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Adaptive material point method for shaped charge simulation

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ABSTRACT

A shaped charge generally consists of a cylinder of high explosive with a cone-shape thin metal liner in one end. Intense pressure generated by explosion forces the liner to collapse. A high velocity jet formed subsequently. Maximum velocity of the jet generated by shaped charge can exceed 10km/s. Shaped charges are useful in defense industry and in oil industry for penetrating hard targets such as armor, tanks, rocks or concrete walls. Numerical simulation plays important role in the design of shaped charges because there are numerous papameters should be considered in the design process. Eulerian hydrocodes[1] are commonly used because of extreme large deformation involved in both detonation and jet formation process. While Lagranian method is still attractive for its ability to simulate history dependent material and track the material interface if mesh distortion problem could be dealt with properly[2]. In this category, particle meshfree methods, such as SPH and MPM, are superior for shaped charge problems to mesh-based methods.

Material Point Method(MPM)[3] has been successfully applied to impact and explosion problems. However, Numerical fracture may occur when two particles are separated by a grid cell. Therefore, it is hard for MPM to depict extreme ductility of the liner material and to achieve detailed solutions simultaneously. As for shaped charge problem, MPM tends to predict an earlier breakup time of the stretching jet. Adaptive material point method(AMPM) is proposed in this paper in order to improve the simulation capability of MPM. Particle is split into two particles when accumulative strain in one direction exceeds a prescribed value, which indicate particle is stretched the most in that direction. On the other hand, particles could be combined when they are under compression.

By using C++ programming language, a three dimensional MPM code with adaptive splitting and combining, MPM3DPP, is developed. Johnson-Cook material model is implemented in order to take strain rate effect and thermal softening effect into consideration. Mie-Grüneisen equation of state is used to treat volumetric response of metal under high pressure. Jones-Wilkins-Lee(JWL) equation of state is used for describing the expansion process of detonation products. Artificial viscosity is added to pressure term to stabilize and capture the shock wave.

Detonation, liner collapse, jet formation and penetraion are simulated as a whole process using MPM3DPP. Numerical simulation provides detailed information of the process regarding jet formation, wave interation, temperature profiles and velocity distribution. Computational results are compared and

agreed well with experimental results and empirical formula[4]. Jet fragmentation is studied numerically to figure out the breakup time. The calculated breakup time agrees well with empirical formula.

REFERENCES

[1] H.L. Lee. *Computer simulation of shaped charge problems*, World Scientific, 2006.

[2] J.F. Molinari. "Finite element simulation of shaped charges". *Finite Elem. Anal. Des.*, Vol. **38**, 921–936, 2002.

[3] D. Sulsky, Z. Chen and H.L. Schreyer. "A particle method for history-dependent materials". *Comput. Methods Appl. Mech. Engrg.*, Vol. **118**, 179–196, 1994.

[4] J.A. Zukas. *High velocity impact dynamics*, Wiley, 1990.