Optimization of multi-functional laminates by a spectral element method

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Abstract

The optimization of the thermal and sound insulation properties of multi-functional laminates and geometrically complex structures is computationally expensive. Even efficient multi-objective optimization algorithms, like genetic algorithms, require a vast amount of calculation iterations to find an optimal or nearly optimal solution. Multi-functional optimization, therefore, requires efficient and accurate methods to calculate the thermal and the acoustic properties. While this is relatively easy to achieve for determining the thermal insulation properties of a multi-layered structure, an accurate calculation of its sound insulation capabilities requires the solution of a strongly coupled fluid-structure interaction problem for a large number of frequencies in a wide range. In this paper, a spectral element method (SEM), which is a variant of the finite element method (FEM) by using high-order shape functions with non-equidistant node distributions, is presented in order to solve the arising fluid-structure interaction problems with a minimum of required degree of freedoms (DOFs), hence reducing the computing time for solving the linear system of algebraic equations while maintaining a high accuracy. The solution procedure is formulated in the frequency domain and a mixture of increasing the polynomial order of the shape-functions and the number of the elements is used. Possible techniques for reducing the computational effort, e.g. the one-way coupled approximation or the two-dimensional models, are presented and discussed. Numerical examples for some optimized structures are shown, and the accuracy and efficiency of the present spectral element method are compared with that of the commercial FE software.

Keywords: Spectral element method, Multi-functional optimization, Multi-layered laminates, Acoustic and thermal insulation, Fluid-structure interaction