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Numerical simulation of material fragmentation with material point method

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Summary

The material point method (MPM) is extended to the simulations of material fragmentation due to detonation. A crack modeling scheme based on contact algorithm with material failure process is developed to study the dynamic crack propagation in plastic media. Particles after failure are transformed to a different velocity field by contact method, which makes the crack surface not constrained by grid lines and free to propagate dynamically in any direction even when the material experiences large plastic strain increments. The random characterization of the fragmentation can be described by both microscopic defect and macroscopic failure. When considering microscopic damage of material, the plastic behavior is described by Gurson model with randomly-distributed initial void of material points. Gurson model can degenerate to J2 plastic theory while the microscopic void is ignored, in which situation the Weibull random failure scheme will be used. Meanwhile, an efficient background-grid-based searching method is proposed to capture the statistical feature of the fragmentation.

Cylinder shell and sphere shell driven by detonation are simulated to validate the proposed model. The metal shell is accelerated due to the interaction with detonation production. Reasonable patterns of the fragmentation and fracture time of the shell are obtained from the simulations. Both the Weibull random scheme and Gurson model with randomly-distributed initial particle voids provide the random characterization of fragments. The advantage of using Gurson model is that the microstructure-based model gives a relatively realistic description of the ductile brittle transition. The statistical behavior of the fragments obtained from the solution follows a power law which is similar as observed in the experiment.

The whole work is conducted in the framework of MPM3D, a three dimensional MPM code for penetration and explosive simulations. It is found that the material point method possesses great potential for simulating high strain-rate, large deformation fragmentation phenomena.