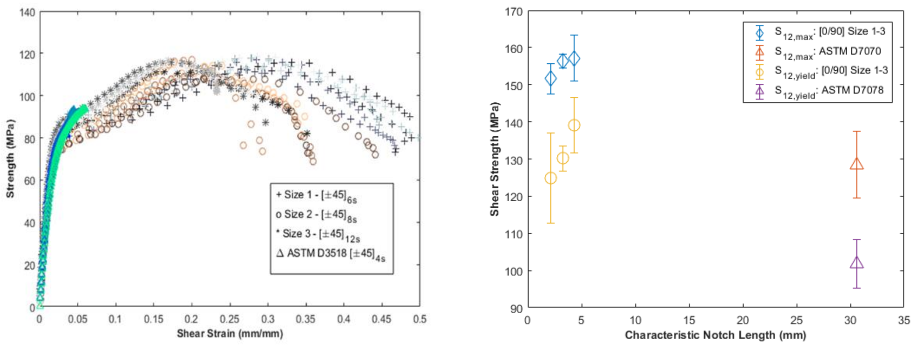


Figure 2: Progressive damage of matrix cracks using image segmentation techniques and machine learning

Any coupon experimentation should be capable of being performed at any geometrical size. Therefore, a size-effect study on the novel geometry was conducted and compared to ASTM experiments. The experimental outputs of the new geometry came into close agreement with standard approaches. This study aims to show a multiscale experimental approach to investigating the shear properties of PMCs.



a) b)

Figure 2: Size effect analysis on the butterfly notch experiment a) stress vs strain and b) strength

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