Comparison between cohesive elements and the Lip-field approach to fracture in 1D dynamic fragmentation

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The dynamic fragmentation phenomenon is characterized as a fast, explosive, and complex failure of solids when submitted to extreme loads. It involves the initiation, propagation, branching, and merging of cracks, leading to fragment formation. Crack modeling is a key factor in the simulation of this complex crack process and is of interest to engineers and researchers engaged in problems involving hypervelocity impacts. An example is the concern of the aerospace industry with the increasing number of space debris orbiting the Earth, since these objects can collide with satellites, leading to a dynamic fragmentation of important structures.

The Lip-field approach to fracture was introduced in [1] for 1D cases and for 2D in [2]. It was also already extended to 1D dynamics in [3]. It is a diffuse damage approach, similarly to most damage mechanics based models, where the loss of strength, or other mechanical property, is a function of an irreversible scalar field called damage. The Lip-field methodology enforces this damage field to be Lipschitz continuous by solving a an optimization problem subject to a Lipschitz constraint.

In the context of the Finite Element Method (FEM), a popular approach to modeling cracks is the Cohesive Zone Model (CZM). It proposes the insertion of cohesive elements on the facets of finite elements when failure conditions are met. By modifying the mesh, jumps in displacement are admitted into the model, and this enables the evolution of the crack opening based on a cohesive law.

Both methodologies (cohesive elements insertion and diffuse damage models) have benefits and drawbacks. Note that for CZM, cracks can only propagate through paths formed by mesh facets, and hence the usual caveat is a strong mesh dependency. On the other hand, for diffuse damage models, when using FE discretizations, a regularization length is used to avoid the concentration of damage and reduce mesh-dependency. Their leading drawback is a high computational cost. They also lack an explicit crack path definition, which comes naturally when using cohesive elements.

In this study, we compare the CZM and Lip-field by means of fragmentation data (i.e. number and size of fragments), and computational cost, in a 1D dynamic fragmentation of an expanding ring. A comparison between the two approaches was done in [3]. Here, we extend this comparison by considering contact forces occurring between newly created cracked surfaces.

The comparisons made in this study contribute to a better understanding of the benefits and drawbacks of each approaches when analyzing fast and complex facture processes.

References

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