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A Finite Element Sub-Partition Method for Crack Extension Simulation

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ABSTRACT

Finite element method (FEM) has been widely employed to study fracture in structures or solids. Crack extending process simulation will bring re-meshing [1] of FE models which usually are inefficient. Though some other methods, e.g. failed element removing [2] and CZM (cohesive zone model) [3], can avoid re-meshing, the former cannot well describe the stress singularities at crack tip and the later needs to preset crack potential path. Extended finite element method (XFEM) [4, 5], which developed in the recent two decades, can simulate crack growth efficiently. It possesses merits of being free from re-meshing and well representing singularity at crack tip without local mesh refining. However, current XFEM faces big difficulty in formulating singular function at crack tip for nonlinear fracture problem.

In this study, a new methodology for simulating crack propagation based on methods of element sub-partition and substructure was suggested. In this method, all the elements incised by a crack group a substructure are sub-partitioned to comply with the crack geometry, as schematically shown in Fig.1. This new XFEM reserves the merits of current XFEM while it can be conveniently expanded to deal with nonlinear and interfacial fractures in traditional FEM frame. The sub-partition introduced additional degrees of freedom are condensed to the original discretized mesh nodes, thus the total freedom degree for global structure computing is invariable, no matter how many new cracks nucleate and how long the existing cracks extend. The accuracy of the singularity at crack tip by this new XFEM was validated by predictions of stress intensity factors (SIF) of central crack in both finite and infinite panels. The materials considered here were isotropic and orthogonal anisotropic. Interfacial fracture is also compared with theoretical solution. Then, it was used to simulate the crack propagation in a multi-ply bi-material beam which was applied three points bending load. Alternations of crack deflecting to (and going along) interfaces of plies and moving transversely, which are often observed in experiments, were well represented. Finally, this model was employed in a unidirectional fiber reinforced composite to simulate the complicated manners of micro cracks nucleation and propagation under transverse loading, as demonstrated in Fig.2. In this scenario, micro cracks nucleate determined by maximum principal stress law, so they take place in stress concentrated region. They may subsequently go forward in matrix or along fiber/matrix interface depending on which direction the ratio of SIF to material's fracture toughness is biggest. With this model, the effects of micro parameters, e.g. fiber volume fraction and fiber/matrix interfacial properties, on the global strength and fracture toughness of unidirectional composite were investigated.

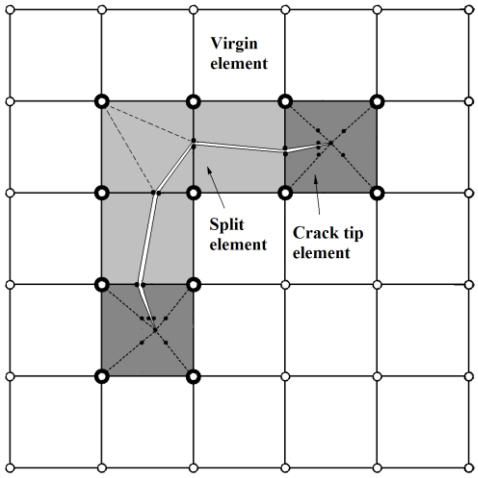
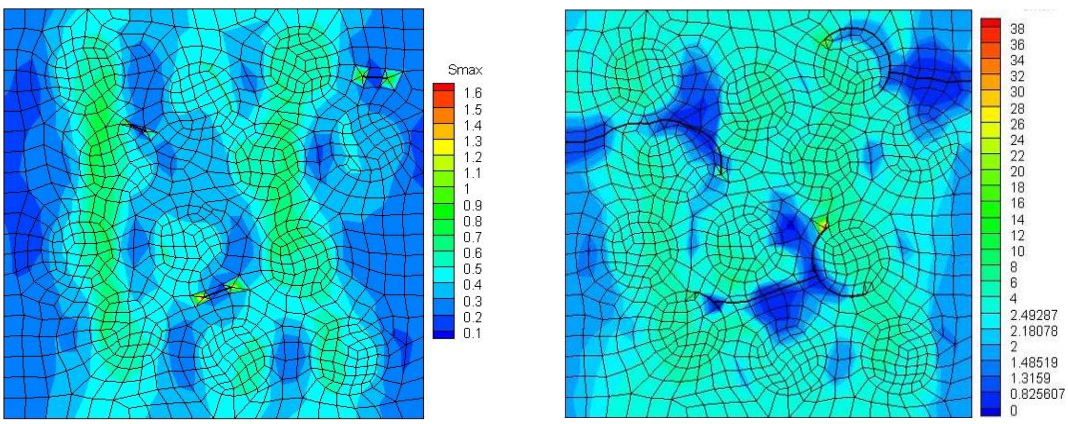


Figure 1: Substructure covering a crack and sub-partition of element in it.



(a) Nucleation (b) Extension

Figure 1: Micro crack nucleation and propagation in unidirectional composited.

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