Simulation of buried explosives using recent advances in the Material Point Method

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Computational methods for simulating buried explosives detonation, blast waves, and ejecta are based on continuum approaches such as Arbitrary Lagrangian-Eulerian and pure Eulerian shock-physics techniques. These methods do not properly account from the transition from solid to fluid-like behavior in the Lagrangian approach nor address advection of internal state variables and fabric tensors in the Eulerian counterpart. A computational framework allowing large deformation kinematics, Lagrangian constitutive state variable tracking, and fracture and fragmentation is needed. The Material Point Method (MPM) is a particle-grid method suitable for solving large deformations in which the constitutive model is history dependent and therefore intolerant to advection errors. The MPM has the advantages of both Eulerian and Lagrangian formulations, but its original formulations (Sulsky et al. [1994, 1995]) suffered accuracy and stability problems that are rectified through a new integrator developed at the University of Utah [Sadeghirad et al., 2011]. Fluid-structure interactions are supported in an open-source framework (Uintah, www.uintah.utah.edu) by coupling a finite-volume, cell-centered, multi-material compressible CFD formulation (Implicit, Continuous fluid, Eulerian: ICE) [Kashiwa and Rauenzahn, 1994] with the new integrator in MPM for the solid.

We present two fluid-structure interaction problems in shock wave propagation. The first is a verification trend test for a 2-D explosion in a flyer-plate impact experiment [Fig. 1]. The second problem involves blast loading in geotechnical centrifuge experiments, which is purported to be predictive of full-scale response via established scaling laws. The specimen (a contain of soil) is are spun on the centrifuge to increase the g-forces in the model to produce identical stresses in both the centrifuge surrogate and the full-scale problem. We will show a quantification of importance of Coriolis body forces in the simulations along with preliminary assessments of the validity of scaling laws using more realistic (irreversible large-deformation) constitutive models than were the basis of the original the scaling laws.

Fig 1 Pressure contours for explosive shock wave.

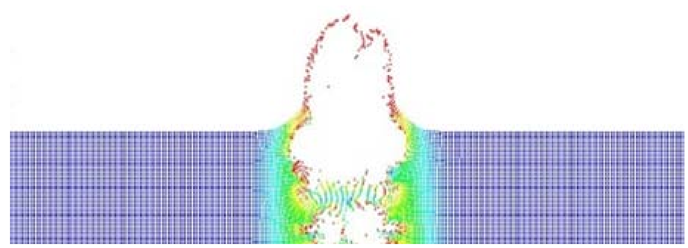

Fig 2 Centrifuge experiment: effect of Coriolis body force (rotation axis out of page and direction of motion to the right)

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