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A COMPATIBLE SOLID SHELL-INTERFACE ELEMENT FORMULATION FOR DEBONDING OF THIN-WALLED STRUCTURES

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Delamination in composite thin-walled structures is a classic topic of major importance in various fields of mechanics and, from the computational point of view, it can still be considered as an open problem today. The problem of delamination between plies and layers of laminates is important to be accurately modelled for the structural assessment of adhesive joints.

Fostered by the use of composite materials in aeronautics, several kinematics theories and finite element approximations for shells under small, moderate or large displacements have been developed in the literature, see, e.g., [1-3] for a wide overview. Regarding modelling of interface fracture, the cohesive zone model (CZM) is typically used as a constitutive model for the interface and it establishes a nonlinear relation between interface tractions and relative opening and sliding displacements between crack faces [4,5].

Traditionally, most of the shell element formulations used for studying delamination in composites approximate the shell geometry as a surface with a given thickness that can vary within the domain of the shell. In this way, the kinematic description of the shell is then referred to the mid-surface of the element, being described by a set of translational and rotational nodal degrees of freedom. For interface elements used to simulate debonding, the thickness of the interface is usually neglected and the kinematics is solely described by the normal and tangential relative displacements at nodes, computed from pure translational degrees of freedom. Therefore, although fully compatible with 2D or 3D solid finite elements, an incompatibility may arise when used together with shells. Hence, coupling the different kinematics of the interface element and of the shell element is a fundamental issue. However, in spite of its importance, it seems not to have been rigorously solved.

An approximate methodology commonly adopted is to compute the displacements at the interface level from the axial displacements and rotations of the nodes in the mid-surface of the neighbouring shells elements, taking into account the thickness of the shells [6-10]. However, except in the limit case of symmetric problems (pure Mode I debonding), nodal rotations of shell elements sharing a common interface are uncoupled and the problem of incompatibility between the shell and the interface kinematics remains unsolved.

In the present work, we propose a fully compatible solid shell-interface element formulation based on the 7-parameter solid shell formulation by Büchter et al. [11], implemented in Abaqus and applied to the analysis of post-buckling problems in composites in [12]. Here, a novel finite element implementation in FEAP [13] is considered. One of the main features introduced by this solid shell formulation is the use of three translational degrees of freedom per node, as for brick elements, solving the problem of the compatibility with 3D interface elements. Numerical examples regarding delamination in thin-walled composites in the field of photovoltaics are finally provided and prove the accuracy of the proposed approach.

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