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BENCHMARKING OF COMMERCIAL CODES BY REFINED SHELL FINITE ELEMENT MODELS IN THE ANALYSIS OF COMPOSITE STRUCTURES

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Summary. *This paper deals with the benchmarking of commercial codes, such as MSC Nastran and ABAQUS, by means of refined shell finite elements formulated on the basis of Carrera's Unified Formulation (CUF). The static analysis of some composite structures (plates and shells) will be performed in order to show capabilities and limits of commercial codes. Particular attention will be given to the study of locking phenomenon and the analysis of transverse stresses along the thickness.*

INTRODUCTION

MSC Nastran e ABAQUS are commercial codes for the finite element analysis of mechanical components, extensively used in aerospace field. These products are very popular with academic and research institutions due to the wide material modeling capabilities and the program's ability to be customized. They also provide a good collection of multiphysics capabilities, making it attractive for production-level simulations where multiple fields need to be coupled. At the first step, this work considers the pure-mechanical analysis of composite structures.

In these codes, the kinematic model used is the First-order Shear Deformation Theory (FSDT) [1,2]. It is well known that FSDT takes into account the transverse shear deformations, but it assumes that the transversal displacement is constant along the thickness, neglecting the stretching effects relative to the transverse normal strain. Moreover, the reduced-selective integration technique is employed to contrast the locking phenomenon that affects finite elements. This technique is very efficient in improving the convergence of the solution but it produces secondary numerical problems, such as the spurious modes in the dynamic analysis. Both these aspects can represent limitations in the use of commercial codes.

For these reasons, this work performs a benchmarking of Nastran and ABAQUS codes by means of the refined models contained in the Unified Formulation (UF). The UF has been formulated by Carrera for the analysis of multi-layered structures and it has been implemented in an academic FEM code called MUL2. Its main feature is the unified manner in which the displacement field $\boldsymbol{u} = (\mathrm{u}, \mathrm{v}, \mathrm{w})$ is expressed:

$$\boldsymbol{u}(\mathrm{x,y,z}) = F_\tau(z)\boldsymbol{u}_{\boldsymbol{\tau}}(x,y) , \quad \text{with } \tau = 0, \dots, N ,$$

where F_τ are the so called thickness functions and u_τ are the unknown in-plane variables. Different refined theories can be obtained by changing the order of expansion N in the thickness direction. Both equivalent-single-layer (ESL) and layer-wise (LW) variable description of variables can be considered, depending on the thickness functions chosen. In the framework of ESL theories, also the FSDT can be expressed.

In recent works, it has been shown that the LW theories are particularly efficient for the analysis of multi-layered structures because they permit to correctly describe the distribution of transverse shear and normal stresses along the thickness [3]. Moreover, the finite elements considered employ the Mixed Interpolation of Tensorial Components (MITC) technique to contrast the locking. In [4], it has been demonstrated that this method permits to avoid the problems produced by reduced integration.

The static analysis of some composite structures will be performed and the results obtained by commercial codes will be compared with MUL2 ones.

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