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Multifield Problems in 3D Structural Analysis of Advanced Composite Plates and Shells

Authors : Salvatore Brischetto, Domenico Cesare

Abstract : Major improvements in future aircraft and spacecraft could be those dependent on an increasing use of conventional and unconventional multilayered structures embedding composite materials, functionally graded materials, piezoelectric or piezomagnetic materials, and soft foam or honeycomb cores. Layers made of such materials can be combined in different ways to obtain structures that are able to fulfill several structural requirements. The next generation of aircraft and spacecraft will be manufactured as multilayered structures under the action of a combination of two or more physical fields. In multifield problems for multilayered structures, several physical fields (thermal, hygroscopic, electric and magnetic ones) interact each other with different levels of influence and importance. An exact 3D shell model is here proposed for these types of analyses. This model is based on a coupled system including 3D equilibrium equations, 3D Fourier heat conduction equation, 3D Fick diffusion equation and electric and magnetic divergence equations. The set of partial differential equations of second order in z is written using a mixed curvilinear orthogonal reference system valid for spherical and cylindrical shell panels, cylinders and plates. The order of partial differential equations is reduced to the first one thanks to the redoubling of the number of variables. The solution in the thickness z direction is obtained by means of the exponential matrix method and the correct imposition of interlaminar continuity conditions in terms of displacements, transverse stresses, electric and magnetic potentials, temperature, moisture content and transverse normal multifield fluxes. The investigated structures have simply supported sides in order to obtain a closed form solution in the in-plane directions. Moreover, a layerwise approach is proposed which allows a 3D correct description of multilayered anisotropic structures subjected to field loads. Several results will be proposed in tabular and graphical formto evaluate displacements, stresses and strains when mechanical loads, temperature gradients, moisture content gradients, electric potentials and magnetic potentials are applied at the external surfaces of the structures in steady-state conditions. In the case of inclusions of piezoelectric and piezomagnetic layers in the multilayered structures, so called smart structures are obtained. In this case, a free vibration analysis in open and closed circuit configurations and a static analysis for sensor and actuator applications will be proposed. The proposed results will be useful to better understand the physical and structural behaviour of multilayered advanced composite structures in the case of multifield interactions. Moreover, these analytical results could be used as reference solutions for those scientists interested in the development of 3D and 2D numerical shell/plate models based, for example, on the finite element approach or on the differential quadrature methodology. The correct impositions of boundary geometrical and load conditions, interlaminar continuity conditions and the zigzag behaviour description due to transverse anisotropy will be also discussed and verified.

Keywords : composite structures, 3D shell model, stress analysis, multifield loads, exponential matrix method, layer wise approach
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