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A GLOBAL-LOCAL APPROACH FOR THE FREE-EDGE ANALYSIS OF COMPOSITE STRUCTURES UNDER THERMAL LOADS

Abstract

Space structures are subject to a severe thermal environment. The periodic variation of the thermal loads can generate mechanical stresses and originate the structure's premature failure. The use of composite materials and, in general, layered structures makes the thermo-elastic problem even more challenging since the difference in the material thermo-mechanical coupling constants can lead to local stress concentrations. These stress singularities can be extremely dangerous at the free-edge of laminated structures since out-of-plane stresses arise to preserve the equilibrium conditions. Transversal stresses can originate delamination and local cracking that would lead to a failure of the entire structure.

The prediction of free-edge phenomena cannot be made using the classical lamination theory for two reasons: (1) the phenomena appear at the mesoscale thus equivalent single layer models fail to predict local stress fields, (2) out-of-plane stresses must be considered. Three-dimensional finite element models can predict accurate stress fields in layered structures but, the small thickness of each layer leads to very high computational costs since the constraint on the element aspect ratio must be considered. Refined Layer-wise models have been successfully used for the analysis of free-edge phenomena but still require high computational cost when large structures are considered.

This work presents a novel global-local approach for predicting free-edge phenomena derived in the Carrera Unified Formulation (CUF) framework. The use of higher-order kinematic models has been demonstrated to provide excellent results when layered structures must be investigated and can easily handle multifield problems. Recent developments of CUF can be used to use to couple elements with incompatible kinematics; thus, refined local models can be easily coupled with global models. The present work extends the use of this approach to the thermo-elastic analysis of layered structures. A fully coupled thermo-elastic model is used; that is, the through-the-thickness thermal gradient is not assumed a priori but evaluated during the analysis. Different levels of local refinement have been investigated to evaluate the efficiency of the present approach. Both equivalent single layer and layer-wise models have been considered to ensure the best trade-off between accuracy and computational cost. Different stacking sequence setups and boundary conditions have been considered. The results demonstrate that the present approach can replicate the three-dimensional solution in the refined area. The current global-local approach ensures a significant reduction in computational costs compared to classical solid models.