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Topology optimised design of robust material microstructures without length scale separation

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ABSTRACT

The work focuses on applying topology optimisation to the design of periodic material microstructures without length scale separation, i.e. considering the complete macroscopic structure and its response, while resolving all microstructural details as compared to the often used homogenisation approach. The approach takes boundary conditions into account and ensures connected and macroscopically optimal microstructures regardless of the difference in micro- and macroscopic length scales.

Dealing with the complete macroscopic structure and its response is computationally challenging as very fine discretisations are needed in order to resolve all microstructural details. This work therefore explores the application of a contrast-independent spectral preconditioner based on the multiscale finite element method (MsFEM) [1,2,3] to large structures with fully resolved microstructural details.

Furthermore, the methodology is applied to the design of structures with multiple blocks of locally periodic microstructures. This is achieved by splitting the design domain into subdomains in which a unique locally periodic microstructure is designed. Smoothly connected microstructures, both within the subdomains and across their interfaces, are obtained by considering the full macroscopic problem and by imposing periodicity and connectivity constraints on the optimised design.

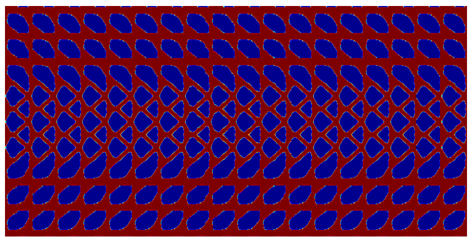
Figure 1: Optimised blocks of locally periodic micro-structures for a short cantilever beam subjected to distributed transverse loading along right-hand side.

The topology optimisation is carried out using the density-based approach combined with a Heaviside projection and a stochastic robust formulation [4]. The methodology is applied to several two-dimensional problems considering minimisation of the macroscopic compliance, corresponding to the maximisation of the stiffness of the macroscopic structure. All of the considered problems are modelled using linear elasticity.

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