An Investigation on Free/Forced Vibration of a Piezoelectric Circular Cylindrical Panel Located on an Elastic Foundation

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Abstract**—**This paper presents an exact three-dimensional free and forced vibration analysis of an axially polarized transversely isotropic piezoelectric circular cylindrical panel on elastic foundation. Due to the wide use of piezoelectric materials as sensor/actuators, to the best knowledge of the authors, no one has studied the effect of imperfection in bonding of these piezo-layers to the host layer for cylindrical panels. Using separation of variables, three-dimensional exact solution is presented under generalized simply supported boundary conditions. In addition, the effect of elastic foundation on both structure natural frequency and steady state frequency response is investigated. For validation purposes the results are compared with those obtained from FEM and the results from previous works. Finally conclusions are made.

Keywords**—**Piezoelectric, cylindrical panel, free vibration, frequency response, foundation.

I. Introduction

Piezoelectric materials have been widely used as transducers, sensors and actuators due to their fundamental direct and converse piezoelectric effects that take place between electric field and mechanical deformation. They are playing a key task as active components in many twigs of science and technology such as electronics, navigation, vibration control, etc.

Haskins and Walsh [1] investigated the free vibration of transversely isotropic piezoelectric cylindrical shell. The wall thickness of the cylinder was assumed to be negligible so two elastic constants are considered in their analysis. By employing the same assumption, Martin [2] studied the vibration of longitudinally polarized piezoelectric circular cylindrical shell. Drumheller and Kalnins [3] used a coupled theory for investigation of vibration of piezoceramic shells of revolution and analyzed the free vibration of a cylindrical shell. Burt [4] simplified the circular cylinder dynamic model to a two-dimensional one and studied the voltage response of radially polarized ceramic. Tzou and Zhong [5] presented a linear theory of piezoelectric shell vibration, which can be simplified to account for spheres, cylinders and plates. Ebenezer and Abraham [6] presented an Eigen function method to find the dynamic response of radially polarized piezoelectric circular cylindrical shells of finite length. Several works based on the methods of three-dimensional theory concentrated on the vibrations of cylinders. Paul [7] derived the frequency equation of a piezoelectric cylindrical shell without any numerical results. Ding *et al*. [8] exactly studied the free vibration of hollow and fluid-filled piezoelectric cylindrical shells on the basis of a decomposition formula for displacements. A more detailed description on related studies can be found in Saravanos and Heyliger [9]. Ding *et al*. [10] solved three dimension free vibration problem for transversely isotropic circular cylindrical panel. They used displacement function method to achieve the natural frequencies of the panel with different boundary conditions. Sharma and Pathania [11] investigated an exact analysis of the free vibration of a simply supported piezoelectric cylindrical panel using three displacement potential functions. They showed that a purely transverse mode is independent of piezoelectric effects and the rest of the motion. Yang *et al*. [12] studied the vibration characteristics of a circular cylindrical piezoelectric transducer using linear piezoelectricity theory. They solved the problem for both free and force vibration. Kapuria *et al*. [13] solved the free vibration and steady state response of cylindrical piezo electric panel by use of an exact two-dimensional piezo-elasticity solution. The piezoelectric layers assumed to be polarized along radial direction. Wang *et al*. [14] solved the exact vibration problem for magneto-electro-elastic circular cylinder with two simply supported ends. They used displacement function method. Kapuria and Kumari [15] considered a benchmark three-dimensional exact piezoelectricity solution in surface-bonded, embedded monolithic piezoelectric and piezoelectric fiber reinforced composite layers. The dynamic equations with variable coefficients are solved using the modified Frobenius method. Wang *et al*. [16] applied a dynamic model based on Love & Kirchhoff thin shell theory. They investigated the conversion of mechanical energy into electrical energy in a cylindrical piezoelectric panel with simply supported boundary conditions. Also, the effect of the curvature is studied. Bodaghi and Shakeri [17] investigated the free and forced vibration of simply supported circular cylindrical FGPM panel. The dynamic transient response of

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