A Fracture Analysis of Solids by using Trimmed FE Mesh coupled with Phase Field for Damaged Material

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1. Introduction

The fracture of material is critical to reliability and stability of structures. To explore a fracture behavior, computational analysis is widely used because the experiments require a huge budget. Many studies on computational fracture analysis have been proposed by using discrete methods and mesh-independent methods.

In this study, trimmed FE mesh coupled with phase field fracture model is proposed for fracture analysis in solid. Phase field of material damage is obtained by solving evolution equation on a background cubic grid. For a hexahedral-dominant mesh of a cracked domain, trimmed-hexahedral elements are obtained by cutting background cubic cells with crack surface based on phase field. The trimmed-hexahedral elements are defined based on the configurations of marching cubes algorithm that represent iso-surfaces in a cubic cell.

The trimmed FE mesh is obtained by cutting locally refined cubic grid. and trimmed-hexahedral elements based on master element approach with explicit shape functions are exploited to reduce the computation time that is one of the main obstacles in computational fracture analysis.

2. Phase field fracture model

The phase field function [1] *d(x)* describes the material damage, that is approximated by an exponential function as

$$d(x) = e^{-|x|/l_0} \quad (1)$$

where l_0 is the length scale parameter determining the width of a non-smooth crack topology. Fig.1 illustrates a diffusive crack in one dimension.

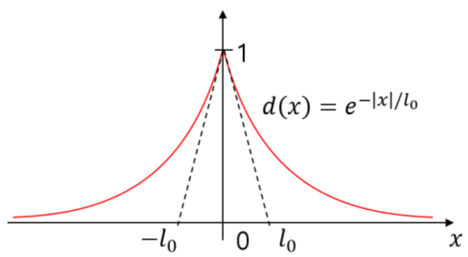

Fig. 1 A diffusive crack in one dimension with the length scale parameter l_0.

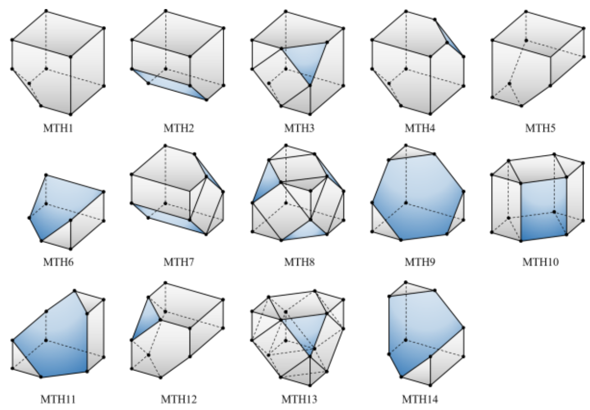

Fig. 2 The 14 configurations of master trimmed-hexahedral elements based on marching cube algorithm.

According to Griffith's energy approach, the energy for creating a new crack surface could be defined as

$$\Psi = \Psi^e + \Psi^d - \Psi^s \quad (2)$$

where Ψ^e is the energy stored in body, Ψ^d is the dissipated in the fracture process, and Ψ^s is the external energy. According to Griffith's theory of fracture, the dissipated energy can be expressed as

$$\Psi^d = \int_\Omega G_c \gamma(d, \nabla d) dV \quad (3)$$

where G_c is the critical energy release rate required to create a unit area of fracture surface and γ is the crack surface density per unit volume.

3. Trimmed FE mesh for a cracked domain

In this study, the set of trimmed-hexahedral elements [2] are defined with the master element based on marching cubes algorithm that proposed for iso-surfaces determined by nodal values of a cube. The damage of phase field fracture at nodes of background grid are used for cutting a cubic cell to generate a hexahedral-dominant mesh with trimmed-hexahedral elements in the crack region. The configurations of trimmed-hexahedral elements are listed in Fig.2.

Iso-parametric shape functions of trimmed-hexahedral elements can be obtained in master element within tetrahedral subdivision interpolated by using conventional shape functions.

To capture the length scale of crack topology, a discretization of domain with crack by cut a background grid is carried out with locally refined grid in the crack region.

As the crack propagates, only a small part of crack front in the hexahedral-dominant mesh is modified by cut with new crack surface defined by updated phase field.

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References

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