Simulation of Fracture and Cutting Processes in Thin-walled Multi-layer Shell Structures

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ABSTRACT

The present work addresses the simulation of blade cutting and fracture propagation in multi-layer shell structures. The study of fracture of laminated thin-walled structures is of importance in a variety of engineering applications and is attracting considerable attention for the difficulties involved in the simulation of fragmentation and delamination phenomena.

The eight-nodes solid shell element, developed in [1] and based on reduced integration with hourglass stabilization, is here adopted to model the shell structures. This kind of element is well suited for the discretization of multi-layered thin-walled structures, obtained by stacking up one or more solid shell elements per layer through the thickness. Furthermore, since solid shell elements are formulated using displacement degrees of freedom only, they allow for the implementation of fully three-dimensional constitutive behaviour and for the cohesive description of fracture phenomena.

In developing a finite element computational tool able to simulate crack propagation in thin-walled structures, several non linearities have to be addressed, i.e. large deformations, contact, crack propagation and delamination. As often done in dealing with highly non linear problems, an explicit dynamics framework is here considered. The main drawback is that using solid shell elements, the element thickness is usually very small if compared to the in-plane dimensions, leading to a very small critical time step in a conditionally stable integration scheme. To overcome this problem, a selective mass scaling technique is introduced, extending the numerical technique proposed in [2] and in [3] to the case of multi-layer shell structures. The basic idea is to locally modify the solid-shell element mass matrix, so that the stable time step is determined only by the minimum in-plane size of the elements, as for classical shell elements, with negligible accuracy losses in inertia dominated problems.

The through-the-thickness crack propagation is described by means of a cohesive approach. Directional cohesive elements, as proposed in [4] and in [5], are introduced along separating element edges to properly reproduce the blade cutting phenomenon, accounting for the interaction between the blade and the process zone in transmitting the cohesive forces between the two flanks of the crack.

The proposed numerical procedure is tested in classical benchmarks of shell dynamic fracture propagation and applied to the simulation of the blade cutting process of a laminated used in the carton packaging industry, as shown in figure 1.

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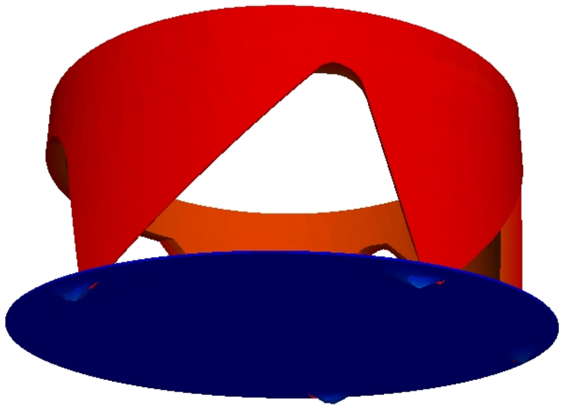

Figure 1: Blade cutting of a laminate used for packaging applications.

References

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