Extended Material Point Method for Crack Problems

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ABSTRACT

The Material Point Method (MPM), which is a FEM-based particle method, has recently been applied to the simulation of fracture mechanics. In this paper, a new algorithm for modelling cracks in the MPM framework, named the eXtended Material Point Method (XMPM), is proposed. The XMPM enriches the nodal degrees of freedom in the region around the crack and the jump function is chosen as the enrichment function to describe the crack. This improvement allows the crack problem, whose displacement and velocity are discontinuous, to be simulated by only one set of background grid mesh, and so multigrid or multiple velocity fields are not necessary.

Then the discretization scheme of the XMPM is derived based on the weak form of the momentum conservation equations, just as the conventional MPM. The technique we lump the mass matrix makes the XMPM can be implemented easily in a conventional MPM code and can degenerate to the conventional MPM when there is no crack.

The Level Set Method (LSM) is also employed in the XMPM for easily tracking crack surfaces. The crack moves with the material points physically, so that the LSM function is carried by particles. In each time step, the LSM function value is mapped to the grid nodes from the particles, and the nodes to be enriched can be identified conveniently from the grid nodal LSM function values. Based on the LSM tracking crack surface and accurate calculation of fracture parameters, crack propagation could be implemented in the XMPM framework. The LSM values of particles around the crack tip should be recalculated as the crack propagates, which does not bring additional computational cost except in the region of the crack tip.

Numerical examples show that the XMPM is accurate to the level of ABAQUS XFEM for the symmetric horizontal crack problem. For both the static and dynamic problems, the results agree well with the analytical solution, experiments and other numerical methods, which illustrate the good performance of the XMPM.

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