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THE MACROSCOPIC RESPONSE, MICROSTRUCTURE EVOLUTION AND MACROSCOPIC STABILITY OF SHORT FIBER-REINFORCED ELASTOMERS AT FINITE STRAINS

Reza Avazmohammadi and Pedro Ponte Castañeda*

Department of Mechanical Engineering and Applied Mechanics, University of Pennsylvania, Philadelphia, PA 19104-6315, U.S.A.,
ponte@seas.upenn.edu, http://www.seas.upenn.edu/directory/profile.php?ID=73

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This paper presents a homogenization-based constitutive model for the mechanical behavior of particle-reinforced elastomers with random microstructures that are subjected to finite deformations. The model is based on a recently improved version of the tangent second-order (TSO) method [1, 2] for two-phase, hyperelastic composites, and is able to directly account for the shape, orientation, and concentration of the particles. After a brief summary of the TSO homogenization method, we describe its application to composites consisting of an incompressible rubber reinforced by aligned, spheroidal, rigid particles, undergoing generally non-aligned, three-dimensional loadings. While the results are valid for finite particle concentrations, in the dilute limit they can be viewed as providing a generalization of Eshelby's results in linear elasticity. In particular, we provide analytical estimates for the overall response and microstructure evolution of the particle-reinforced composites with generalized neo-Hookean matrix phases under non-aligned loadings. For the special case of aligned pure shear and axisymmetric shear loadings, closed-form expressions for the effective stored-energy function of the composites with neo-Hookean matrix behavior may be obtained. Moreover, we investigate the possible development of "macroscopic" (shear band-type) instabilities in the homogenized behavior of the composite at sufficiently large deformations. These instabilities whose wavelengths are much larger than the typical size of the microstructure are detected by making use of the loss of strong ellipticity condition for the effective stored-energy function of the composites.

Explicit results will be given for neo-Hookean and Gent elastomers reinforced with spheroidal particles of prolate and oblate shapes with various aspect ratios and volume fractions, subjected to aligned and non-aligned macroscopic loading conditions. In addition, to assess the accuracy of the model, we compare our results with corresponding finite element results available from the literature for the special case of spherical particles, and good agreement is found. For non-spherical particles, the results indicate that the possible rotation of the particles has a major influence on the overall response of the elastomeric composites. Furthermore, it is found that the composite may develop macroscopic shear localization instabilities, as a consequence of the geometric softening induced by the sudden rotation—or flopping—of the particles, when a sufficiently large amount of compression is applied along the long axes of the particles.

REFERENCES

[1] P. Ponte Castañeda, P. and E. Tiberio. A second-order homogenization method in finite elasticity and applications to black-filled elastomers. *J. Mech. Phys. Solids* **48**, 1389–1411, 2000.

[2] R. Avazmohammadi and P. Ponte Castañeda, P. Tangent second-order estimates for the large-strain, macroscopic response of particle-reinforced elastomers. *J. Elasticity* **112**, 139–183, 2013.