A Cell Method Code for Fracture Mechanics

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Abstract

Si è implementato un codice di calcolo per la modellazione della propagazione delle fessure tramite il Metodo delle Celle (CM). La geometria del crack viene aggiornata tramite una tecnica di propagazione intra-mesh. La mesh viene rigenerata automaticamente ad ogni aggiornamento. Il codice è stato implementato in Matlab su EIDOS. Si presentano i risultati relativi a propagazione in Modo Misto.

A numerical code for modeling crack propagation using the Cell Method (CM) has been implemented. The crack geometry is updated with an intra-element propagation technique. Automatic remeshing is activated after each update. The code was implemented in Matlab on EIDOS. Results for Mixed Mode crack propagation are presented.

Introduction

Modeling the propagation of a crack through a mesh is difficult because the geometry of the mesh must be modified as the crack propagates. Two different strategies are available to study fracture mechanics using the finite element method (FEM). The first strategy describes fracture as a sharp drop in the normal stress, due to the evolution of damage to the material. The second strategy represents the crack as a displacement discontinuity described by the separation of its edges. Many authors have developed innovative techniques to simulate the propagation through a finite element mesh, such as the meshless method, the element-free Galerkin method, the arbitrary local mesh replacement method, the boundary element method and nodal relaxation. In particular, nodal relaxation can be achieved using two different techniques: inter-element propagation, which is mesh dependent, since the crack propagates along mesh boundaries; and intra-element propagation, which is mesh independent, since the direction of propagation is computed by a variety of criteria. The first method is faster than the second, since it does not require a remeshing stage, but it is less accurate.

In this study, the second strategy is chosen. A combination of nodal relaxation with intra-element propagation and remeshing is adopted. This technique is used to implement a code using the CM [Tonti (in press)].

The change in mesh topology is rarely supported by classical FEM numerical codes. Thus, the present work is original in two ways. It represents one of the first implementations of the CM for fracture mechanics, and presents a remeshing technique that is able to easily take into account a general change in the mesh topology.

Theoretical basics of the CM

The CM is a new numerical method for solving field equations. The essence of this method is to provide a direct finite formulation of field equations, without requiring a differential formulation.

All existing numerical methods for the solution of field equations take a differential formulation as their starting point. A finite formulation is derived from the differential formulation by one of various discretization methods. Even the boundary element method (BEM) and the finite volume method (FVM), which use integral formulation, are based on a differential formulation.

The CM is very similar to the direct or physical approach initially used in the FEM. It is also similar to the FVM and can be considered as a generalization of the finite differences method (FDM). Nevertheless, for all these methods it has not been possible to attain greater than second order convergence. Consequently, the physical approach fell out of favor. The CM (based on a different philosophy) permits the use of interpolation functions, as used in the FEM. Thus, the physical approach can be revived.

A peculiarity of the CM is the use of dual meshes instead of the single mesh utilized by differential methods.

Numerical results

The following images show discretization of the longitudinal section, and stress analysis of a compressed concrete cylinder. The stress analysis is carried out using the CM code developed by the author. All images are generated using a graphical tool developed by the author.

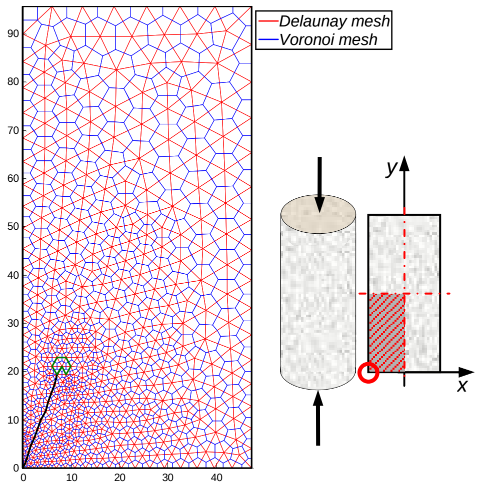

Figure 1 Delaunay and Voronoi discretization of the space domain

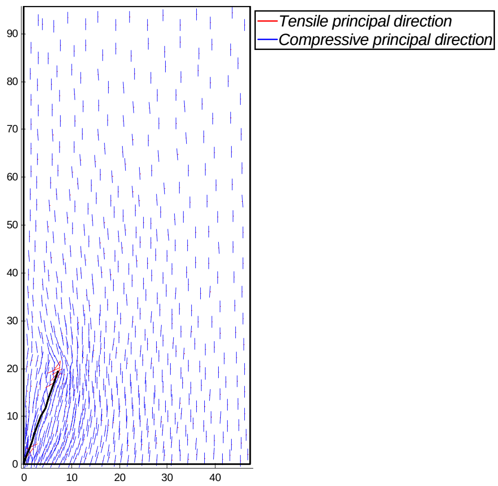

Figure 2 Computed tensile and compressive principal stress directions

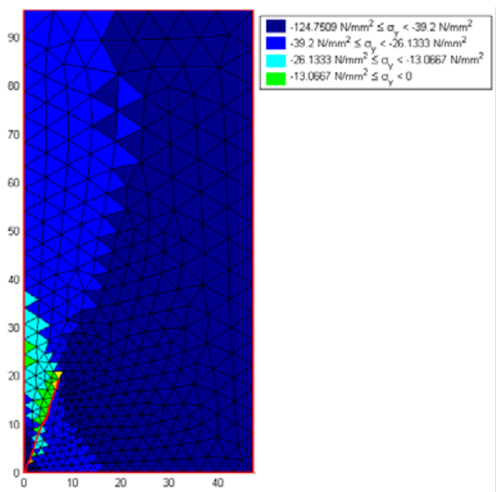

Figure 3 Computed stress field in the y axis direction

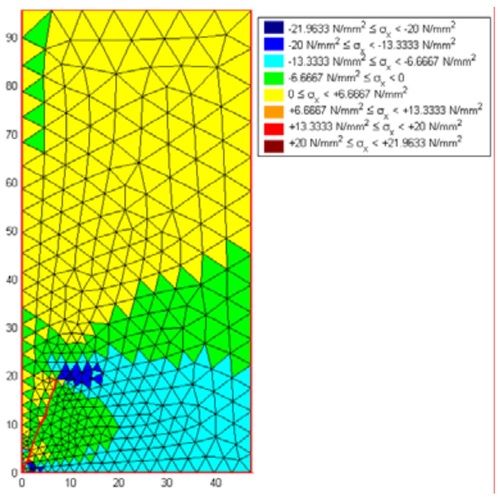

Figure 4 Computed stress field in the x axis direction

Conclusions

A sequential code for modeling crack propagation has been implemented. This code is able to predict the crack path with a good degree of precision. Nevertheless, the resulting computing proved very expensive. Thus, parallel-processing of the code is of utmost importance to improve the efficiency of the numerical model. Moreover, a revised implementation using a high-level computing language (e.g. Fortran), instead of Matlab, is strongly suggested.

Acknowledgments

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Publications

[1] Ferretti, E, *Crack propagation modeling by remeshing using the Cell Method (CM)*, to appear in CMES. Editor-in-Chief Atluri.

[2] Ferretti E., *Modellazione del Comportamento del Solido Cilindrico Compresso*, Ph.D. Thesis, University of Lecce, Italy, 2001.

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[4] Ferretti E. et al, *Impiego del Metodo delle Celle nella Stima dei Fattori di Intensificazione degli Sforzi*, Proceedings of AIAS 2000, 2000, pp. 699-708.

[5] Tonti E., *A Finite Formulation of Field Equations: the Cell Method*, to appear in CMES. Editor-in-Chief Atluri.