Shape optimization of bimaterial periodic microstructures subject to stiffness and local stress constraints

L. Noël, L. Van Miegroet and P. Duysinx
University of Liege: Department of Aerospace and Mechanical Engineering
Chemin des Chevreuils 1, B52, 4000 Liege, Belgium
Corresponding author: Lise.Noel@ulg.ac.be

Sigmund [2] showed that material tayloring could be formulated as a structural optimization problem. Most of the work available in the literature is based on a compliance-type formulation.

Microstructural geometries can be rather complex. Level Set description is an efficient way to deal with complex microgeometries, especially when dealing with realistic data coming from imaging. Discontinuities, holes or inclusions can be efficiently described by Level Sets. In addition, fixed mesh methods and non conforming finite element approximations such as the extended finite element method (X-FEM) coupled with Level Set description of geometries can further present several advantages [1] to study those difficult problems.

Using a classical finite element method approach (FEM) to perform shape optimization also raises important remeshing problems. Each modification of the geometry leads to systematic remeshing to keep an undistorted and conforming mesh. Recently Van Miegroet [3] developed an interesting approach based on Level Set description and X-FEM approach for shape optimization. The parameters of Level Sets features can be considered as design variables, while design problems can be formulated as optimization problems including various global and local restrictions (compliance, displacement, stresses . . .).

In this paper we extend the previous work to tackle the problem of microstructural design under both stiffness and strength constraints. The shape of microstructural inclusions and defects will be parameterized. X-FEM method enables considering void-solid as well as bimaterial microstructural geometries. The material tailoring problem is formulated as a shape optimization problem subject to effective properties constraints and later considering bounds over local stresses in the microstructures under specific prescribed macroscopic strain fields.

The developments will be illustrated on several academic test cases. At first we revisit the classical problem of shape optimization of microstructures design investigated by Vigdergauz [4]. The analytical optimal shape of a single inclusion can be recovered using numerical optimization in a very flexible way. Then the microstructural optimization is extended to tailor effective properties with the control of local responses at the microstructural scale. Applications considering stiff/soft inclusions are also investigated.

On-going work investigates the presence of damage inclusions modeled as very weak material inclusions introduced in the microstructure. Shape optimization of 3D microstructures is also expected.

References

[1] N. Moes, M. Cloirec, P. Cartraud, and J.-F. Remacle. A computational approach to handle complex microstructure geometries. *Computer Methods in Applied Mechanics and Engineering*, 192:3163 – 3177, 2003.

[2] O. Sigmund. Materials with prescribed constitutive parameters: An inverse homogenization problem. *International Journal of Solids and Structures*, 31(17):2313 – 2329, 1994.

[3] L. Van Miegroet and P. Duysinx. Stress concentration minimization of 2d filets using x-fem and level set description. *Structural and Multidisciplinary Optimization*, 33(4):425–438, 2007.

[4] S. Vigdergauz. The effective properties of a perforated elastic plate numerical optimization by genetic algorithm. *International Journal of Solids and Structures*, 38:8593 – 8616, 2001.