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Hierarchic 2D Models for Piezoelectric Sandwich Shells

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ABSTRACT

Adaptive structures made of multilayered shells with embedded piezoelectric layers can provide an attractive structural enhancement in many technical applications. By utilizing the shear actuation mechanism, the piezoelectric coupling effects inside the laminate can be maximized by placing the piezolayers in the core of the shell, i.e., by referring to a piezoelectric sandwich construction [1]. This contribution proposes a hierarchic two-dimensional (2D) modeling approach for these structures by extending the well established Unified Formulation [2,3] to curved shell geometries and shear actuation mechanism.

According to the Unified Formulation, a large number of 2D models are proposed with different axiomatic expansion orders for the field variables distribution along the composite cross-section. Reference can be made to either equivalent single layer or layer-wise descriptions. Finally, *classical* models based on the standard "generalized displacement" approach are complemented with a new class of *advanced* models based on a dedicated partially mixed formulation. By allowing the independent approximation of the "generalized displacement" and of the transverse electromechanical fluxes, the partially mixed models can exactly fulfill all peculiar continuity requirements between adjacent layers with different electromechanical properties. Particular attention is devoted to the representation of the internal electrode-covered interfaces and their electrical conditions because they play a decisive role in the estimate of the piezoelectric coupling efficiency.

Free-vibration frequencies as well as linear static actuator and sensor responses are computed for different configurations of shear-actuated piezoelectric shells. The system of 2D partial differential equations governing the coupled electromechanical problems is solved in strong form by utilizing the Navier method. Closed-form exact solutions are found for a certain class of shell geometries, constitutive properties of the laminate and boundary and loading conditions. By virtue of the high-order thickness approximations and of the exact representation of the electromechanical interfaces, the most accurate advanced models are shown to accurately recover exact 3D solutions available in literature [2–5]. New reference solutions are proposed for configurations in which the 3D solution is not available. These can be a valuable guide for verifying future numerical models of piezoelectric sandwich shells (based, e.g., on the Finite Element Method).

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