Visco-hyperelastic modeling of automotive elastomeric bushings with emphasis on the coupling effect of axial and torsional deformations

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ABSTRACT

Elastomers have wide and ever increasing applications in several industries. For example, elastomeric bushings are used in automotive suspension systems to reduce amplitude of vibrations as well as shocks. In this study, a compressible visco-hyperelastic approach is employed to investigate the behavior of these bushings. Time-discrete form of the material model (Exp–Ln visco-hyperelastic model) is developed to be used in numerical simulations. By means of analytical solutions derived for pure torsion of a solid circular cylinder, the numerical implementation is validated and then, the response of an elastomeric bushing is investigated in torsional, axial, and combined deformations. It is shown that, the numerical model well simulates the nonlinear time dependent response of the bushing in different deformation rates. The nonlinear coupling effect of the axial displacement on the torsional moment (observed in experiments) is thoroughly investigated and the capability of different hyperelastic material models is examined in predicting such coupling effects. The comparisons reveal that the proposed approach well predicts the coupling effect of axial displacement on torsional moment where it is not the case for other compared models. It is of great importance to realize which property of the hyperelastic material models is responsible for predicting this coupling effect. Regarding the derived analytical solution for torsion of circular cylinders, it is realized that, predicting this secondary effect (coupling) is an intrinsic property of the Exp–Ln hyperelastic model which comes from the second derivative of the strain energy function with respect to the strain invariants. It is concluded that the signs of the second derivatives of hyperelastic strain energy functions are additional criteria in definition of these functions for rubber-like materials.

Furthermore, a multistep relaxation test is simulated to identify the hysteretic behavior. Finally, fully relaxed response of the bushing for torsional and combined torsional-axial deformations is predicted and compared with those of experiment as well as three other constitutive models.