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A Static Analysis of Piezo-laminated Shell Structures

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Abstract: An analytical solution for piezo-laminated shell structure and/or shell embedded smart material lamina and influenced by thermo-magneto-electro-elastic (TMEE) load are presented in this paper. A novel fundamental theory was derived based on the generic first-order transversally shearable deformation theory (FSDT) involving Codazzi-Gauss geometrical nonlinearity, in which this fundamental equations and its boundary conditions were strenuously derived using Hamilton's principle with cooperating of Gibbs free energy functions. The theory is casted in a version of general laminated composite shell of revolution in order to be simplified to account for commonly occurring shell geometries and intended for wide range of common smart materials. Then, the developed theory was applied on case of piezo-laminated composites shell of rectangular plane-form having large curvature. The generic forced-solution procedure for the responses was derived, and its mode shapes were evaluated in the simply supported boundary condition. The center deflection was selected among the primary variable for validation and verification purpose. Four different laminations schemes were considered in this study.

Keywords: Composite structures, Smart composite, Magneto electro elastic, Reduced constitutive matrix, shell/plate/lamina

INTRODUCTION

Structronics are concept of (Structures + Electronics), which are synergistic integration of smart, adaptive or responsive materials, that contains the main structure and the distributed functional materials (e.g., piezoelectric, piezomagnetic, electrostrictive, magnetostrictive, and the alike materials). Furthermore, structronic refer to a class of structures had the capability of simultaneously sensing/ actuating; mechanical, electrical, magnetic and even thermal effects, as well as simultaneously generating a control forces to eliminate the undesirable effects or to enhance the desirable one. Whereas structronics are largely improves the working performance and lifetime of devices that construct from it.

Several accurate solutions of structronics shell have been presented using 3-D and 2-D theories or the discrete layer approaches. The exact closed-form solutions for multilayered piezoelectric-magnetic and purely elastic plates have been proved for special cases of Pan's analysis. Pan and Heyliger [1] demonstrated the free vibration analysis of the simply supported and multilayered MEE plates under cylindrical bending. Then Heyliger [2] studied two cases of the MEE plates subjected to static fields, one under cylindrical bending and the other of completely traction-free under surface potentials. Following up the previous Stroh formulation, Pan and Han [3] presented the 3-D solutions of multilayered and FG MEE plates. Wang J., Chen L., and Fang S. [4] proposed a modified state vector approach to obtain 3-D solutions for MEE laminates, based on the mixed formulation of solid mechanics.

By an asymptotic approach, Chih-Ping Wu and Yi-Hwa Tsai [5] studied 3-D static and dynamic behavior of doubly curved functionally graded MEE shells under the mechanical load, electric displacement, and magnetic flux by considered the edge boundary conditions as full simple supports.

In comparison with the recently development of 3-D solutions of piezo-laminates [1]-[5], we found that the literature dealing with theoretical work in piezo-laminated shell composites concerning coupled field phenomena in general and in TMEE in particular, is rather scarce, especially for shear deformation studies. In addition, the distribution of sensors and actuators in the shell structure are not well understood.

In this article, a geometrically nonlinear theory of piezo-laminates composite shell/ plates based on the first-order transversely shearable model will be developed. New issues elicited by the structural lamination, such as the distributions of center deflection over the thickness of shell are addressed. The results supplied herein are expected to provide a foundation for the investigation of the interactive effects among the thermal, magnetic, electric and elastic fields in thin-walled structures and of the possibility to apply the TMEE adapting.