

TOPOLOGY OPTIMIZATION OF 316LSI STAINLESS STEEL STRUCTURES PRODUCED BY CMT-WAAM

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Abstract

Additive manufacturing enables the production of metallic components with complex geometries while allowing control of material properties through appropriate selection of process parameters. These capabilities make additively manufactured metallic structures particularly well suited for topology optimization as both geometry and mechanical behaviour can be adapted to functional requirements. Wire-arc additive manufacturing processes (WAAM), in particular, enable the fabrication of near-net-shape metallic parts while maintaining high geometric flexibility.

This work investigates topology optimization of metallic structures manufactured using additive processes. The analyzed material is 316LSi stainless steel fabricated using Cold Metal Transfer Wire Arc Additive Manufacturing (CMT-WAAM). Due to the layer-by-layer deposition and the complex thermal cycles inherent to the WAAM process, the material develops a direction-dependent microstructure that results in anisotropic mechanical behaviour. Consequently, the elastic material properties obtained in uniaxial tensile tests depend on the sample orientation relative to the deposition direction. Experimental characterization of the considered material indicates orientation dependence of both Young's modulus and Poisson's ratio, with the anisotropy being particularly pronounced for the Poisson's ratio. Furthermore, it has been shown that these orientation dependencies can be well described using an orthotropic linear elastic model calibrated using experimentally determined elastic constants corresponding to different orientations relative to the deposition direction; i.e. values of Young's modulus for the orientations 0°, 45° and 90° and Poisson's ratio for the orientation 0°. In this work, topology optimization is performed for simple structures of the analyzed WAAM produced material for different

boundary conditions and loading configurations while assuming the plane stress conditions and the elastic material behaviour. The optimization is performed using the 88-line MATLAB code, which originally employs an isotropic elastic linear material model. To account for the anisotropic behaviour of the material, an orthotropic elastic linear material model is implemented in the code. Structural layouts are obtained using the Bi-directional Evolutionary Structural Optimization (BESO) algorithm, which iteratively removes and adds finite elements to maximize structural stiffness under a prescribed volume constraint.

By performed analysis, the influence of the material model, loading orientation relative to the material deposition direction and the prescribed volume constraint on the resulting optimal topologies is investigated. The results demonstrate that the constitutive model of the additively manufactured material affects the optimization outcome. The isotropic and orthotropic material model resulted in noticeable different optimal material distribution. The presented approach demonstrates the application of the BESO topology optimization algorithm to structures made of experimentally characterized orthotropic WAAM material, providing insight into the interaction between manufacturing induced material anisotropy and optimal structural layouts.