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HYGRO-THERMAL ANALYSIS OF MULTILAYERED STRUCTURES BY MEANS OF MITC9 SHELL ELEMENTS BASED ON THE CUF

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Summary. *The present work deals with the linear static analysis of multilayered plates and shells under hygro-thermal loads. To this aim, the refined shell elements, formulated by the authors on the basis of Unified Formulation (UF), have been extended to the hygro-thermal problem. The governing equations are derived using the Principle of Virtual Displacements (PVD) extended to the hygro-thermal case. The Mixed Interpolated Tensorial Components (MITC) method is employed to contrast the membrane-shear locking phenomenon that usually affects shell finite elements. The hygro-thermal profile is assumed linear in the thickness direction. The thermal conductivity and moisture diffusion coefficients do not depend on the temperature. Results are compared with some reference solutions from the literature.*

1. INTRODUCTION

The analysis of composite structures subjected to hygrothermal environment is generally based on the classical lamination theory, and first-order shear deformation theory. For accurate predictions, the higher-order displacement fields yielding quadratic variation of transverse shear strains have been introduced by many researchers for the analysis of laminates subjected to mechanical loads. But, the application of higher-order theories for the study of thick multi-layered laminates under hygrothermal–mechanical load seems to be scarce in the literature.
Three-dimensional elasticity analysis carried out in the past for thick laminates subjected to

thermal loads reveals the non-linear variation of in-plane displacements through the thickness and abrupt discontinuity in slope at any interface, and thickness stretch/ contraction effects in the transverse displacement. Although higher-order theories based on discrete layer approach account for slope discontinuity at the interfaces, the number of unknowns to be solved increases with the increase in the number of layers. The authors propose the Unified Formulation for evaluating the hygro-thermal effects in laminated structures in order to employ different theories with different kinematic assumptions. One of the most interesting features of the Unified Formulation consists in the possibility to keep the order of the expansion of the variables field and the kinematic approach along the thickness of the plate/shell as parameters of the model. In so doing, both equivalent single layer (ESL) and layer-wise (LW) descriptions of the variables are allowed.
This formulation has already shown all its potentiality as a base for finite elements in the mechanical analysis of multilayered shells in [1] and has proved to give very accurate results for the thermal analysis of multilayered composite structures in [2]. This excellent performance motivated the present extension of the formulation for studying the hygrothermal effects on the laminates. The shell elements here used have nine nodes, and the mixed interpolation of tensorial components method is employed to contrast the membrane and shear locking phenomenon. Some results from the static analysis of plates and shells subjected to hygro-thermal variations along the thickness will be provided in order to show the efficiency of models presented.

References

[1] M. Cinefra and E. Carrera. Shell finite elements with different though-the-thickness kinematics for the linear analysis of cylindrical multilayered structures. *International Journal for Numerical Methods in Engineering* 93, 160–182, 2013.

[2] M. Cinefra, S. Valvano and E. Carrera. Heat conduction and Thermal Stress Analysis of laminated composites by a variable kinematic MITC9 shell element. *Curved and Layered Structures* 2, 301–320, 2015.