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Large strain nonlinear viscoelastic modeling of polymer nanocomposites

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ABSTRACT

Polymer nanocomposites, where nanofillers (carbon black, silica, etc.) are incorporated into rubberlike polymeric matrix, provides high-performance material properties that combine the matrix's high ductility, high damping, and good abrasion resistance and fillers' high stiffness and strength. A linear viscoelastic modeling tool has earlier been developed by the group incorporating an interphase regime between matrix and fillers with properties different from the bulk matrix. However, the linear viscoelastic model is inadequate for capturing the strain-dependent and rate-dependent viscoelastic behavior of the nanocomposites under large deformation. In this study, the constitutive modeling of the incompressible, isotropic polymer matrix consists of two parts: pure hyperelasticity and nonlinear viscoelasticity. The Marlow model was chosen to describe the hyperelastic behavior. Different nonlinear viscoelastic models, including the Adaptive Quasi-linear Viscoelastic (AQLV) model and the Bergstrom–Boyce model, were compared for predicting the relaxation behavior of both the pure rubber and the nanocomposites at different strain levels. The AQLV model was selected for detailed study and calibrated. A three-phase (matrix, fillers, and interphase) composite model was implemented in Abaqus using a Scanning Electron Microscope images based reconstruction as the geometric input. Simulations on the strain-dependent viscoelastic properties of the nanocomposites are performed with assumption for the interphase properties based on AFM testing. The simulated results are compared with composite experimental data in frequency domain to provide further information on the properties of interfacial polymer in the composites.