An exact 3D electro-elastic shell model for static and free vibration analysis of smart structures

Original
An exact 3D electro-elastic shell model for static and free vibration analysis of smart structures / Brischetto, Salvatore; Cesare, Domenico. - (2024). (ICCS27 27th International Conference on Composite Structures Ravenna (Italy) September 3-6, 2024).

Publisher:
School of Engineering and Architecture, Ravenna Campus of University of Bologna, Italy

Published
DOI:

AN EXACT 3D ELECTRO-ELASTIC SHELL MODEL FOR STATIC AND FREE VIBRATION ANALYSIS OF SMART STRUCTURES

Salvatore Brischetto and Domenico Cesare

The future design of aircraft and spacecraft is directly connected to the improvement in knowledge about multilayered and single-layered piezoelectric smart structures. In multilayered piezoelectric smart structures these is the possibility of embedding several layers made of isotropic, orthotropic and composite materials in order to have some specific peculiarities and the structural capability to withstand operative loads. The electro-elastic coupling of the piezoelectric materials has multiple uses, such as the capability to adapt their shape as an electric potential act onto the structure (the so-called "actuator" behavior), the capability to provide a specific electric potential in output in the case of deformations acting on the structure (the so-called "sensor" behavior) or the capability of detecting and suppressing vibrations in wing structures. All these capabilities are fundamental in the health monitoring of aerospace structures. A wide-range knowledge about the behaviors of these multilayered smart structures in terms of geometry and material stacking sequence is mandatory for the future design of aircraft structures that must be able to manage the action of multi-field loads during a classical in-flight operative condition.

The present work is related to a coupled 3D exact electro-elastic shell model for the static and free vibration analysis of smart structures. The proposed formulation is based on a set of four equations that must be simultaneously solved in closed form. The set of equations is composed of the 3D equilibrium equations for the elastic field and the 3D divergence equation of electric displacement for the electric field. This set of second order partial differential equations is written considering the mixed curvilinear orthogonal reference system valid for spherical shells. Proper considerations regarding the radii of curvature along the two in-plane directions allow to specialize this formulation for plates, cylinders and cylindrical shells. The solution method involves the Navier harmonic forms in the in-plane directions and the exponential matrix method in the thickness direction. The simply supported constraints are analyzed to obtain a closed form solution. The layer-wise approach is granted thanks to the correct imposition of interlaminar continuity conditions in terms of displacements, transverse shear/normal stresses, electric potential and transverse normal electric displacement. This approach is useful to obtain a proper evaluation of the three-dimensional behavior of piezoelectric multilayered structures having in-plane and out-of-plane elastic and electric anisotropy.

Some tabular and graphical results will be presented for the static and free vibration analyses of simply supported spherical and cylindrical shells, plates and cylinders to understand the global behavior of multilayered smart structures. Static analyses are performed in terms of displacements, stresses, strains, electric potentials and electric displacements along the thickness direction when an electric potential or a mechanical load is applied at the outer surfaces of the structure. Free vibration analyses are computed in terms of circular frequency values and vibration modes in both open and closed circuit configurations.

The proposed results can be useful for those scientists interested in the development of two-dimensional or three-dimensional numerical/analytical formulations for static and free vibration analyses of single-layered and multilayered piezoelectric smart structures.