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Topology Optimization of Lightweight Structures Tailored for Non-Planar Additive Manufacturing

Van Dung Nguyen[1], Erin Kuci[2]

[1] Centre de recherche en aéronautique (Cenaero), Belgium. vandung.nguyen@cenaero.be
[2] Centre de recherche en aéronautique (Cenaero), Belgium. erin.kuci@cenaero.be

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Abstract

Additive manufacturing offers the possibility of fabricating complex structures. However, conventional single-axis and layer-wise fabrication imposes significant manufacturing constraints that limit both structural performance and design efficiency. Overhang restrictions require the use of support structures, which can adversely affect the mechanical behavior of 3D-printed components. Non-planar additive manufacturing can alleviate these limitations by enabling continuous reorientation of the build direction during additive manufacturing process, expanding the feasible design space, and reducing the need for support mechanisms. Our work focuses on the development of a topology optimization framework for non-planar additive manufacturing. The proposed method incorporates overhang constraints defined with respect to varying build directions, enabling the generation of support-free designs compatible with non-planar fabrication strategies. The framework is implemented within a hybrid density-based and level-set topology optimization scheme [1,2], where manufacturability constraints are directly enforced throughout the optimization process. This ensures that the resulting designs are both structurally efficient and directly manufacturable. Multiple case studies are considered to assess the performance of the proposed approach. The obtained results show that the mechanical performance of the 3D printed component is improved without the need for support structures.

Keywords:

Topology Optimization Levelset Non-Planar Additive Manufacturing Lightweight Structures

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