Multi-scale asymptotic computations for piezoelectric modal problem of perforated composites

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Abstract

A novel multi-scale asymptotic finite element algorithm by the Second-Order Two-Scale (SOTS) analysis method is proposed for the piezoelectric modal problem in periodically perforated domain. The piezoelectric eigenvalue problem is formulated in perforated domain with periodic coefficients. Then by the multi-scale asymptotic expansion method, the eigenfunctions and eigenvalues are expressed in the power series of periodicity to the second-order terms. The homogenized modal equations, the effective material coefficients and the first- and second-order correctors of the eigenfunctions are derived. The homogenized constitutive matrix are the same as the one in the corresponding static piezoelectric problem. The eigenvalues are obtained by the so-called “corrector equation”, and the first- and second-order correctors are calculated in terms of the integration forms of the correctors of the eigenfunctions. Analytical expressions of the homogenized material coefficients are obtained for the laminated composites and the finite element procedures to numerically compute the homogenized solutions and the correctors are established. Numerical experiments are carried out for one and two dimensional perforated domains. It is validated that the SOTS analysis method is effective to identify the piezoelectric eigenvalues of the porous structures and the original eigenfunctions for both the displacement and the electric potential field can be reproduced by adding the correctors to the homogenized solutions.

Keywords: piezoelectric modal analysis; Porous composites; periodic configuration; asymptotic expansion homogenization; finite element simulation