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Abstract

The size-dependent geometrically nonlinear free and forced vibration behaviors of nanoscale beams are studied in this article using a numerical approach. The size effects are captured using Mindlin's second strain gradient theory (SSGT) in which the second- and third-order derivatives of displacement components are taken into account in the strain energy density. The basic relations are first derived using the Timoshenko beam theory and SSGT. Then, the variational differential quadrature (VDQ) method is adopted to solve the obtained governing equations in the context of variational formulation. Comprehensive numerical results are given to investigate the influences thickness-to-lattice parameter ratio on the nonlinear free and forced vibrations of nanobeams under different types of end conditions. Also, comparisons are made between the predictions of SSGT and the first strain gradient theory as well as the classical elasticity theory.

Keywords: Mindlin's second strain gradient theory; Timoshenko nanobeam; VDQ method

1. Introduction

Micro/nanobeams have many applications in micro-electro-mechanical systems (MEMS) including actuators [1], atomic force microscopes (AFM) [2, 3], sensors [4-6], etc. Various beam models based on the Bernoulli–Euler, Reddy-Levinson and Timoshenko theories are extensively employed for the mechanical analysis of microbeams [7-13]. As known, the Bernoulli–Euler

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