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Vibration analysis of horn-shaped single-walled carbon nanotubes embedded in viscoelastic medium under a longitudinal magnetic field

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Abstract: Based on nonlocal Euler-Bernoulli beam theory, vibration characteristics are investigated for a horn-shaped single-walled carbon nanotube (SWCNT) which is embedded in a viscoelastic medium and subjected to a longitudinal magnetic field. Governing equations of motion are derived for vibration analysis of horn-shaped SWCNTs, where the Lorentz magnetic force, the surrounding viscoelastic medium and variable cross-section have been taken into consideration. Subsequently, perturbation method (PM) and transfer function method (TFM) are employed to compute the natural frequencies and the corresponding mode shapes for horn-shaped SWCNTs with arbitrary boundary conditions. The obtained results are first compared with the results available in the literature, where good agreement is achieved. The validation of the model is followed by a detailed parametric study of the effects of nonlocal parameter, taper parameter and longitudinal magnetic field on the vibration of horn-shaped SWCNTs. The results demonstrate the efficiency of the developed model for vibration analysis of a complicated multi-physics system comprising horn-shaped SWCNTs, viscoelastic medium and a magnetic field in longitudinal direction.

Keywords: Horn-shaped carbon nanotubes; Vibration characteristics; Viscoelastic medium; Magnetic field; Nonlocal continuum theory

1. Introduction

Carbon nanotubes (CNTs) [1] have attracted considerable attention due to their exceptional mechanical, electrical and chemical properties [2-4]. These novel properties make CNTs promising for the building blocks of fluid storages [5,6], nanocomposites [7,8], nanosensors [9,10] and nano-electromechanical systems (NEMS) [11]. To meet the needs of engineering, various structure and morphologies have been synthesized for the CNTs, such as single-, double-, multi-walled, as well as Y-, bamboo- and horn-shaped CNTs [12-14]. Among these, horn-shaped CNTs with variable cross-section are of great interest in design of novel nanostructures and vibration control devices [15,16] and have become one of the most attractive new forms [17]. Recently, the interest of research has been transferred to the distinctive behavior of CNTs subject to a magnetic field, which has a great potential for future engineering applications in nanotechnology. As a result, the study of vibration responses of horn-shaped CNTs in a magnetic field may provide valuable information for the above mentioned potential applications of CNTs.

Up till now experimental techniques [18], molecular dynamic (MD) simulations [19] and especially, continuum mechanics theories [20-22] have been employed in the study of CNT nanomechanics. The continuum mechanics models are of particular interest due to the difficulty in nanoscale experiments [23,24] and computational cost in MD simulations [19]. In the last two decades efforts have been made to elaborate such models originally for macroscopic structures to enable their use in the area of nanomechanics. The nonlocal continuum mechan-