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# Coupled High-Order Layerwise Laminate Theory for Cylindrical Sandwich Composite Shells with Piezoelectric Actuators and Sensors

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## Introduction

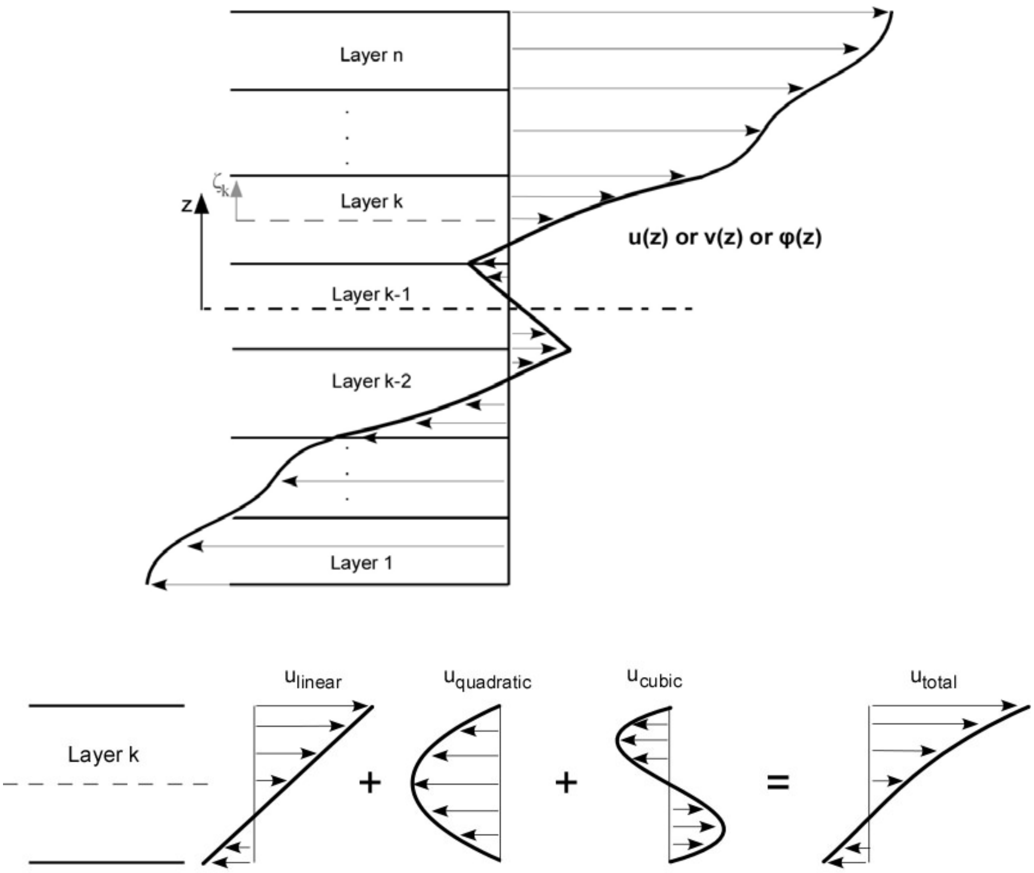
Smart sandwich shells with composite faces and foam core and embedded piezoelectric actuators and sensors combine the superior mechanical properties of sandwich structures, such as, high flexural stiffness to mass ratio, with the capability to monitor the structural response on-site in real-time. The high thickness and inhomogeneity in properties through the thickness in a sandwich composite structure can lead to complex parabolic profiles of interlaminar shear strains and stresses. The high shear stresses affect the global electromechanical response, but most importantly have a severe effect on the local stress field at the interface between composite and piezoelectric layers. In order to adequately capture these effects, formulation of novel layerwise laminate models is essential, which may yield robust predictions of the global response, but also accurate local predictions of the interlaminar and interfacial shear stresses and the deformed state of the laminate through the thickness. The objective of the proposed work will be to present a high-order theoretical framework and a corresponding finite element for predicting the coupled global and local electrostatic response of sandwich composite cylindrical shells with piezoelectric actuators and sensors, as well as, to investigate the sensitivity of the response to structural parameters such as thickness, ply orientation and lamination.

## Method of Approach

A previously published displacement based high-order layerwise theory for sandwich composite plates [1] will be extended for predicting the response of shell structures with piezoelectric layers polarized through their thickness. The kinematic assumptions through the thickness of the sandwich composite laminate will include linear, quadratic and cubic approximations of the in-plane displacements and the electric potential through the thickness of each discrete layer, while the transverse displacement will be assumed to remain constant through the thickness of the laminate (Fig. 1). Interlaminar shear stress compatibility conditions will be explicitly imposed to ensure continuous interlaminar shear stresses across discrete layers' interfaces and their vanishing at the free surfaces.

**Expected Results**

Validations of the developed theory with coupled linear layerwise theories for composite and sandwich composite shells [2] with piezoelectric actuators and sensors will be performed. The predictions will include distributions of mechanical (displacements, strains, stresses) and electric (electric potential and field) parameters through the thickness and along plane.




(a)

(b)

**Figure 1.** Schematic representation of the high-order layerwise laminate theory in a typical laminate configuration. a) Kimematic approximation through the thickness for the in-plane displacements and electric potential, b) Assumed field components through the thickness of a discrete layer.

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