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On the flexoelectric effect on nonlinear vibration of three-layered functionally graded cylindrical microshells

ASGHAR FARAMARZI BABADI [1*], YAGHOUB TADI BENI [1,2], KRZYSZTOF KAMIL ŻUR [3*,**]

1. Faculty of Engineering, Shahrekord University, Shahrekord, Iran
2. Nanotechnology Research Center, Shahrekord University, Shahrekord, Iran
3. Faculty of Mechanical Engineering, Bialystok University of Technology, Bialystok, Poland
* Presenting Author
**Corresponding Author: k.zur@pb.edu.pl

Abstract: According to past research, the flexoelectricity effect is dependent on the strain gradient noticeable in micro/nanoscales. It can be concluded that flexoelectricity has a considerable effect on the electromechanical behavior of structures in small scale. For the first time, the first-order shear deformation theory (FSDT) and the reformulated flexoelectric theory is used to study nonlinear free vibration of three-layered cylindrical microshell made of a functionally graded piezoelectric (FGP) core and two layers of flexoelectric material. Equations of motion and corresponding boundary conditions are derived from variational Hamilton's principle. Change a volume element due to the elastic deformation is taken into account, so it creates a source of nonlinearity in the derived equations of motion. The nonlinear partial differential equations are numerically solved by perturbation method. Effects of crucial geometric, material and scale parameters on the dynamic response of the flexoelectric structure are comprehensively investigated and discussed.

Keywords: first-order shear deformation theory, reformulated flexoelectric theory, FGM, microshell, nonlinear dynamics

1. Background

Optimized performance of intelligent small structures such as microbeams, microshells, microplates in such cases as measurement equipment, medical equipment, electronic equipment is a fundamental issue in micro- and nanoelectromechanical systems (MEMS/NEMS) [1,2]. Due to the application of MEMS and NEMS in the mechanical, chemistry, and aerospace industries and because of their high performance and high accuracy in adverse environmental conditions, researchers have paid special attention to these systems and tried to determine their electromechanical responses in different environmental conditions. Due to electromechanical properties, mechanical energy (tensile, pressure, bending, and twisting) and electrical energy (voltage, electric field, and electrical polarization) can be converted to each other, and used in the construction of transducers, sensors, actuators, resonators at diverse scales.

Considering the fact that the properties of the functionally graded materials are common in structures at micro scale, therefore, the functionally graded flexoelectric cylindrical microshell is the object of our investigation. By deep investigation of the previous studies, it can be found that modified flexoelectric theory has not been used to study the nonlinear vibration of the flexoelectric cylindrical microshell under electrical loadings [4,5]. Additionally, the effect of functionally graded material on the electromechanical behavior of the flexoelectric microshell under electric forces based on the

modified flexoelectric theory has not been investigated in previous studies. The present study on the behavior of this type of microstructure fills the gaps in the existing literature.

2. FGP microshell

In this study, we consider a three-layer flexoelectric microshell with a total thickness of $h_t = h + 2h_f$, where h_t, h and h_f are the total thickness, core thickness and thickness flexoelectric layers of the structure, respectively. The microshell has a radius equal to R, a length equal to L and a thickness equal to h_t. The upper and bottom layer are assumed to be made of two different flexoelectric materials, and the core is made of functionally graded of two piezoelectric materials. The properties of the microshell core are quite different in the direction of thickness. The schematic of microshell model is presented in Figure 1.

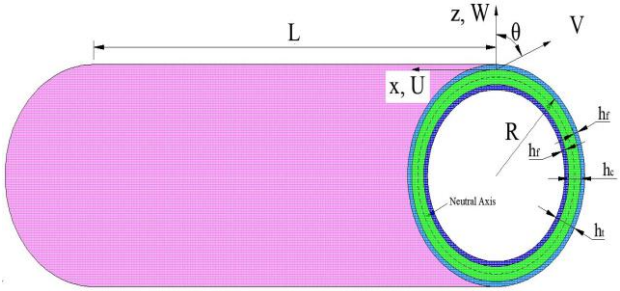

Fig. 1. The geometry and coordinate system of the microshell.

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