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Three-dimensional modeling of interfacial stick-slip in carbon nanotube nanocomposites

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Abstract

A 3D nonlinear constitutive theory is proposed to describe the hysteretic response of non-functionalized carbon nanotube nanocomposite materials caused by the shear stick-slip between the carbon nanotubes and the polymer chains of the hosting matrix. The theory combines the mean-field homogenization method based on the Eshelby equivalent inclusion theory, the Mori–Tanaka homogenization approach, and the concept of inhomogeneous inclusions with inelastic eigenstrains introduced to describe the shear stick-slip. The evolution of this inelastic eigenstrain flow is regulated by a constitutive law based on a micromechanical adjustment of the von Mises function associated to the interfacial stress discontinuity. The 3D model is implemented in explicit dynamic form in a finite element platform called FEniCS. The time integration scheme utilises the Extended Average Mean Value Theorem together with a special form of the Impulse-Momentum Law. Parametric studies show that the predicted damping capacity of carbon nanotube nanocomposites made of epoxy or PEEK polymers is in agreement with previous results. Moreover, a validation of the proposed model is achieved comparing the experimentally obtained force-displacement cycles with the theoretical response of nanocomposite specimens.

Keywords: Nanostructured composites, Carbon nanotubes, Eshelby-Mori-Tanaka homogenization, 3D smooth plasticity, Damping capacity

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