Adaptive mesh refinement and coarsening for the analysis of three-dimensional phase field fracture with discrete cracks

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Phase field models (PFMs) for material failure have been used to perform the fracture analysis of structures for crack initiation and propagation. In the PFMs, the total potential energy of a cracked elastic body can be given based on the variational approach combined with the Griffith's theory of fracture [1], wherein the variational principle to the potential energy leads to a minimization problem of the dissipation energy released to propagate a diffusive crack of damage phase field [2].

In order to accurately approximate the diffusive crack with high gradients of deformation and phase fields, the mesh in the damaged region should be sufficiently small compared to the characteristic length scale. Since a globally fine mesh for the analysis of phase field fracture demands on huge computational resources, an adaptive mesh refinement technique can be efficiently used to trace the crack trajectory with locally refine meshes. Although adaptive mesh refinement can improve the accuracy of solutions in the analysis of phase field fracture, very fine local meshes should be used near the crack tip and the crack surfaces. Accordingly, the computational cost significantly increases as the crack propagates because the number of elements along the crack trajectory increases rapidly.

A combined continuous-discontinuous approach can be used to enhance the efficiency of the analysis of phase field fracture by creating discontinuous discrete cracks for the fully damaged materials. Discrete cracks provide an accurate description of crack surfaces by detaching or eliminating fully damaged materials.

In this paper, we present a novel adaptive mesh refinement and coarsening technique using trimmed hexahedral (TH) elements for the analysis of phase field fracture with discrete cracks. An initial TH mesh is generated by cutting a hexahedral background grid with the boundary of a solid domain, as shown in Fig. 1. The boundary region is then composed of TH elements while hexahedral elements remain in the interior domain. Octree-based TH meshes are adaptively constructed from the initial TH mesh using an energy-based criterion during the analysis of phase field fracture, wherein the transition mesh interface is seamlessly connected by using compatible shape functions.

Discrete cracks are created by cutting octree-based TH meshes with critical damage isosurfaces that represent the crack surfaces. The crack surfaces of discontinuous discrete cracks can be then defined by the cut faces of TH elements. An energy-based criterion is employed to find the regions for mesh refinement. Mesh coarsening is also performed in the fully damaged regions with small amount of crack driving energy to reduce the computational cost. Fig. 2 schematically illustrates the octree-based mesh adaptation strategy for the analysis of three-dimensional phase field fracture with discrete cracks.

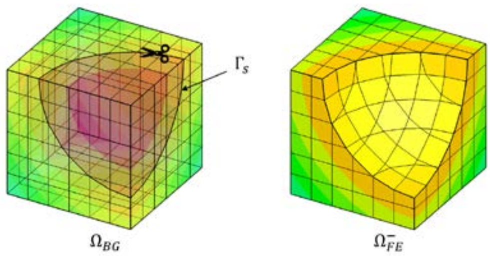

Fig. 1 An initial TH mesh generated by cutting a background hexahedral grid with the boundary of a solid domain.

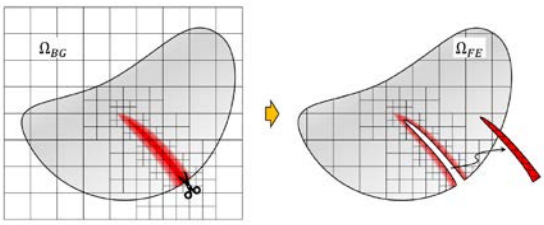

Fig. 2 Schematics of a discrete crack created by cutting an octree-based background mesh with critical damage isosurfaces for the analysis of phase field fracture.

References

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