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Axisymmetric boundary condition problems for transversely isotropic piezoelectric materials

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Highlights

- The quasi-static boundary condition problem for transversely isotropic piezoelectric media is considered based on the Hamiltonian state space formulation.
- Upon the separation of variables method, a set of general solutions spanning over the complete solution space is derived.
- Boundary conditions can be descried by the fundamental solutions using the boundary integration.

Abstract

This paper presents an exact analysis of deformation and stress field in a finite cylinder under axisymmetric boundary conditions. The problem is formulated based on the state space formulation for transversely isotropic piezoelectric media. Upon the separation of variables method, we get a set of general solutions spanning over the complete solution space to cover all axisymmetric boundary conditions. Furthermore, a rigorous solution which satisfies the end conditions is determined by using eigenfunction expansion. Numerical results show that the local effect is significant but confined to boundary layer near the fixed end where the displacement and stress are remarkably different from those of other regions.

*Keywords:*Cylinder; Axisymmetric boundary condition; piezoelectric media; State space

1. Introduction

Piezoelectric materials exhibit distinctive electro-mechanical interaction in that they can produce an electric field with given mechanical deformation (direct piezoelectric effect) and conversely can generate a mechanical deformation with applied electric field (inverse piezoelectric effect). Owing to this coupled behavior, piezoelectric materials are receiving wide attention in fields of smart structures and microelectromechanical system [1, 2]. However, for the problems with the presence of defects, analytical analysis of piezoelectric solids can be conducted only for the cases involving idealized conditions. Therefore, a great interest is received in developing approximated methods with which the electro-mechanical coupling problems with more complicated conditions can be analyzed effectively, and some important achievements have been made is this aspect [3, 4]. For example, Chen [5] derived Green’s functions of an infinite body for 3D problems in anisotropic piezoelectric materials and obtained their derivatives of the first and second degree with the contour integrals over the unit circle by using the three-dimensional Fourier transforms. Pan [6] introduced the generalized Mindlin’s solution for an anisotropic piezoelectric half-space with general boundary conditions on the surface and calculated the quantum dot induced by elastic and piezoelectric fields in certain semiconductor substrates. Kwon