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ABSTRACT

Concurrent Topology Optimisation Framework for Minimum Compliance: Formulation, Implementation and Experimental Validation

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This work presents an optimisation framework based on topology optimisation, employing a concurrent optimisation procedure where two design variables are defined for each element on the mesh. The framework is applied to two distinct scenarios: In the first scenario, an orthotropic material is considered to optimise both topology and fibre angle concomitantly to minimise the compliance of carbon fibre-reinforced polymer structures. The optimisation is constrained by admissible volume fractions of material inside the design domain, with analyses performed on two classical benchmark cases: 3-point and 4-point bending loading scenarios. The optimum topologies are manufactured using the fused filament fabrication (FFF) 3D printing method and validated experimentally. The results are also compared to optimal topologies for isotropic materials, demonstrating the superior stiffness and strength of the optimised orthotropic designs.
In the second scenario, an optimisation procedure is developed to distribute hollow spheres in a structure to minimise compliance using a multiscale approach. The method is constrained by an admissible relative density and incorporates geometrical parameters—internal and external diameters—whose effective properties are predicted via the asymptotic homogenisation method (AHM). Experimental tests on 3D-printed structures validate the approach, showing that optimised designs significantly outperform homogeneous distributions of hollow spheres with the same relative density. Both frameworks underscore the potential of topology optimisation combined with concurrent design approaches to advance lightweight and high-performance structures, particularly in the context of additive manufacturing.