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MESHING STRATEGIES FOR THE ALLEVIATION OF MESH-INDUCED EFFECTS IN COHESIVE ELEMENT MODELS

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The classical cohesive theory of fracture finds its origins in the pioneering works by Dugdale, Barenblatt and Rice [1, 2, 3]. In their work, fracture is regarded as a progressive phenomenon in which crack formation takes place across a cohesive zone ahead of the crack tip and is resisted by cohesive tractions. Cohesive zone models are widely adopted by scientists and engineers perhaps due to their straightforward implementation within the traditional finite element formulation. Some of the mainstream technologies proposed to introduce the cohesive theory of fracture into finite element analysis are the eXtended Finite Element Method (X-FEM) and cohesive elements.

Sukumar et al. [4] first utilized the X-FEM for modeling 3D crack growth by adding a discontinuous function and the asymptotic crack tip field to the finite elements. Subsequently, the method was extended to account for cohesive cracks [5]. It is worth noting that while the X-FEM approach can potentially deal with arbitrary crack paths, it becomes increasingly complicated for problems involving pervasive fracture and fragmentation.

On the other hand, the cohesive element approach consists on the insertion of cohesive finite elements along the edges or faces of the 2D or 3D mesh correspondingly [6, 7, 8, 9]. Even though this approach is well suited for problems involving pre-defined crack directions, a number of known issues affect the its accuracy when dealing with simulations including arbitrary crack paths, namely, (i) problems with the propagation of elastic stress waves (artificial compliance), (ii) spurious crack tip speed effects (lift-off), and (iii) mesh dependent effects (c.f. [10] for a comprehensive review). Despite these well known limitations, the robustness of the method makes it one of the most common approaches for pervasive fracture and fragmentation analysis.

Some of the limitations present in early approaches to cohesive element models were addressed by subsequent research efforts. For example, artificial compliance and lift-off effects can be avoided by using an initially rigid cohesive law [8] or, more elegantly, a discontinuous Galerkin formulation with an activation criterion for cohesive elements [11, 12]. However, the problem of mesh dependency is still an active area of research.

Mesh-dependent effects are direct consequence of cracks being able to propagate only across boundaries between bulk finite elements. That is, the topology of the mesh forces cracks to follow paths that in general require more energy per unit crack extension (greater driving forces) than those followed in the original continuum. In this work, we first focus on the effects that common topologies have on two main mesh-dependent effects, namely: mesh-induced toughness and mesh-induced anisotropy. We then illustrate how to decrease mesh-induced anisotropy through K-means meshes. Finally, we introduce a new type of mesh, termed conjugate-directions mesh, which greatly alleviate both effects.

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