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A FDM-based experimental benchmark for evaluating fatigue crack propagation in anisotropic linear elastic materials

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Abstract

Understanding crack propagation in anisotropic materials is a key challenge for the reliable design of structural components subjected to cyclic loading, particularly in safety-critical applications. This issue is especially critical for materials whose anisotropy is induced by their manufacturing process, such as additively manufactured polymers, where the orientation of deposited material can strongly influence fracture properties and damage evolution. Despite the growing industrial interest in these materials, the lack of well-validated experimental benchmarks still limits the rigorous assessment and validation of fatigue crack propagation models capable of accounting for anisotropic fracture behavior. In this work, we propose a new experimental benchmark, instrumented by Digital Image Correlation (DIC), dedicated to the evaluation of fatigue crack propagation models in anisotropic linear elastic materials. The benchmark relies on Compact Tension specimens manufactured by Fused Deposition Modeling (FDM) using polycarbonate filaments, with different build orientations. The versatility of the printing process is exploited to generate specimens exhibiting a pronounced directional dependence of fracture toughness, while maintaining controlled and repeatable microstructural features. The experimental configurations are specifically designed to remain within the framework of two-dimensional Linear Elastic Fracture Mechanics

(LEFM). Detailed analysis of experimental results shows that, under these conditions, the crack propagation behavior is not influenced by the build orientation, despite the strong anisotropy in fracture resistance [1]. Beyond its role as a benchmark for model validation, this experimental campaign provides a controlled and well-instrumented framework to improve the fundamental understanding of crack propagation mechanisms in anisotropic materials. The insights gained are expected to be relevant not only for FDM-printed polymers, but more broadly for anisotropic materials produced by advanced manufacturing routes.

Keywords:

Linear elastic fracture mechanics (LEFM) Additive manufacturing Fused deposit modeling (FDM)

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