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Coupled Two-Scale Material Optimization for Lattice Structures using different upscaling techniques

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Abstract

A coupled two-scale material optimization approach in linear elasticity using lattice structures is presented. In a previous work [1], a coupled two-scale material optimization problem using homogenized lattice structures is presented. In the current work, the homogenization as upscaling formula is replaced by a modified multiscale finite element method (MSFEM), based on [2].

For a chosen base cell, a macroscopic element stiffness matrix is calculated from a microscopic scale with the help of MSFEM or homogenization. The shape of the cell is varied by several design parameters. For computational efficiency, a MSFEM/homogenization material catalogue is precomputed for a discretized set of design values beforehand. During the optimization, called online phase, the values of the design parameters on each cell are mapped C^1-continuously to their macroscopic quantities. The solutions of the optimization method can be interpreted as continuously connected lattice structures suitable for additive manufacturing.

Additionally, regularization techniques are added which not only yield to existence of an optimal solution, but also control how fast the local microstructure can vary from point to point in the macroscopic domain.

The usage of coarse macroscopic meshes is essential in this approach, since the overall featuresize of the lattice structure is often limited by manufacturing constraints. Consequently, both upscaling techniques are analyzed by focusing on their suitability for relatively coarse lattice structures.

Finally, numerical compliance optimization results are shown and validated for MSFEM and homogenization as upscaling method. Since SIMP solutions provide an upper bound for the two-scale results, the two-scale structures are compared with SIMP designs for multiple load cases.

References

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[2] M. Buck, O. Iliev, H. Andrä, Multiscale finite element coarse spaces for the analysis of linear elastic composites, Fraunhofer ITWM report, 2012.