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Damping Optimization of Viscoelastic Cantilever Beams and Plates Under Free Vibration

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Viscoelastic damping materials, such as elastomers or polymers within their glass transition, are widely used to absorb vibrations of structures. The polymer linear viscoelastic properties exhibiting several relaxation times, well reproduced by rheological models such as the generalized Maxwell model, confer them a large range of applications [1]. The current work focuses on finding the optimal design of viscoelastic cantilever beams and plates to maximize their damping capacities.

The optimal material distribution is reached using sizing and shape optimization methods. These techniques are well known and very efficient within the elastic framework, for various objective functions [2]. However, the extension of these methods to viscoelastic materials is rather recent. The goal of the present work is to optimize the thickness of a cantilever beam and simultaneously optimizing the thickness and shape of a cantilever plate using Hadamard's boundary variation method, in order to maximize the damping of these structures under free vibration. Representing the viscoelastic properties of polymers by a generalized Maxwell model allows us to study the impact of viscoelastic parameters, without neglecting the frequency dependence of Poissons ratio for the cantilever plate.

The main results of this work are, on the theoretical side, the rigorous derivation of sizing and shape sensitivities by the adjoint approach, which is new, to the best of our knowledge, for a generalized Maxwell model with frequency-dependent Poisson's ratio, and, on the numerical side, the optimization of cantilever beams and plates as well as a sensitivity analysis of the viscoelastic parameters. Our numerical examples show that the optimal designs are very sensitive to the material parameters, with a possible inversion of the thickness profile when the relaxation time is varying. Furthermore, this work shows how to apply shape optimization to homogeneous viscoelastic structures in an industrial context, through the use of the level-set method, and addresses the numerical difficulties encountered.

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