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ABSTRACT

Flexural wave propagation in carbon nanotubes (CNTs) can be described through higher-order elasticity theories so as to capture the dispersive behavior induced by the inherent nanoscale heterogeneity. Motivated by experimental dispersion characteristics of metal nano-structured crystals, a new three-length-scale gradient formulation has been recently developed by the authors. In addition to the Laplacian of the strain, this model incorporates two higher-order inertia gradients for an improved dispersion behavior. A discrete medium with lumped masses at multiple scales of observation and combination of lumped mass and distributed mass at the macro-scale is introduced here to provide a micro-mechanical background to the proposed three-length-scale gradient model. The next aim of this paper is to assess the ability of this model to simulate flexural wave dispersion occurring in CNTs. We employ gradient-enriched Euler-Bernoulli and Timoshenko beam theories incorporating either stress gradients, or a combination of both strain gradients and inertia gradients – the latter leading to novel gradient-enriched beam theories. It is demonstrated that the proposed three-length-scale gradient elasticity formulation is able to capture the wave dispersion characteristics arising from Molecular Dynamics simulations with high accuracy for a wide range of wave numbers. Advantages over alternative formulations of higher-order beam theories with stress gradients or combined strain-inertia gradient enrichments are discussed for comparative purposes.

KEY WORDS: Carbon nanotubes; Wave dispersion; Nonlocal elasticity; Gradient elasticity; Internal length scale; Euler-Bernoulli beam; Timoshenko beam; Stress gradient; Strain gradient; Inertia gradient.