Recent Advancements and Applications in Development of SMART Crack Growth Simulation

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Abstract
SMART (Separating, Morphing, Adaptive and Remeshing Technology) is a finite element based crack growth simulation framework[1] recently developed in the ANSYS Mechanical Solver. Crack representation is essential for FE based fracture and crack growth simulation. The ability to control the mesh and ensure mesh quality at remeshing are essential for robust and accurate crack growth prediction. In this paper several examples and benchmarks are presented to demonstrate the effectiveness and validity of the SMART framework for complex crack propagation simulation. We will then present the latest technological advancements in SMART development related to meshing control with special focus on meshing refinement and coarsening, and adaptive crack initiation.

Introduction
The fracture mechanics based tolerance assessment of complex structural components requires; 1) capability of effective modeling of complex 3D mixed mode cracks propagation under both static and fatigue loads; 2) accurate prediction of the crack initiation and fatigue crack growth (FCG) residual life for structures; 3) ability to predict the catastrophic failure of the structures. Special methods such as mesh free and XFEM[1] may be available, but its application is generally limited. Finite Element Method (FEM) based on remeshing and mesh adaptivity techniques for simulation of crack propagation process have been intensively used in the past several decades by many researchers and are still the best approach. General purpose FE software for real world large scale crack propagation simulation are largely no exist until recent SMART development.
SMART crack growth simulation framework has successfully integrated crack growth mechanics and crack representation into finite element solution kernel and therefore allows effective, automatic and seamless end-to-end simulation of crack growth. Adaptive remeshing for crack representation is performed only locally to crack front. Mapping is performed automatically for all types of boundary conditions and loadings including temperature, displacement, force, distributed surface pressure, centrifugal force, and initial strain/stress etc. Both distributed and shared memory parallel process are supported, and a second MPI communicator is developed to support fracture and crack growth parallel computing. Several examples are presented to demonstrate the use of SMART for very complex crack propagation situation.

Results
A typic fracture analysis requires fine meshes around crack tip/front and meshes should become coarse when they are away from crack tip/front. When crack starts to propagate, the best meshing scheme is maintaining finer meshes only around crack tip/front and coarsening other region of meshes, it is particularly important that the old fine crack tip/front meshes needs to be coarsened. An effective mesh coarsening and refinement scheme is essential for large scale crack growth simulation.

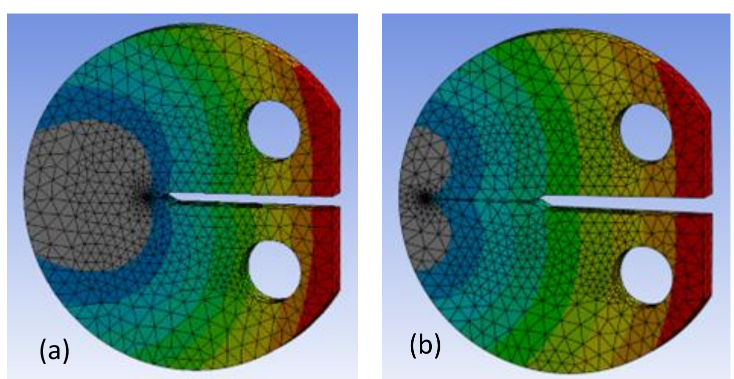


Fig. 1 Disc compact tension specimen

Fig. 1 is finite element model of disc compact tension (CT) specimen that is used for comparison of meshing coarsening schemes. Fig. 1(a) and (b) are meshes of two different crack extensions with a fine-tuned coarsening scheme. Fig. 2a compares the resulting numbers of FE nodes from the two schemes and Fig. 2b compares the calculated cycle counts vs crack extension.

Ability to automatically model crack initiation is of great interest for fracture mechanics simulation. SMART has introduced an automatic crack initiation procedure based on modern statistical data analysis technologies for identifying the locations and orientations of the initial cracks/defects. Fracture criterion is based maximum principal criterion. Initial crack sizes are either user defined via command or program chosen by our solver based on the mesh sizes around crack initiation location. A simple perforated plate with an initial edge crack is used to illustrated crack propagates and cuts into the hole, and then a new crack is initiated from opposite side of the hole and propagates further, Fig. 3.

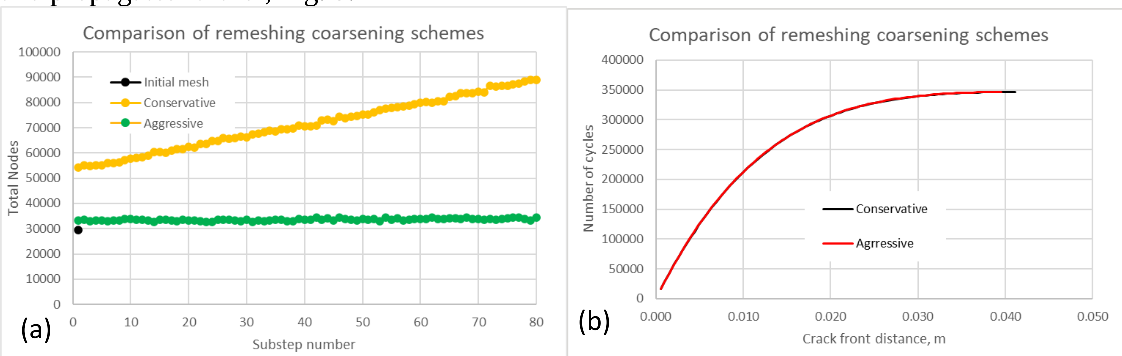
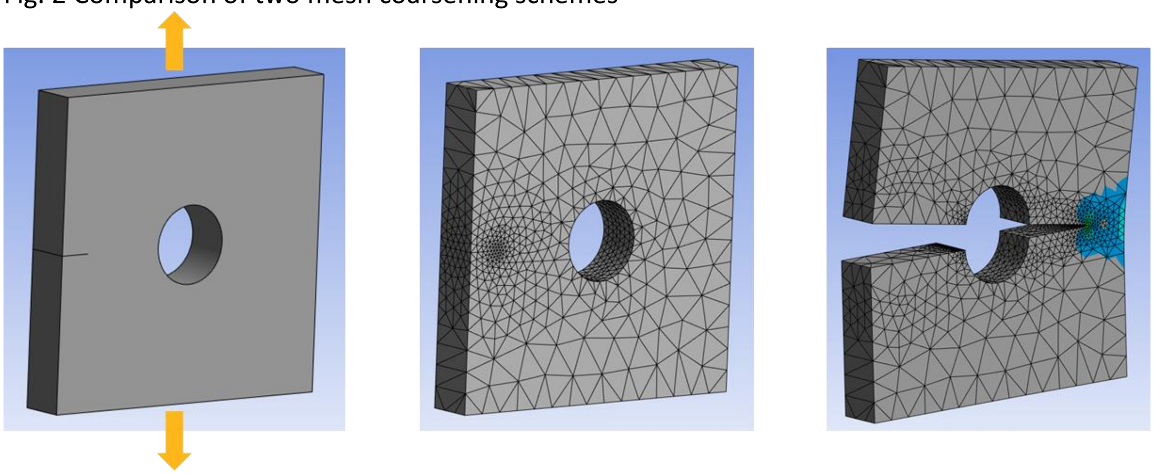


Fig. 2 Comparison of two mesh coarsening schemes



(a) (b) (c)

Fig. 3 (a) Perforated tensile specimen with an edge crack, (b) FE mesh, (c) Crack propagation and initiation.

Conclusions

This paper presents several examples to demonstrate SMART as a general and effective finite element framework for crack propagation simulation. Mesh control and mesh quality are essential for a successful crack propagation simulation. This paper also demonstrated how SMART integrates meshing control into the FE solver to ensure an effective and robustness crack growth simulation.

References

[1] Ansys, Inc., Ansys Mechanical APDL Fracture Analysis Guide
[2] T. Belytschko, H. Chen, J. Xu, and G. Zi, Dynamic crack propagation based on loss of hyperbolicity and a new discontinuous enrichment, International Journal for Numerical Methods in Engineering, 58:1873-1905, 2003