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Incorporating the effect of orientation hardening in an effective temperature nonequilibrium theory for glassy polymers JINGKAI GUO, Johns Hopkins Univ, RUI XIAO, Hohai Univ, THAO NGUYEN, Johns Hopkins Univ — Amorphous polymers exhibit a wide range of time and temperature dependent behavior. Recently, Xiao and Nguyen developed an effective temperature theory that can capture a wide variety of nonequilibrium behaviors at moderate strains. At large strains, the stress response of glassy polymers is dominated by strain hardening as a result of chain alignment. The goal of this study was to extend the effective temperature theory to large deformation and make it capable of modeling strain hardening from deformation-induced molecular alignment. We compared two approaches. In the spirit of internal state variable thermodynamics theory, we introduced a series of stretch-like internal state variables to characterize the molecular resistance to plastic flow associated with each inelastic mechanism. The dependence of free energy on the internal state variables naturally gives rise to a deformation dependent back stress. The flow rule and the evolution of effective temperatures were derived in a thermodynamically consistent manner. In the second approach, we introduced a steady-state limit in the evolution of the effective temperature characterizing the nonequilibrium structure of the material. Both approaches can well capture the experimentally measured phenomena of orientation hardening, including the development of deformation-induced anisotropy in the yield strength and hardening modulus, the Bauschinger effect, and differences in the hardening moduli in tension and compression of pre-oriented specimens.

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