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Microstructural topology optimization of viscoelastic materials for maximum modal loss factor of macrostructures

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Abstract

The geometric layout and physical properties of a viscoelastic damping material have a significant influence on the damping performance of a passive constrained layer damping (PCLD) structure. This paper presents a two-scale optimization method and aims to find the optimal microstructural configuration of the viscoelastic material (i.e. the optimal effective properties of the material) with maximum modal loss factors of the macrostructures. The modal loss factor is obtained by using the Modal Strain Energy (MSE) method. The material microstructure is assumed to be homogeneous in the macro-scale, i.e. the macrostructure is composed of periodic unit cells (PUC). In the optimization formulation, the relative densities are introduced as the design variables for the material microstructure design, based upon the idea of the Solid Isotropic Material with Penalization (SIMP) method of topology optimization. The modal loss factor of the structure is assigned as the objective function. All the sensitivities of the modal loss factor with respect to the design variables are derived analytically and the optimization problem is solved by Method of Moving Asymptote (MMA) method. Several examples of the design optimization of viscoelastic cellular materials are presented to demonstrate the validity of the method. The effectiveness of the design method is illustrated by comparing a solid and an optimized cellular viscoelastic material as applied to a cantilever beam with the PCLD treatment.