Tuning effective dynamical properties of periodic media by FFT-accelerated topological optimization

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Abstract

We are interested in the dynamics of two-phase periodic materials, whose phase distribution is optimized to obtain specific dispersive properties (typically, to maximize the dispersion in given directions of wave propagation). The presented study [1] concerns 2D scalar waves (e.g. acoustic or transverse shear waves), and sets a framework for future extensions to 2D and 3D elastic waves and to applications to the control of these waves.

We propose an algorithm that relies on several mathematical and numerical tools. First, we use the two-scale asymptotic homogenization method, up to the second-order, to obtain an effective dispersive model valid for low and medium frequencies. From this model, one can define simple dispersion indicators and cost functionals to be minimized to achieve certain goals.

This minimization is performed thanks to a topological optimization algorithm [2], which relies on the concept of topological derivative (TD) of the cost functional. The TD quantifies the sensitivity of the functional to a localized phase change in the unit cell, and therefore indicates optimal locations where to perform these phase changes. The TD of the cost functionnal can be computed from the TDs of the coefficients of the homogenized model, whose expressions were determined in a previous work [3].

Finally, the cell problems underlying the homogenized model, whose solutions are needed to compute the TDs at each iteration, are solved thanks to FFT-accelerated solvers [4].

Tuning effective dynamical properties of periodic media by FFT-accelerated topological optimization,
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