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Enhancing the Damping Properties of Viscoelastic Composites by Topology Optimization

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ABSTRACT

Vibrations, if undamped, might be annoying or even dangerous. Most often some kind of damping mechanism is applied in order to limit the vibration level. Vibration insulators, for instance of rubber material, have favorable damping characteristics but lack the structural stiffness often needed in engineering structures. Thus, materials or composites with high stiffness and high damping are of great interest to the industry.

The inherent compromise between high stiffness and high damping in viscoelastic materials has been treated theoretically [2, 3] and experimentally [1]. It has been shown that high stiffness and high damping can be realized by Hashin-type composites or Rank-N laminates. However, in order to manufacture such composites it is favorable to obtain single length scale microstructures, i.e. without multiscale structures such that the materials can be manufactured by modern manufacturing techniques. As an example, by the use of e.g. SLM/SLS - Selective Laser Melting/Sintering, an open metallic microstructure can be *printed* and in a subsequent process the porespace can be filled with a high loss compliant material.

Yi and co-workers [6] applied topology optimization to design the 2D microstructural layout of a stiff elastic and a soft viscoelastic material constituent in order to obtain high damping, however, without specific focus on neither the theoretical bounds [2] nor the manufacturability. In this work we extend this work and consider manufacturability by use of various filtering techniques [4, 5]. The inverse homogenization problem is formulated such that the imaginary part of the bulk modulus for the composite is maximized while the real part is constrained from below. This formulation makes it possible to exploit the microstructures related to the upper bound of the imaginary part of the bulk modulus.

Figure 1 shows the bounds on the bulk modulus for a viscoelastic composite using the formulation of [2] along with preliminary structures obtained using topology optimization. It is seen that for low bulk stiffness, the obtained designs approach the bounds for viscoelastic composites.

The theoretical bounds exist for a limited combination of base materials e.g. with equal Poisson's ratio and isotropic composites. In our work we will, numerically, further exploit the parameter space in order to search for composites that offer favorable compromises between loss and stiffness for different loading scenarios. Further, we will extend the study to three dimensions and in future work we plan to investigate the possibility for using the nonlinear response of viscoelastic materials such as rubber to further enhance the damping capabilities.
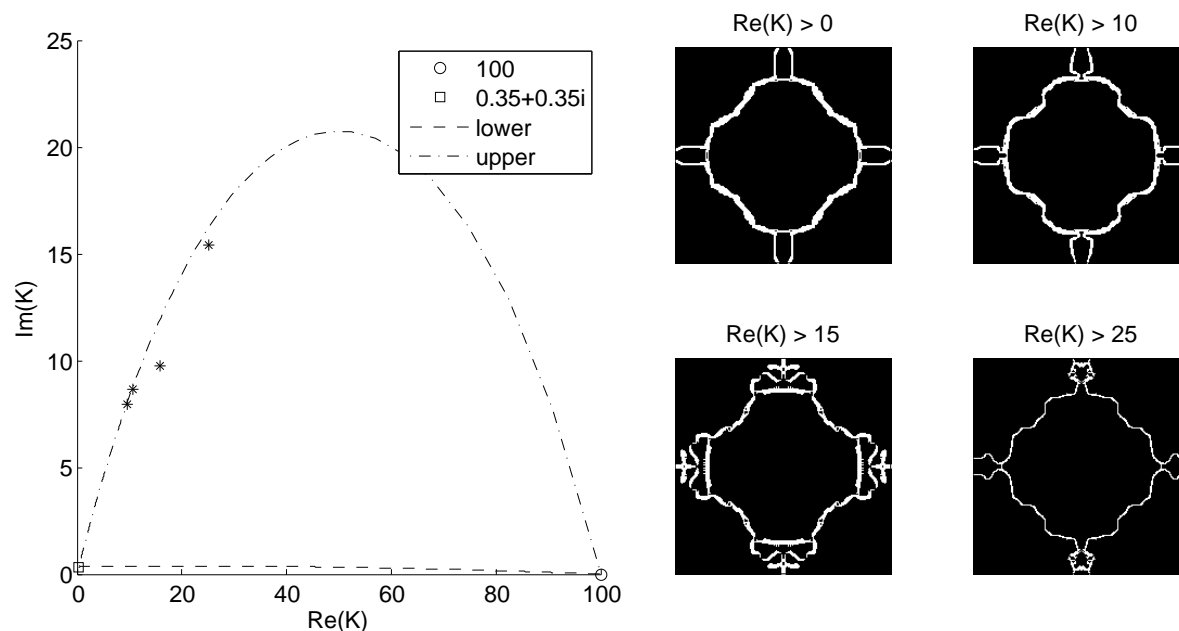
Figure 1: The figure shows the optimized material structures that approach the upper bound. The structures are made from two isotropic materials with equal Poisson's ratio of 0.3. One constituent (black) is a relatively stiff elastic material while the other (white) is a more compliant viscoelastic material having a bulk modulus of $K_1 = 100$ and $K_2 = 0.35 + 0.35i$

References

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