Blade cutting simulation with crack propagation through thin-walled structures via solid-shell finite elements in explicit dynamics

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ABSTRACT

To simulate the crack propagation due to blade cutting of a thin-walled shell structure, we propose a numerical technique based on solid shell finite elements [1] and explicit time integration.

The limitation on the critical time step due to the small thickness along the out-of-plane direction is overcome through a selective mass scaling, capable to optimally define the artificial mass coefficient for distorted elements in finite deformations [2]: since the selective scaling cuts the undesired, spurious contributions from the highest eigenfreqeuencies but saves the lowest frequencies associated to the structural response, and since the method preserves the lumped form of the mass matrix, the calculations in the time domain are conveniently speeded up.

The interaction of the cutting blade with the cohesive process zone in the crack tip region is accounted for by means of the so-called directional cohesive interface concept [3]. Unlike in previous implementations [3-4], through-the-thickness crack propagation is also considered. This is of critical importance in particular in the case of layered shells, where one solid-shell element per layer is used for the discretization in the thickness direction and it is a necessary ingredient for future possible consideration of delamination processes. Several computational problems, typical of the explicit dynamics analysis of these type of structures, such as hourglass control and spurious oscillations, are critically discussed [5].

We show, by using benchmarks from the literature on dynamic fracture of shells and by applying the proposed procedure to the cutting of a thin-walled laminate used for packaging applications [5], that this is a promising tool for the prediction of the structural response of thin-walled structures in the presence of crack propagation induced by blade cutting.

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