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# A parallel discontinuous Galerkin/cohesive-zone computational framework for the simulation of fracture in shear-flexible shells

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**Abstract**

We propose a computational framework for the simulation of deformation and fracture in shells that is well suited to situations with widespread damage and fragmentation due to impulsive loading. The shell is modeled with a shear-flexible theory and discretized with a discontinuous Galerkin finite element method, while fracture is represented with a cohesive zone model on element edges. A key feature of the method is that the underlying shear-flexible shell theory enables the description of transverse shear fracture modes, in addition to the in-plane and bending modes accessible to Kirchhoff-Love thin shell formulations. This is especially important for impulsive loading conditions, where shear-off failure near stiffeners and supports is common. The discontinuous Galerkin formulation inherits the scalability properties demonstrated previously for large-scale simulation of fracture in solids, while avoiding artificial elastic compliance issues that are common in other cohesive model approaches. We demonstrate the ability of the framework to capture the transverse shear fracture mode through numerical examples, and the parallel computation capabilities of the method through the simulation of explosive decompression of the skin of a full-scale passenger aircraft fuselage.

*Keywords:* shells, fracture, discontinuous Galerkin, cohesive zone, parallel computing

## 1. Introduction

Fracture is a critical concern in the engineering of many shell structures, e.g., blast protection of ships and submarines, ship grounding, vehicle crashworthiness, and accident reconstruction and analysis for passenger aircraft. Advances in computing power notwithstanding, direct simulation of shell structures with three dimensional continuum methods is impractical, particularly in cases when the structure is large, fracture is widespread, and the failure locations are not known a priori. Shell theory remains the method of choice to attack these problems. In this work, we develop a computational framework for the simulation of deformation and fracture in shells that is well suited to simulating scenarios with massive damage and fragmentation under highly impulsive loading. The consideration of fracture driving forces is quite general and comprises the full range of modes possible for shells: in plane forces, bending, and transverse shear.

We model fracture as a process of surface decohesion in the style of Barenblatt [1, 2]. In particular, our approach belongs to the family of methods that implement the cohesive fracture concept through *interface elements* that allow fracture on element boundaries. This technique was originally developed for fracture in solids (see, e.g., [3, 4] and the review of the technique in [5]), and was adapted to the special case of shells in the last decade [6, 7]. Our approach builds on this work in a number of ways. The framework here is based on a discontinuous Galerkin (DG) spatial discretization using a finite deformation, Reissner-Mindlin

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