

Multi-scale Topology Optimization of Thermoplastic Composites targetting Freeform Manufacturing

Erin Kuci¹, Van Dung Nguyen²

¹ CENAERO, Belgium. erin.kuci@cenaero.be

² CENAERO, Belgium. vandung.nguyen@cenaero.be

Paper ID: 532

[Symposium S6: Additive manufacturing: challenges and solutions](#)

Abstract

Thermoplastic composites offer the key advantage of recyclability, but their use is often constrained by the high cost of moulds. Although additive manufacturing removes the need for moulds, conventional 3D printing is typically limited to planar, layer-by-layer deposition. Freeform (non-planar) additive manufacturing overcomes this restriction by enabling continuous reorientation of the build direction during fabrication. In this work, we extend multi-scale topology optimization to fully exploit the anisotropic behavior of composite materials. We propose a topology optimization framework implemented within our proprietary finite element software, Morfeo [1]. High-performance designs are achieved by incorporating multiple design variables, enabling the integration of lattice architectures within the optimization process [2,3]. At the mesoscale, dedicated design variables are used to parameterize the lattice substructure. At the macroscale, the lattice is implicitly represented through an equivalent material model obtained via homogenization. The optimization problem is formulated using a hybrid approach that combines density-based and level-set XFEM methods. The level-set formulation ensures accurate representation of boundaries and stress fields, while the density field facilitates hole nucleation during optimization. Stress constraints are also incorporated to preserve mechanical integrity under deformation. Finally, leveraging the flexibility of our optimization solver, we compare the performance of the resulting structures under different modeling assumptions and material descriptions, including isotropic and anisotropic lattice behaviors.

Keywords:

Freeform Manufacturing multiscale topology optimization lattices composites structures

References:

- [1]MORFEO. A manufacturing oriented finite element software, Cenaero, Belgium. <http://www.cenaero.be>
- [2]Jansen, M., and O. Pierard. A hybrid density/level set formulation for topology optimization of functionally graded lattice structures." Computers & Structures 231 (2020): 106205.
- [3]Jansen, Miche, Olivier Pierard, and Nicolas Poletz. "Topology optimization of additive manufacturing components with lattice structures for multiphysics applications." International Journal for Multiscale Computational Engineering 20.1 (2022).