TH EE IMEN I NAL ANALYTICAL S LUTIC F PIEZ THER OELASTIC SP SE OF PLATE A D SHELLS

by

SANTOSH KAPURIA
Department of Applied Mechanics

Submitted
in fulfilment of the requirements of
the degree of
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Dedicated to

my father Late Sachindra Kapuria
whose ideas and thoughts have always inspired me

CERTIFICATE

This is to certify that the thesis entitled "Three Dimensional Analytical Solutions for Piezothermoelastic Response of Plates and Shells" being submitted by Mr. Santosh Kapuria to the Indian Institute of Technology, Delhi for the award of the degree of Doctor of Philosophy in Applied Mechanics is a record of original bonafide research work carried out by him under our supervision and guidance. The thesis work, in our opinion, has reached the requisite standard fulfilling the requirements for the degree of Doctor of Philosophy.

The results contained in this thesis have not been submitted in part or full to any other University or Institute for the award of any degree or diploma.

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Santosh Kapuria

ABSTRACT

Three dimensional (3D) exact analytical solutions for static piezothermoelastic response of some piezoelectric and hybrid (cross-ply substrate with piezoelectric layers) plates and shells are presented. The 3D strain-displacement relations, electric field-potential relations, thermal, force and charge equilibrium equations and the coupled piezothermoelasticity constitutive equations, are solved subject to the exact satisfaction of the boundary conditions of the structure and the interface conditions in the case of multilayered structure. The solution also involves determination of the unknown extraneous charge densities at the interfaces where prescribed potential or potential difference is applied. The 3D solutions are used to assess two dimensional (2D) uncoupled classical lamination theory (CLT and CST), and first order shear deformation theory (FSDT) of plates and shells, using Flugge's approximations for the latter. The 2D solutions are used in the 3D equilibrium equations and strain-displacement relation to obtain transverse stresses and an improved value of deflection. The inverse problems of estimating the pressure or temperature field from the measured potential difference are solved. The effect of geometrical parameters is ascertained on through-the-thickness variations of various entities, and the feasibility of reducing the deflection and stresses by proper actuation is studied. Effectiveness of various actuation schemes for shape control is examined for rectangular plates and cylindrical panels. Orthorhombic materials of crystal class mm2 / class 6mm are considered.

Plane strain solution for cylindrical bending and 3D solution of simply supported rectangular plates are presented using analytical solution of the governing differential equations with constant coefficients. Levy-type solution is also presented for rectangular plate with two edges simply supported using a mixed formulation of uncoupled FSDT and CLT. The plane strain solution of cylindrical bending of simply supported cylindrical panels is presented using analytical solution of Euler-Cauchy form of governing equations. The 3D solutions of simply supported, finite cylindrical shell under axisymmetric and general load are presented, wherein the governing differential equations with variable coefficients are solved by the modified Frobenius method using a product of an exponential function and a power series. The 3D axisymmetric solutions are presented for (1) a finite, transversely isotropic, axially polarised, piezoelectric cylindrical shell, (2) a transversely isotropic piezoelectric clamped circular plate and (3) a hybrid clamped circular isotropic elastic plate bonded to a transversely isotropic piezoelectric plate using potential function method.

It is concluded from the results that the effect of the thickness of the structure on the through-the-thickness distributions of various entities depends on the nature of load and the geometry. The distributions tend to be piecewise linear or uniform as the number of layers increases or the structure becomes thin. The potential in the actuator of the hybrid structure has almost linear variation across its thickness. The deflection and the maximum stress in the substrate due to thermal and pressure load can be reduced by suitable actuation. An actuated layer is most effective for shape control, when placed on the loaded surface of the structure. The error in 2D theories is less for the mechanical load than the thermal or potential load.

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