A dynamic phase-field fracture model with a programmed, wave-based initiation

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EXTENDED ABSTRACT

Phase-field fracture models have become a widely adopted framework for simulating crack initiation and propagation in brittle materials due to their ability to avoid mesh dependency and capture complex crack topologies under dynamic loading conditions (Francfort & JJ, 1998; Bourdin, et al., 2000; Hofacker & Miehe, 2013). Building on the dynamic phase-field implementation previously validated for quasi-static and impact scenarios in LS-DYNA (Rudshaug, et al., 2024), this work introduces a novel fracture initiation concept inspired by experimental findings: programmable fracture waves.

Unlike conventional approaches that rely on local stress or energy-based criteria (Miehe, et al., 2010; Ambati, et al., 2014), the proposed method allows the user to define the fracture initiation location, time, and propagation speed of a fracture initiation wave. At the programmed initiation time, a radial activation front expands from the chosen origin at a user-specified speed, progressively enabling the phase-field evolution in its wake. This mechanism mimics experimentally observed phenomena where cracks propagate radially from the location of fracture initiation in a wave-like manner, as seen in ring-on-ring experiments on brittle glass.

The objective of this study is to develop and assess the performance of this programmable initiation strategy within a dynamic phase-field framework. The extension builds on the staggered solution scheme of Hofacker and Miehe (2013), previously implemented in LS-DYNA through user-defined solid and shell elements (Rudshaug, et al., 2024). While the governing evolution equation remains energy-driven, fracture activation is restricted to regions reached by the propagating initiation front, enabling precise control over fracture onset and progression. Numerical experiments are conducted on brittle glass specimens subjected to quasi static and dynamic loading, investigating the predictability of the programmable wave-based initiation.

This work introduces a spatially and temporally programmable fracture initiation mechanism for phase-field models, enabling simulation of phenomena previously inaccessible to stress-based criteria. Preliminary results indicate that the approach captures crack propagation patterns similar to ring-on-ring experiments. The flexibility of defining the fracture initiation location opens new possibilities for further coupling with stochastic fracture initiation models like the Glass Strength Prediction Model (Rudshaug et al., 2023).

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