Global/local capabilities of MUL2 for the nonlinear analysis of composite structures

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Summary: MUL2 is an in-house finite element (FE) platform whose structural formulation is based on the Carrera Unified Formulation (CUF). This work presents some of the latest capabilities of CUF and MUL2 concerning the structural analysis of complex composite structures. The modelling exploits global/local techniques and the node-dependent-kinematics (NDK) recently proposed within CUF. Assessments consider the evaluation of failure indexes along free edges, the tensile strength of notched specimens, and failure progression. Performances are evaluated in terms of accuracy and computational costs, and perspectives on advanced NDK modelling are drawn.

ABSTRACT

The virtual testing of composite structures necessitates structural models with advanced capabilities and computational efficiency. Examples of advanced capabilities are the detection of out-of-plane stress components and the detection of local effects, for instance, in the proximity of free edges. The computational efficiency is necessary to unleash the use of refined models to the upper levels of the test pyramid. Furthermore, the extension of such models to industrial cases widens the set of requirements, including, for instance, the analysis of structures with tens of layers.

CUF offers many opportunities to handle the modelling challenges listed above by incorporating the selection of structural theories into the set of inputs of the analysis. In other words, while, in commercial codes, a user is forced to use First Order Shear Deformation Theories, via CUF, any-order models are available. The combined use of CUF and 1D or 2D FE results in significant improvements of performance as compared to 3D FE.

Recently, CUF developments have led to the introduction of NDK to enforce a node-wise distribution of structural theory and further improve efficiency. Also, the synergy between NDK and classical global/local approaches makes the interface with commercial codes much less problematic [1, 2, 3].

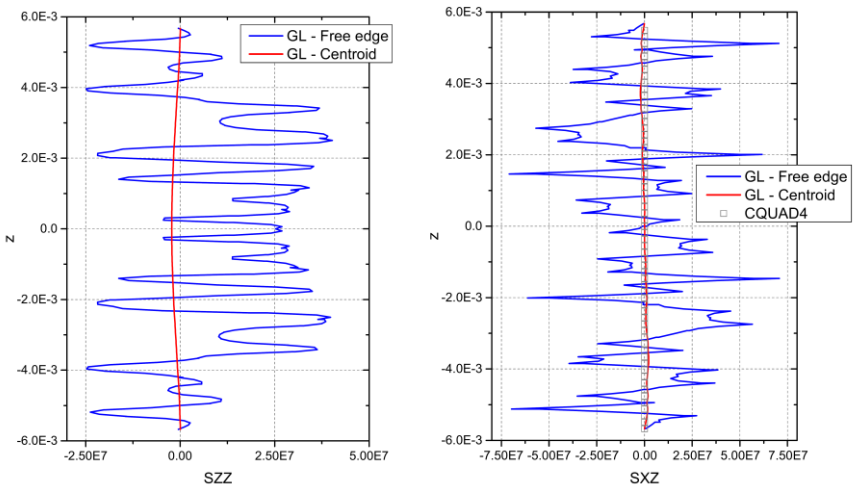

Figure 1 Free-edge peeling and transverse shear stress distributions along the thickness of a 64-layer laminate [2]

Figure 1 shows a numerical example concerning the out-of-plane stress distributions at different points of a laminate with tens of layers. Such distributions do not require post-processing techniques, e.g., numerical integrations, as they stem from the use of the constitutive equations.
The use of CUF can significantly extend the range of applicability of numerical models to problems with high modelling and computational complexity. Examples are the multifield modelling of manufacturing, the nonlinear progressive failure analysis, and the virtual testing of complex structures.

References

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[3] M. Petrolo, M.H. Nagaraj, I. Kaleel, E. Carrera, A global-local approach for the elastoplastic analysis of compact and thin-walled structures via refined models, Computers and Structures, Volume 206, 2018, Pages 54-65.