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Large deflection geometrically nonlinear analysis of functionally graded multilayer graphene platelet-reinforced polymer composite rectangular plates

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Abstract

A large deflection geometrically nonlinear analysis of functionally graded (FG) multilayer graphene platelet-reinforced polymer composite (GPL-RPC) rectangular plates subjected to uniform and sinusoidal transverse mechanical loadings is performed in this article. Based on the sinusoidal shear deformation plate theory and von Kármán nonlinear strain-displacement relations, the nonlinear governing equilibrium equations and boundary conditions are developed by using the principle of virtual work. It is assumed that the weight fraction of GPL nanofillers layer-wisely changes across the thickness of plate. The effective Young's modulus of FG-GPL-RPCs is approximately calculated via the modified Halpin-Tsai model. Also, the effective Poisson's ratio and mass density are determined by employing the rule of mixture. The investigation is performed by using a numerical solution approach. To evaluate the nonlinear bending stiffness of FG multilayer GPL-RPC plate, the discretization of governing equations and boundary conditions is carried out using the generalized differential quadrature (GDQ) method, and the pseudo arc-length continuation technique is employed to solve the set of nonlinear algebraic discretized equations to obtain the load-deflection curve. Numerical problems are given to reveal the influences of GPL distribution pattern, weight fraction, geometry of GPL nanofillers, length-to-thickness and edge conditions on nonlinear bending responses of the GPL-RPC plates.

Keywords: Graphene nanoplatelet; Functionally graded nanocomposite; Sinusoidal shear deformable rectangular plate; Nonlinear bending; GDQ method.

1. Introduction

Since 1985, with the introduction of fullerene by Kroto et al. [1] and consequently carbon nanotubes (CNTs) by Iijima [2], graphene by Novoselov et al. [3] and its associated allotropes [4], the carbon nanostructures have received much attention from researchers and industrial fields. Recently, the attention of both scientific and industrial communities has been attracted to the polymer matrices reinforced by the CNTs and graphenes. This is due to the remarkable and unique mechanical, electrical and physical properties of CNTs and graphenes [5-9] as well as their widespread applications in nano- and micro-electro-mechanical systems (NEMS and MEMS) such as the next generation of nanoelectronics and many others. Although CNTs can be regarded as good candidates for the polymer matrix reinforcement to improve their mechanical properties, their uniform dispersion

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