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# ON MACRO/MICROSTRUCTURE OPTIMIZATION TECHNIQUES IN MULTISCALE COMPUTATIONAL MATERIAL DESIGN

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Computational design of engineering materials accounting for their microstructure has gained considerable interest in the computational mechanics community. Whereas one-scale optimization techniques (i.e. macroscopic topology and material arrangement of structures) are nowadays relatively well established, simultaneous, hierarchically coupled, optimization of both scales is a promising research subject deserving further exploration. This work is an attempt to evaluate the performance of a numerical tool based on:

a) A description of the multiscale material behaviour using a two-scale homogenization procedure [1].

b) A continuum, gradient-based, optimization scheme based on the interior point method [2].

c) Optimal design of the microstructure topology and arrangement using SIMP (Solid Isotropic Material with Penalization) techniques [3].

d) Optimal design of the macrostructure topology coupled with the optimal arrangement of components at the microstructure.

In this scenario, a preliminary exploration of a computational scheme for optimization of the arrangement of the material components in the microstructure, coupled with the topology optimization at the macrostructure is presented.

In a first step, the microstructure topology is considered fixed, and the material properties of the components (e.g. the Young modulus) are continuously described by means of a “density-like” parameter, similarly to what is done in well-established single-scale topological optimization procedures [3]. Then, values of that parameter, for all components in the RVE and, are considered as the “design variables” (lying in the micro-scale). In addition, the objective function is defined at the macro-scale (e.g. minimum weight, minimum compliance etc.), which, together with some restrictions, defines the optimization problem.

Solution of this problem provides: a) a description of the optimal microstructure arrangement in every RVE, in terms of the distribution of the density-like parameter, b) the macroscopic, RVE-averaged, values of that parameter, supplying an indicator of the optimal topological description of the macrostructure. Therefore, this results into a combined two-scale optimization procedure, simultaneously providing the optimal microstructure arrangement at every point of the macrostructure and the optimal structure topology.

A number of representative numerical simulations show the performance and possibilities of the

proposed method.

## REFERENCES

[1] J.A. Hernández, J. Oliver, A.E. Huespe, M. Caicedo. High-Performance Model Reduction Procedures in Multiscale Simulations, Monograph CIMNE 127, 2012.

[2] Byrd, R.H., Mary E. Hribar, and Jorge Nocedal, "An Interior Point Algorithm for Large-Scale Nonlinear Programming, SIAM Journal on Optimization," SIAM Journal on Optimization, Vol 9, No. 4, pp. 877–900, (1999).

[3] Bendsøe, M.P., Sigmund, O., Topology Optimization Theory, Methods and Applications, Springer (2003).