A general constitutive model of soft elastomers

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Abstract

It is a long-standing challenge to predict the general constitutive behaviors of soft elastomers under finite deformation, since most of the constitutive relations calibrated from uniaxial tension tests cannot accurately characterize the responses under complex deformation states. In this paper, we develop a general constitutive model of soft elastomers based on a new microscopic picture, in which the free energy is decomposed into two parts: one comes from the cross-linked network and the other from the entangled network. To calibrate and verify the proposed constitutive model, we test several kinds of materials including vulcanized rubber, natural rubber, Entec Enflex S4035A TPE, silicone rubber, and Tera-PEG gel. The results are compared with those from other similar constitutive models (extended tube model and nonaffine network model). With only three material parameters, our model not only captures the softening with a stress plateau and hardening with a sharp rise in stress, but also accurately characterizes the constitutive behaviors of soft rubberlike materials under various deformation states. As an example, we show that the model can predict well the inhomogeneous deformation of an inflated balloon diagram. This constitutive model possesses considerable advantages in the applications of soft robots, soft electronics, elastomeric transducers, etc.

Keywords: thermodynamics, constitutive model, elastomer