Torsional Vibration of Size-dependent Viscoelastic Rods using Nonlocal Strain and Velocity Gradient Theory

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Abstract

In this paper the torsional vibration of size-dependent viscoelastic nanorods embedded in an elastic medium with different boundary conditions is investigated. The novelty of this study consists of combining the nonlocal theory with the strain and velocity gradient theory to capture both softening and stiffening size-dependent behavior of the nanorods. The viscoelastic behavior is modelled using the so-called Kelvin–Voigt viscoelastic damping model. Three length-scale parameters are incorporated in this newly combined theory, namely, a nonlocal, a strain gradient, and a velocity gradient parameter. The governing equation of motion and its boundary conditions for the vibration analysis of nanorods are derived by employing Hamilton's principle. It is shown that the expressions of the classical stress and the stress gradient resultants are only defined for different values of the nonlocal and strain gradient parameters. The case where these are equal may seem to result in an inconsistency to the general equation of motion and the related non-classical boundary conditions. A rigorous investigation is conducted to prove that that the proposed solution is consistent with physics. Damped eigenvalue solutions are obtained both analytically and numerically using a Locally adaptive Differential Quadrature Method (LaDQM). Analytical results of linear free vibration response are obtained for various length-scales and compared with LaDQM numerical results.

Keywords: Torsional nanorod; nonlocal strain and velocity gradient theory; viscoelasticity; Kelvin–Voigt model; torsional vibration.

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