A mesoscopic constitutive model for simulating rate-dependent plasticity and creep in unidirectional polymer composites

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Abstract

Although modeling the rate-dependent plastic response of polymers has seen significant advances in recent years, accounting for the complex combined behavior of fibers and polymer matrix in a composite material is still subject to ongoing research. In this work, we present a mesoscopic constitutive model for simulating rate-dependent plasticity and creep in continuous fiber reinforced polymer composites. The model is an extension of an isotropic viscoplastic constitutive model for neat polymers, based on the Eyring flow theory. The direction dependence of the composite is taken into account through a set of transversely isotropic invariants. For obtaining an accurate response under finite deformations, the re-orientation of the transversely isotropic plane under plastic deformations is properly taken into account in the constitutive equations. Furthermore, the model requires only a few parameters for the direction, rate and pressure dependence of the composite. The performance of the mesoscopic constitutive model is assessed by comparing the response with that from a recently developed micromodel for Carbon/PEEK with fibers and matrix explicitly described. The micromodel is first used to identify the elasticity and rate-dependent plasticity parameters of the mesomodel through numerical homogenization. It is then demonstrated that the mesoscopic constitutive model gives a similar response as the micromodel subjected to off-axis uniaxial tension and compression under various strain rates. The strong anisotropy of the composite, which is hyperelastic in fiber direction, and rate-dependent plastic in transverse direction, is well captured. Furthermore, the constitutive model can simulate creep deformations under constant stress, which enables the model to be used for simulating plastic deformations in unidirectional composites under short- and long-term loading.

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