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Advanced models for the accurate evaluation of interlaminar stresses in composites with applications to free-edge effects and delamination

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The present study presents a novel methodology for the accurate evaluation of interlaminar stresses in generic composite laminates which is based in the use of refined 1D theories with non-local assumptions over the cross-section. The numerical simulation of the interlaminar stresses in laminated structures is a topic of major interest in the composite community. In many structural applications, the high stress concentrations that arise at the free edges of the interfaces provoke the appearance of delamination zones, which reduce the performance of the composite component and give rise to further failure modes. In this matter, analytical and semi-analytical models have proven to be a useful tool, although they are usually limited to certain geometries and boundary conditions. On the other hand, the use of 3D finite element models can extend this study to general problems, but they require very refined discretizations to capture the localized effects that arise at the interfaces between layers, restricting in great manner its use. To solve this issue, in this work the Carrera's Unified Formulation is employed to reduce the 3D problem to a 1D analysis in which non-local higher-order polynomials are employed to expand the variables over the cross-section plane. Standard shape functions are used to interpolate the variables along the beam axis, whereas only-displacement assumptions and mixed displacement-stress assumptions based on the RMVT are considered over the section of the laminate in a layer-wise sense. The use of locally-defined expansion domains allows the user to refine the model in the zones of interest, i.e. the free-edges, while the mesh of the longitudinal axis remains coarse. In this manner, the computational size of the model can be reduced by orders of magnitude in comparison to solid models, and moreover, different boundary conditions and geometries can be evaluated. Results of tensile, bending and torsion cases in composite laminates are presented, as well as bonded joints tests.