Computational design of microstructure for structural optimization

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ABSTRACT

This work is addressed to the optimization of the macroscopic mechanical response of a body by altering the parameters that define the micromechanical response of the material, which is allowed to vary throughout the body. Mathematically speaking, it is an optimization problem where the goal function depends on the macroscopic displacement field and the design variables are the (micro-)parameters defining the microstructure at a series of sampling points embedded in the body.

The macroscopic mechanical problem is solved using the finite element method, where each node of the mesh is allowed to have a different microstructure, characterized by a finite (usually few) number of micro-parameters.

As an example of application, we consider a fibrous microstructure made of straight rigid fiber bundles, with a rather flat elliptical cross section. Fibers are assumed to have a perfectly planar orientation and motion, and to be linked by punctual elastic joints, which leads to a macroscopic continuum of elastic nature. Using a numerical implementation of such a local discrete homogenization model, rheological functions of a fully explicit orthotropic macroscopic planar model were identified [1], showing that the very complex heterogeneous nature of such random fiber networks could be properly described by three micro- parameters: main orientation, orientation intensity and fiber fraction.

Finally, an optimization problem is solved to determine the optimal distribution of microstructure throughout a given structure in order to minimize or maximize the stiffness of the structure under a given load. Optimization cases where a local stress concentration is minimized are also discussed.

REFERENCES

[1] C. Marullier, Etude multi-échelles des couplages entre les propriétés hygroélastiques des papiers et leur microstructure, PhD thesis, Univ. Grenoble I, France (2013).