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Magnetically affected stochastic stability of a single-layer graphene sheet resting on a viscoelastic foundation

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Abstract. In this paper we analyzed the stochastic stability of a single-layer graphene sheet resting on a viscoelastic foundation and influenced by the in-plane magnetic field. The mechanical model of a graphene sheet laying on a polymer based foundation is given as an orthotropic and viscoelastic nanoplate resting on the Kelvin-Voight's type of viscoelastic medium. Also, we assume that the graphene sheet is influenced by the in-plane random forces variable with time and the in-plane magnetic field. Based on the Eringen's nonlocal continuum theory and Kirchhoff – Love plate theory, the governing equation of motion is derived considering the influence of Lorentz magnetic force obtained from classical Maxwell relations. In order to investigate the stochastic stability of such system, the moment Lyapunov exponents and Lyapunov exponent are considered by using the perturbation method. The predicted approximated analytical results for the *p*-th moment Lyapunov exponents are validate by the Monte Carlo method. Moreover, the boundaries of almost-sure and moment stability of the viscoelastic nanoplate are determined as functions of different system parameters. The influences of the nonlocal and magnetic field parameters, stiffness and damping coefficients and spectral density on the moment Lyapunov exponents are investigated through several numerical examples. Presented results show that the in-plane magnetic field could be successfully used to improve stability performances of nano-electromechanical systems based on graphene sheets.

Key words: Nonlocal elasticity theory; Stochastic stability; Monte Carlo simulation; Magnetic field; Graphene sheet.

1. Introduction

Advanced materials and nano-scale structures with improved mechanical, thermal and electrical properties, such as graphene sheets, are widely used in many nanoelectromechanical devices. Thus, knowing the dynamic behavior of nanostructures is very important for development of a new class of nano-systems like nano-actuators and nano-sensors influenced by different physical fields. By browsing the literature, one can find many studies where mathematical models are developed to study dynamics behavior of actuators and sensors based on graphene sheets for application as nano-resonators [1], for drug screening [2], bio-sensing [3], infrared-triggered actuators [4], gas sensors [5] etc. Therefore, vibration analyses of nanoplate like structures has become an important topic of investigation among the scientists and engineers working in the field of nanotechnology [6, 7].

By experimental observations, it has been found that the small-scale effects play a significant role in the physical behavior of nano-structures [8]. However, performing experiments on the nano-scale level is not an easy task due to weak control of parameters in the system and high-cost of such research [9]. For this reason, the investigators are focused on developing the theoretical methods. In the branch of theoretical models, two main classes exist: (i) atomistic models, and (ii) continuum models. Atomistic methods such as deterministic and stochastic molecular dynamics, density function theory etc., are very import and useful for nano-structures composed of a small number of particles [9]. However, for the systems that are composed of a large number of particles, this method is computationally prohibitive [10, 11]. Due to mentioned disadvantages of the experimental and atomistic methods, theoretical models based on continuum theories attracted a great attention of researchers in recent years. One of the first theories that take into account size effects and atomic forces through a single material parameter is nonlocal continuum theory developed by Eringen and co-workers [12, 13]. Such continuum theory showed to be very effective in describing the mechanical behavior of various nanostructures and nanocomposites compared to other methods. This reflects in far less computer resources needed to obtain the results compared to molecular dynamics simulations or other computationally expensive methods. It is important to note that the value of nonlocal parameter is usually obtained by fitting the results obtained from the nonlocal continuum model with the results from molecular dynamics simulations or using the dispersion curves obtained from Born–Karman model of lattice