Computational design of engineering materials: an integrated approach for multi-scale topological structural optimization

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ABSTRACT

Multiscale topological material design, aiming at obtaining optimal distribution of the material at several scales in structural materials is still a challenge. In this case, the cost function to be minimized is placed at the macro-scale (compliance function) [1], but the design variables (material distribution) lie at both the macro-scale and the micro-scale [2]. The large number of involved design variables and the multi-scale character of the analysis, resulting into a multiplicative cost of the optimization process, often make such approaches prohibitive, even if in 2D cases.

In this work, an integrated approach for multi-scale topological design of structural linear materials is proposed. The approach features the following properties:

• The “topological derivative” is considered the basic mathematical tool to be used for the purposes of determining the sensitivity of the cost function to material removal [3]. In conjunction with a level-set-based “algorithm” [4] it provides a robust and well-founded setting for material distribution optimization [5].

• The computational cost associated to the multiscale optimization problem is dramatically reduced by resorting to the concept of the online/offline decomposition of the computations. A “Computational Vademecum” containing the micro-scale solution for the topological optimization problem in a RVE for a large number of discrete macroscopic stress-states, is used for solving that problem by simple consultation.

• Coupling of the optimization problem at both scales is solved by a simple iterative “fixed-point” scheme, which is found to be robust and convergent.

• The proposed technique is enriched by the concept of “manufacturability”, i.e.: obtaining sub-optimal solutions of the original problems displaying homogeneous material over finite sizes domains at the macrostructure: the “structural components”.

The approach is tested by application to some engineering examples, involving minimum compliance design of material and structure topologies, which show the capabilities of the proposed framework.

REFERENCES