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Some recent advances in the Material Point Method for high-rate large-deformation penetration and blast loading.

Computational methods for simulating penetration, blast waves, and associated ejecta have been traditionally based on Arbitrary Lagrangian-Eulerian (ALE) or purely Eulerian techniques that can incur errors in the transition from solid to fluid-like behavior due to large distortion of Lagrangian finite elements or remapping (advection) errors in Eulerian mixing or finite-element grid remeshing. When direct modeling of micromorphology is used to guide the development of macroscale constitutive models, inordinate time and resources are spent simply generating meshes and (if the material is porous) predicting, defining, and modeling thousands of contact surfaces. The Material Point Method (MPM) has emerged as a powerful – and still practical – way to model such problems. MPM is especially attractive in the engineering community because it can be easily added as an option to existing finite-element and finite-difference frameworks. A basic tutorial on the MPM will be provided, explaining that (like FEM) it solves the weak form of the momentum equation on a (structured or unstructured) background grid. However, instead of saving data at grid nodes and element Gauss points, all data (velocity, stress, temperature, etc.) are saved at so-called material points at locations not intrinsically coupled to the grid morphology. Large-deformation accuracy and stability shortcomings in early MPM formulations are now rectified through "Convected Particle Domain Interpolation (CPDI)," which allows particle domains to become large in comparison to the background grid, potentially giving results similar to a discrete-element method for arbitrary-shaped grains, while retaining accuracy competitive with finite elements when using about the same number of MPM particles as Gauss points in a continuum simulation. An enrichment option to CPDI further opens many avenues for further development, including automatic refinement in high-gradient regions, especially near material interfaces. This seminar has a strong focus on code verification that must precede validation (where "verification" and "validation" are defined consistent with ASME standards). For verification, the importance of the so-called method of manufactured solutions is emphasized and illustrated through an example simulation involving massive shear in the interior of a ring-shaped domain. Validation will be illustrated via applications of the MPM to well-bore shaped charge jet completion and 20-g centrifuge experiments of buried explosives.