Congress on Numerical Methods in Engineering CMN2017
Valencia, 3–5 July, 2017

Computational homogenization procedure for acoustic problems

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ABSTRACT

In the past couple decades, there has been a growing interest among the scientific community on the concept of acoustic metamaterials. These are artificially engineered structures designed to achieve unusual dynamical properties otherwise not present in naturally occurring materials. In this context, computational methods offer a powerful tool to enable a complex, sophisticated design of such materials for several targeted applications. As a first step towards this aim, a general multiscale framework based on homogenization theory which accounts for inertial effects is proposed in this work. In contrast to similar recent approaches currently found in the literature, the model presented here is grounded on the application, at each scale, of the classical postulates of continuum mechanics, namely the linear and angular momentum balance laws, in addition to mass and energetic (mechanical power) equivalence between scales. This retrieves, as a consequence, the variational form of the Hill-Mandel principle which is otherwise used in other works [1, 2] as the base postulate upon which the homogenization theory is build. Then, although the results are mostly equivalent in all cases, the *primitive* and *physical* character of the present approach allows for a direct interpretation of the resulting equations and constitutes a solid departing point for further generalizations. The resulting variational principle of the micro-macro coupling is expressed in terms of Lagrange multipliers which are used to directly identify the expression of the homogenized macroscopic stress and inertial terms. The framework is specifically tailored for the study of Locally Resonant Acoustic Metamaterials (LRAM). In this regard, the proposed methodology offers a clear interpretation that allows us to simplify the model by simply employing physical hypotheses based on the separation of scales. These assumptions are used to split the fully coupled micro-macro set of equations into a quasistatic and an inertial system. The information provided from the inertial system considering only the dominant vibration modes has proven to accurately capture the influence of local resonance phenomena at the macroscopic scale. The model has been assessed by performing dispersion studies considering the proposed multiscale scheme and full Direct Numerical Simulation (DNS) concerning both homogeneous and heterogeneous macroscopic material layers composed of resonating microstructures.

REFERENCES

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