Nonlinear Natural Frequencies of Functionally Graded Axisymmetric Annular Microplates Based on the Modified Couple Stress Theory

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Abstract. In this study, axisymmetric nonlinear natural frequencies of simply supported functionally graded (FG) annular microplate is investigated. In the formulation, it is considered that the mechanical properties such as modulus of elasticity, shear modulus of elasticity and material properties such as density of the FG microplate change in the thickness direction. The size effect is taken into account by using the modified couple stress theory (MCST). Formulation is based on Mindlin plate theory and the nonlinearity in the formulation is due to von Karman's large deformation assumption. The governing nonlinear partial differential equations of motion and boundary conditions for the FG microplate are derived by using variational approach and Hamilton's principle. Harmonic balance method is utilized in order to obtain a nonlinear eigenvalue problem. An iterative eigenvalue solver is used to determine the nonlinear natural frequencies of the FG microplate as a function of vibration amplitude.

Introduction

Functionally graded materials (FGMs) are a special class of composites with mechanical properties varying smoothly in one direction due to continuous change in the volume fractions of the constituent phases from one surface to another. This provides superior properties and improved performance to FGMs in preferred directions when they are compared to homogenous materials. Therefore, FGMs are used in several areas, including, such as spaceplane body, rocket engine components, automotive engine components, living tissues like bones and teeth, armor plates, bullet-proof vests, thermal barriers, protective coatings, turbine blades and sensors. In recent years, FGMs are also used in micro/nano-scale applications such as micro/nano-electro-mechanical systems (M/NEMS), thin films and probes for atomic force microscopes. It is shown that the deformation behavior of such nanomaterials is size dependent and the use of the classical continuum theory, i.e. size independent theory, for nanomaterials does not always provide accurate results [1]. Therefore, non-classical higher order continuum theories such as nonlocal elasticity theory, strain gradient theory, classical couple stress theory and its modified version, are developed and used for nanostructures. By using modified version of couple stress theory, Esraghi et al. [2] investigated the axisymmetric linear free vibrations and static deflections of FG annular and circular microplates. Ke et al. [3] presented annular micro-plate model for nonlinear free vibration analysis based on MCST, Mindlin plate theory and von Karman geometric nonlinearity. The motivation of this study is to extend these studies in terms of formulations, solution methods and numerical results with respect to different parameters.

Results and Discussion

The nonlinear free vibrations of axisymmetric simply supported FGM annular microplates (Fig. 1) has been studied. Numerical results for dimensionless linear and nonlinear natural frequencies are obtained and compared with the results available in the literature. It is observed that developed iterative eigenvalue solver utilizing HBM improves the solution time significantly. The effect of inhomogeneity constant and length scale parameter on the nonlinear natural frequencies are investigated. Results obtained showed that increase in inhomogeneity constant cause a descent in both linear and nonlinear natural frequencies. The increase in the ratio of plate thickness to length scale parameter results in a decrease in the nonlinear natural frequency.

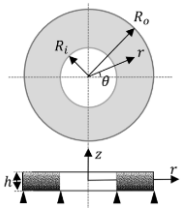

Figure 1: Schematic for a simply supported annular FGM plate

References

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