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Free vibration analysis of size-dependent shear deformable functionally graded cylindrical shell on the basis of modified couple stress theory

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Abstract

In this paper, size-dependent equations of motion for functionally graded cylindrical shell were developed using shear deformation model and rotation inertia. Material properties of the shell were assumed as continuously variable along thickness, and consistent with the variation in the component's volume fraction based on power law distribution. To consider the size effect, modified couple stress theory in conjunction with first order shear deformation shell model were used, and general equations of motion and classical and non-classical boundary conditions were derived based on Hamilton's principle. Finally, in the special case, using the Navier procedure, the free vibrations of simply supported functionally graded cylindrical nanoshell were obtained, and the effects of parameters such as dimensionless length scale parameter, distribution of FG properties, thickness, and length on the natural frequency were identified and was compared with the classical theory. Results obtained through the modified couple stress theory are indicative of the considerable effect of the size parameter, particularly in bigger thicknesses and shorter lengths of nanotubes, on the natural frequency.

Keywords: First order shear deformation shell model, Functionally graded material, Modified couple stress theory, Size effect

1. Introduction

From a micro-scale perspective, having unique properties such as high stiffness and great thermal resistance capacity, functionally graded materials (FGMs), as specific materials made by the combination of two materials, usually metal and ceramics, have received great attention as structural constituents exposed to intense temperature conditions such as aerospace, nuclear plants, and other engineering applications [1-6]. There is a variety of models for FGM materials in the macro scale some of which will be discussed here. Jomehzadeh et al. examined the bending of a part of FG annular sector plates using the first order shear deformation plate theory [7]. They identified the effect of parameters such as plate thickness, ratio of internal radius to external radius, and boundary conditions on deformation and stress. Using classical and first order and various higher order shear deformation beam theories, Şimşek studied