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Concurrent Design of Composite Structure and Continuous Toolpath for Additive Manufacturing of Fiber-Reinforced Polymer Composites

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ABSTRACT

The advancement of continuous fiber-reinforced polymer additive manufacturing (CFRP-AM) enables the fabrication of structures with complex geometries and superior properties. However, current design methodologies consider toolpath design and structure optimization as separate stages, with toolpath design typically serving as a post-processing step after structure optimization. This sequential methodology limits the full exploitation of fiber reinforced polymer composites (FRPC) capabilities, particularly in achieving optimal structural integrity and manufacturability. In this paper, a manufacturing-oriented method is proposed for designing continuous FRPC structures, in which the structural layout and continuous fiber toolpaths are simultaneously optimized. The integrated design with manufacturable fiber toolpaths is achieved by a scalar field projection topology optimization (SFPTO) method, where the scalar field projection is used to simulate periodic and continuous toolpaths. Given the scalar field corresponding to the geometry layout and toolpaths, the gradients of the field are formulated as the design variables in a compliance minimization problem and solved with a non-convex gradient-based optimization scheme. The ability of the proposed approach to handle integrated optimization of material densities and continuous toolpaths on both single and multiple load case scenarios is demonstrated. The results show that the proposed approach bridges the gap between structural integrity and precise toolpath planning, providing a comprehensive framework for the concurrent optimization of CFRP-AM.

KEYWORDS

Topology optimization; scalar field projection; toolpath planning; fiber reinforced polymer composites; additive manufacturing

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