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Investigation of viscoelastic structures with extreme damping and high stiffness using negative stiffness layered composites

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ABSTRACT

Materials that exhibit high damping are often used in structures to reduce noise and vibrations; however, most materials display an inverse relationship between stiffness and damping. Therefore, materials that display both high damping and stiffness are of great interest in many structural applications. Earlier analysis using linearized viscoelastic theory has demonstrated that high damping and high stiffness can be simultaneously achieved using viscoelastic layered composites consisting of a lossy polymer and a stiff constituent. In this research we use finite element simulations to analyze the finite deformation response of these viscoelastic layered composites in cyclic compression. We demonstrate using nonlinear finite element analysis that geometric nonlinearities affect the response of these composites at finite but moderate macroscopic strain amplitudes. In addition to the softening, the composite exhibits negative stiffness above a certain amplitude threshold, i.e., the value of the stress decreases when the strain is increased. By combining the layered composites with another constituent material, these geometric nonlinearities and the negative stiffness are exploited to obtain viscoelastic composites with higher damping than the constituents. Both analytical formulae based on composite theory and finite element simulations are used to guide the optimal choice of the geometrical parameters of the composite topology and of the material constituents to achieve extreme damping and high stiffness.