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Temperature effects on the vibration and stability behavior of multi-layered graphene sheets embedded in an elastic medium

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Abstract. This communication presents the thermal vibration and stability analysis of the multi-layered graphene sheets (MLGS) modeled as multi-nanoplate system (MNPS) embedded in an elastic medium. Nonlocal elasticity and Kirchhoff-Love plate theories are used for nanoplates, which are considered as orthotropic. Elastic medium is represented by the Winkler's spring model, which couples adjacent nanoplates in MNPS. Governing equations are derived and exact closed form solutions for nonlocal frequencies, critical buckling loads and critical buckling temperature are obtained by using the Navier's and trigonometric methods. The analytical results are validated with the corresponding results in the literature, results obtained via molecular dynamics simulation and numerical method of solution of the system of algebraic equations. To consider the thermal effects on the vibration and stability behavior of MNPS we adopted the coefficient of thermal expansion (CTE) obtained from the experimental results found in the literature. In the parametric study, effects of temperature change, nonlocal parameter, number of nanoplates and change of mediums stiffness on dimensionless nonlocal frequencies, critical buckling load and critical buckling temperature are investigated.

Key words: Natural frequency; critical buckling load; critical buckling temperature; thermal effects; multi-layered graphene sheets.

1. Introduction

In recent time, many theoretical studies of graphene sheets and other nanoplate like structures are performed using the nonlocal theory of Eringen. In some works, in order to examine their influences on the mechanical behavior of nanoplates, various field effects such as magnetic field or temperature field are considered. The main reason for an increased interest for such studies is their possible application in modeling and design procedures of micro-electromechanical (MEMS) and nano-electromechanical (NEMS) devices.

There are a number of plate like structures on the nano-scale level grown from different materials like gold nanoplates, silver nanoplates, boron nitride (BN) nanoplates, zinc oxide (ZnO) nanoplates, graphene sheets etc. [1-6]. In many cases, nanostructures are having improved electrical, mechanical and thermal properties compared to the conventional materials. Graphene is one of the best-known nanostructures and the first free-standing two-dimensional crystal that was discovered by Novoselov in 2004 (see [7]). Since graphene has altered physical, optical and chemical properties compared to its bulk counterpart graphite, it is convenient for various applications in optomechanics, optoelectronics, electronics, electrochemistry and biomedicine [8, 9]. In addition, advanced materials as nanocomposites based on graphene sheets dispersed in polymer matrix were revealed in [10]. Further, ability to distinguish single and multi-layer graphene sheets and to apply them as electro-mechanical resonators was achieved in [11, 12].

To meet future requirements of modern NEMS devices and extend their lifetime, it is important to solve the problem of heat transfer. Developing efficient thermal interface materials can prevent many technical failures such as melting, burning, fracture, creep etc., caused by increased dissipation of power in miniaturized devices. Such thermal interfaces needs to be constructed of materials with high thermal conductivity that makes graphene superior candidate to meet this demand since it has very high thermal conductivity [13]. The second prominent parameter that induces a thermal stress in graphene is the coefficient of thermal expansion (CTE) which also plays a large role in MEMS and NEMS devices [14]. In the literature, many different methods to measure CTE of graphene have been suggested [15-19]. In some of the works, a negative value of CTE is measured in the whole temperature range. The others have measured a transition from the negative to

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