NODE-DEPENDENT KINEMATIC SHELL ELEMENTS FOR THE ANALYSIS OF SMART STRUCTURES

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Abstract

In the present work, a new class of shell finite elements is proposed for the static analysis of composite multilayered structures embedding piezoelectric layers as actuators and sensors. The accurate description of the mechanical and electric fields along the multilayer is ensured by the shell Finite Elements (FE) with equivalent-single-layer and layer-wise capabilities. The novelty of the present shell element consists in the use of node-dependent shell theory assumptions. The new finite element allows for the simultaneous analysis of different subregions of the problem domain with different kinematics and accuracy, in a global/local sense, see Fig. 1. The structural theory of the shell element is a property of the FE node in this present approach, and the continuity between two adjacent elements is ensured by adopting the same kinematics at the interface nodes. The main advantage of the present node-dependent variable kinematics element is that no ad-hoc techniques and mathematical artifices are required to mix the fields coming from two different and kinematically incompatible adjacent elements, because the shell structural theory varies within the finite element itself. It is possible to reduce the computational costs by assuming refined theories only in those zones/nodes of the structural domain where the resulting strain and stress states present a complex distribution. At the same time, computationally cheaper, low-order models can be used in the remaining parts of the shell where a localized detailed analysis is not necessary. The governing equations are derived using the Principle of Virtual Displacements (PVD) extended to the electro-mechanical case. This model has already shown good results in the mechanical analysis of multilayered composite plates[1], and in the mechanical analysis of complex structures by the use of one-dimensional node-dependent kinematics for the coupling of beam models[2]. The Mixed Interpolated Tensorial Components (MITC) method is employed to contrast the shear locking phenomenon that usually affects shell finite elements. One of the most interesting features of the unified formulation consists in the possibility to keep the order of the expansion of the state variables along the thickness of the shell as a parameter of the model.With node-dependent kinematics it is possible to keep the order of the expansion of the

state variables and models along the main reference plane of the shell structure as a parameter of the model. The electrical potential assumption for the layered actuators and sensors has been extended, from a layer-wise (LW) modeling, to an equivalent-single-layer (ESL) description, in the same way the displacements assumptions on the composite layers are described by a ESL and LW models. Some results from the static analysis of shells under electro-mechanical loads will be provided, in order to show the efficiency of models presented.

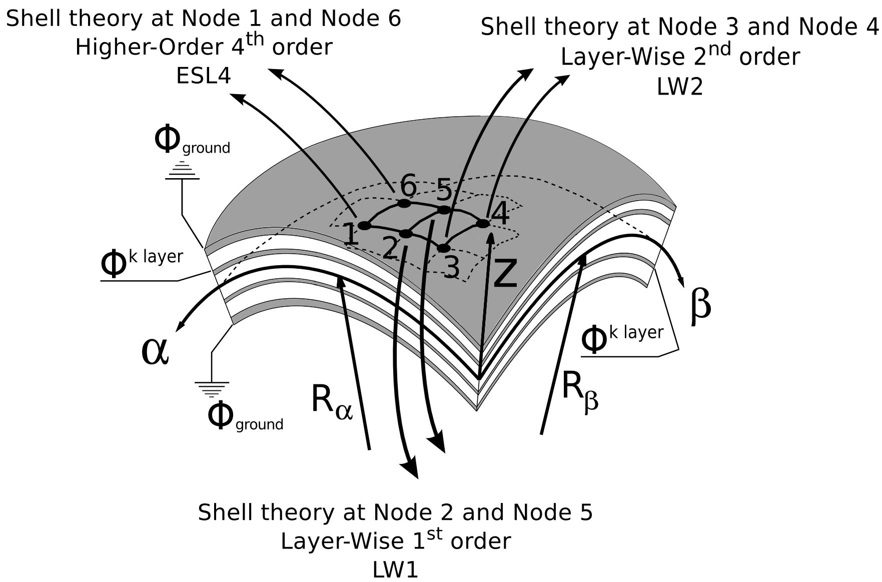

Figure 1: Node-dependent kinematic finite element example for a composite multilayered shell with piezoelectric layers.

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