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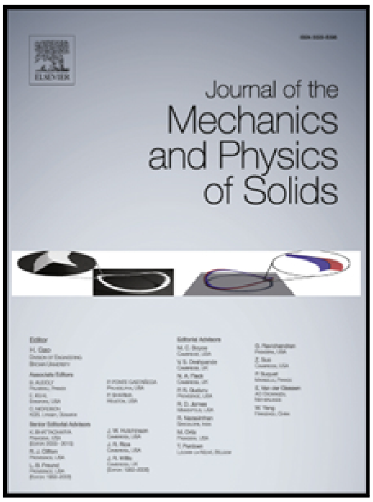

A micro-macro constitutive model for finite-deformation viscoelasticity of elastomers with nonlinear viscosity

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A micro-macro constitutive model for finite-deformation viscoelasticity of elastomers with nonlinear viscosity

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Abstract

Elastomers are known to exhibit viscoelastic behavior under deformation, which is linked to the diffusion processes of the highly mobile and flexible polymer chains. Inspired by the theories of polymer dynamics, a micro-macro constitutive model is developed to study the viscoelastic behaviors and the relaxation process of elastomeric materials under large deformation, in which the material parameters all have a microscopic foundation or a microstructural justification. The proposed model incorporates the nonlinear material viscosity into the continuum finite-deformation viscoelasticity theories which represent the polymer networks of elastomers with an elastic ground network and a few viscous subnetworks. The developed modeling framework is capable of adopting most of strain energy density functions for hyperelastic materials and thermodynamics evolution laws of viscoelastic solids. The modeling capacity of the framework is outlined by comparing the simulation results with the experimental data of three commonly used elastomeric materials, namely, VHB4910, $_{\mathrm{HNBR}}$50 and carbon black (CB) filled elastomers. The comparison shows that the stress responses and some typical behaviors of filled and unfilled elastomers can be quantitatively predicted by the model with suitable strain energy density functions. Particularly, the strain-softening effect of elastomers could be explained by the deformation-dependent (nonlinear) viscosity of the polymer chains. The presented modeling framework is expected to be useful as a modeling platform for further study on the performance of different type of elastomeric materials.