Computational Modelling of Dynamic Crack Propagation

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ABSTRACT

This paper is concerned with the numerical simulation of dynamic crack propagation in three-dimension. Although dynamic fracture has been widely investigated in continuum mechanics, it remains a challenging topic. To simulate dynamic crack propagation, we require a physical and mathematical description to determine (a) when a crack will propagate, (b) the direction of propagation and (c) how far/fast the crack will propagate. Furthermore, we require a numerical setting to accurately resolve the evolving displacement discontinuity.

In this work we present a mathematical derivation and numerical implementation that can achieve these goals, solving for conservation of momentum in both the spatial and material domains. This paper represents a generalisation of the authors' previous work on static crack propagation [1] in brittle materials. The approach taken is based on the principle of global maximum energy dissipation, with configurational forces determining the direction of crack propagation. This approach has been successfully adopted by a number of other authors in the context of quasi-static analysis, e.g. [1,2].

In the context of the numerical setting, we adopt the Arbitrary Lagrangian-Eulerian (ALE) method, as a kinematic framework to describe movement of the nodes of the finite element mesh independently of the material. Thus, we are able to resolve the propagating crack without influence from the original finite element mesh, and maintain mesh quality. We are primarily concerned with solving crack propagation in large 3D problems. The efficient solution of such problems, with a large numbers of degrees of freedom, requires the use of an iterative solver for solving the system of algebraic equations. In such cases, controlling element quality enables us to optimise matrix conditioning, thereby increasing the computational efficiency of the solver. The resulting system of equations is highly nonlinear and requires a solution strategy that enables us to trace the entire transient response.

The performance of this modelling approach is demonstrated on a number of numerical examples, illustrating dynamic crack propagation in both brittle and quasi-brittle materials. The examples illustrate that the results are mesh objective and that the analysis is efficient and robust.

REFERENCES

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