A one-field formulation of elasto-plastic shells with fracture applications

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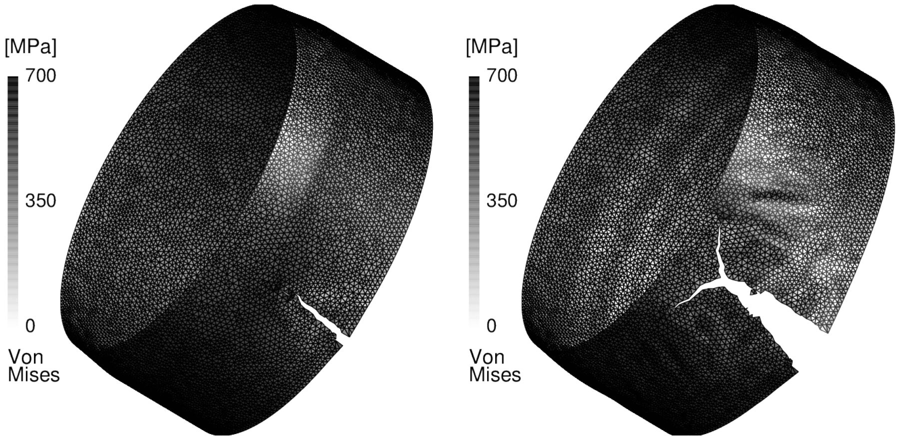
ABSTRACT

The main feature of Discontinuous Galerkin (DG) methods is their ability to take into account discontinuities of the unknown field in the interior domain of studied problems. In such formulations the integration by parts is realized on the elements leading to boundary integral terms These terms between elements ensure the continuity and compatibility of the solution in a stable manner, which makes DG attractive to ensure weakly the C0 continuity and/or the C1 continuity. For non-linear Kirchhoff-Love shells, the C0/DG formulation - the C0 continuity is ensured as usual by considering continuous shape functions and the C1 continuity is weakly ensured by DG interface terms in a stable and consistent way - leads to a one-field formulation, where the displacements are the only unknowns of the problem [5].

DG methods have also an advantage when it comes to simulate fracture with a cohesive approach. Indeed, the classical cohesive methods suffer from severe limitations. The intrinsic approach, which inserts the cohesive elements at the beginning, requires an initial slope in the traction separation law and suffers from lack of consistency, while the extrinsic cohesive method, which inserts the cohesive elements during the simulation when a fracture criterion is reached, suffers from difficult parallel implementation due to the topological mesh modifications happening during the simulations. To overcome these limitations, new methods were developed and in particular, an approach based on a C0-discontinuous Galerkin formulation where continuity between elements is ensured weakly by the interface elements. These interface elements can be easily replaced by a cohesive element during the simulation, leading to an efficient fracture framework [4, 6].

We have recently extended this approach for linear shells [1] to obtain a full DG formulation of thin bodies, where discontinuities in the C0 and C1 fields are weakly enforced using consistent interface elements, and where the interface elements can be used to integrate the cohesive law when a fracture criterion is met. Moreover, a new cohesive law based on the reduced stresses of the thin bodies formulation is developed to propagate a fracture through the thickness. This cohesive model dissipates the right amount of energy during crack initiations and/or propagations.

These developments are extended to non-linear elasto-plastic shells and are implemented in parallel, which allows to simulate complex fracture problems. As a validation example, the study of a blasted notched-cylinder is performed, for which experimental and numerical (by XFEM method) data are reported in the literature by [3]. Figure 1 illustrates the results obtained at different times. It can be seen that the simulation allows to model crack propagation, as well as the bifurcation happening when the crack reaches the top of the cylinder. Also, it appears that with the elasto-plastic framework, the crack speed numerically predicted matches the experimental measures [2].



(a) $t = 592\ \mu s$ (b) $t = 1300\ \mu s$

Figure 1: Crack propagation in the blasted cylinder.

Acknowledgment. G. Becker is a PhD candidate at the Belgian National Fund for Education at the Research in Industry and Farming.

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