Stress minimization of lattice structures

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In the recent years, additive manufaturing has allowed to build complex geometries with a small minimum length scale (lattice structures). This manufacturing revolution has directly impacted on the field of topology optimization, enabling the classical homogenization techniques to resurrect. This is the case of the recent work [1] where optimal lattice structures have been obtained when minimizing compliance. In this work, we follow the techiniques developed in [1] but we focuse on controlling the stress norm of the structure, one of the kew aspects in structural design. In this case, the main idea is to consider, in the homogenization theory, the stresses appeared in the micro-structure. For that propose, the macro-scopic stresses are corrected via the amplifactor tensors. In this sense, we extend the results obtained in [2] (rank-q laminates) for the case of lattice structures.

As in work [1], the microstructure is described by two geometrical parameters and the orientation of the cell. However, in this case, we propose a smooth geometry of the microstructure to reduce stress concentration. The optimization process is divided in three steps. **Step 1.** For a wide number of parameters, we compute and save the homogenized material properties of the microstructure (amplificators, homogenized constitutive tensor and fraction volume). This pre-computed data jointly with a linear interpolation forms what we call the computational Vademecum. **Step 2.** The considered optimization problem (stress norm as cost and volume as constraint) is solved by using a standard projected gradient for updating the microstructural parameters. For the orientation of the cell, we propose to align it with the principal stress direction following the results obtained in [1]. This choice comes from an accurate analysis of the amplificators components. **Step 3.** Finally, we proceed with the deshomogenization process [1]. Basically, it consists in the description of the geometry via a level-set function which depends on the micro-scopic coordinates and parameters. The first depends on the micro-scopic coordinate $y = x/\varepsilon$ while the second on the macro-scopic coordinate x. Some geometrical techniques are then considered to avoid singularities in the orientation field.

The work ends showing several numerical results. First, the values of the amplificators for the proposed smooth micro-scopic geometries will be compared with a non-smooth ones. Finally, the optimization process for both cases and the optimal deshomogenized structures will be shown.

References

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[2] G Allaire, F Jouve, and H Maillot. "Topology optimization for minimum stress design with the homogenization method". In: *Structural and Multidisciplinary Optimization* 28.2-3 (2004), pp. 87–98.