Computational multiscale analysis of mechanical and dynamical metamaterials

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ABSTRACT

Engineering analyses of structures and devices call for efficient numerical methods that accurately capture the behaviour of the constituting materials. For highly heterogeneous materials, homogenization methods substitute the heterogeneous microstructure by an effective continuum that can be solved at the engineering level. Among the plethora of homogenization methods, computational homogenization constitutes a powerful tool to establish a two-scale coupling of complex nonlinear materials. Whereas the method has been used for a variety of problems, a new challenge arises when metamaterials are considered. Metamaterials reveal microstructures that induce a pronounced emergent effect at the macro-scale. This contribution focuses on the advanced homogenization of dynamical and mechanical metamaterials.

Dynamical metamaterials are for instance used for inhibiting sound and vibration transmission in a wide frequency range. First, a computational homogenization scheme applicable to resonant acoustic metamaterials will be outlined [1]. Exploiting linearity, a closed form micromorphic continuum homogenization approach for this class of materials is obtained. The corresponding dispersion spectra are accurately captured, and the solution of initial boundary value problems is thereby at reach. As a special case of dynamical metamaterials, metafoams will be presented [2]. Metafoams are a special class of foams combining thermo-viscous dissipation with local resonance. Direct numerical simulations and the homogenization of these metafoams (extracting relations between microstructure and effective properties) are demonstrated.

Spatial micro-scale fluctuation fields also emerge in mechanical metamaterials, driven by elastic instabilities. Mechanical metamaterials do not trivially satisfy the classical scale separation principle that underlies conventional homogenization strategies. Upon loading, these microstructures develop fine scale fluctuation patterns that directly influence the coarse scale behaviour. Exploiting a kinematical ansatz that incorporates the microstructural patterns, a micromorphic continuum is recovered [3].

The key aspects of the different homogenization methods and the resulting (emergent) continua will be highlighted, whereby several demonstrative examples will be shown.

REFERENCES

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