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Topology optimization of viscoelastic materials on damping and frequency of macrostructures

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Abstract

Damping and natural frequency are the most important characteristics for evaluating the performance of dynamic structures. This paper proposes a topology optimization algorithm based on the bi-directional evolutionary structural optimization (BESO) method to designing viscoelastic materials. This algorithm optimizes damping and natural frequency of macrostructures by tailoring microstructures of viscoelastic materials. The material microstructures are assumed to be composed of periodic unit cells (PUCs) and the effective properties of the PUC are extracted by the homogenization theory and further integrated into the analysis of the macroscopic structure. To improve the performance of dynamic structures, the inverse homogenization is conducted to seek the best distribution of the base materials within the PUC. Numerical examples are presented to demonstrate the effectiveness of the proposed algorithm, which optimizes the microstructures of viscoelastic cellular or composite materials for 2D and 3D structures.

Keywords: Two-scale topology optimization; Viscoelastic materials; Modal damping; Natural frequency

1. Introduction

Viscoelastic materials have been widely used in controlling noise and vibration of engineering products due to their favourable characteristics in dissipating dynamic energy [1, 2]. Damping treatment approaches including active, passive, and hybrid passive-active methods [3-8] have been developed and applied to many industrial fields. From the perspective of designing light-weight structures with high performance, the optimization for damping treatment has been extensively studied. Lifshitz and Leibowitz [9] optimally designed the passive constraint layer for structural damping. Baz and Ro [10] investigated the optimization of the active constraint layer for damping treatments. Plunkett and Lee [11] proposed a method to increase the energy dissipation in the viscoelastic layer by constraining it with a stiffer covering layer with optimal length. Alam and Asnani [12] derived the governing vibration equations for multi-layered plates and demonstrated that the damping of flexural modes could be optimally controlled by selecting a proper thickness ratio of the layers. Lall and Nakra [13] investigated the parameter optimization of modal loss factor and displacement response for sandwich plates. Zheng, et al. [14], [15] proposed the layout optimization of the constraint damping layer for minimizing vibration energy and sound radiation of plates and cylindrical shells. Li and Liang [16] proposed the response surface method (RSM) to analyse and optimize the sound radiation level of the vibrating panel.