A micromechanical model for hyper-elastic rubber-like materials and numerical resolution by the ANM algorithm

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Abstract

We will discuss a new microstructure-driven hyper-elastic model to describe the behavior of elastomer-like materials. At the scale of the Representative Volume Element (RVE), we propose to model each macromolecular chain using micromechanical elements: linear elastic springs to represent the segments between the cross-linking points and non-linear elastic spiral springs to illustrate the flexibility of the rotations around the cross-linking points. We thus obtain a behavioral model with only three characteristic parameters. We study the effect of the number of macro chain segments and the shape of the RVE using either the Newton-Raphson algorithm or a high-order algorithm from the Asymptotic Numerical Method (ANM) family. In the ANM algorithm, the solution to the non-linear problem is sought branch by branch, each branch being represented by a Taylor series. Numerical simulations are presented on different RVEs, under three types of boundary conditions, and are compared with Treloar's (1944) experimental data to identify the three material parameters and demonstrate the robustness of the proposed model. These comparisons show that the proposed model can reproduce the experimental behavior of polymeric materials with only three characteristic parameters. We also present a numerical method for dealing with macroscopic structures in the context of the proposed microscopic modelling of elastomeric materials where phenomena can occur at both macroscopic and/or microscopic scales. The proposed approach combines a two-level analysis (microscopic and macroscopic) with ANM. Unlike the FE2 method, the use of a Taylor series representation allows non-linear microscopic problems to be transformed into a sequence of linear microscopic problems. In this way, an analogy with classical linear homogenization can be made to construct a behavioral relationship at each order.