A FIRST-PRINCIPLES ABRASION ALGORITHM FOR PROJECTILE MASS LOSS DURING PENETRATION

P. E. Dunn and B. S. Holmes

Applied Research Associates, Inc.
Southwest Division
4300 San Mateo Blvd. NE
Albuquerque, New Mexico, 87110
pdunn@ara.com

Applied Research Associates, Inc.
Silicon Valley Office
2672 Bayshore Parkway, Suite 1035
Mountain View, California 94043
sholmes@ara.com

An empirical abrasion algorithm for determining the mass loss of a projectile as it penetrates a softer target[1] has been developed and incorporated into an explicit dynamic Lagrangian finite-element code[2]. This abrasion model is empirical in that it relies on experimentation to determine an abrasion coefficient relating the interface stresses and velocities to the abrasion rate. Thus, this abrasion algorithm is limited in use because it depends on the ability to determine the abrasion coefficient for every combination of projectile and target materials.

A new abrasion model has been developed for penetration into concrete targets that eliminates this guesswork in calculating the abrasion rate. This model first calculates a representative aggregate particle size based on the projectile's tip velocity using the Grady-Kipp fracture model[3]. The distribution of particles on the surface of the projectile is calculated by assuming that the radius of the fracture zone is 1/3 the diameter of the projectile.

Slip line theory[4,5,6] is then used to calculate the abrasion rate of the projectile surface. An initial estimate of the abrasion rate is first calculated by idealizing the aggregate particles as cubes. The initial estimate further assumes that each of these cubes can only be oriented about a plane of symmetry passing through the axis of the projectile. Slip line theory can then be readily applied to these idealized conditions to calculate an initial, idealized abrasion rate that is wholly dependent on weapon and target material properties and on weapon-target interface stresses and velocities. The idealized abrasion rate is then corrected in an approximate fashion to account for non-cubic particle shapes and non-aligned particle orientations.

This new abrasion model has been coded into the finite-element code as an alternative option to the default, empirical abrasion algorithm. Two-dimensional comparison analyses have been conducted using the same test cases as Forrestal *et al*[7] and Beissel & Johnson[1]. The new model compares favorably against previously published experimental and analytic results over a wide range of impact velocities.

References

[1] S.R. Beissel and G.R. Johnson, "An Abrasion Algorithm for Projectile Mass Loss During Penetration," *International Journal of Impact Engineering*, v. 24, p. 103-116, 2000.
[2] G.R. Johnson, R.A. Stryk, T.J. Holmquist, and S.R. Beissel, *Numerical Algorithms in a Lagrangian Hydrocode*, Report WL-TR-1997-7039, Wright Laboratory, US Air Force, Ft. Walton Beach, FL, 1997.
[3] D. E. Grady and M.E. Kipp, *J. Mech. Phys. Solids*, v. 1, p. 95-118, 1987.
[4] K. Komvopoulos, N. Saka, and N. P. Suh, "Plowing Friction in Dry and Lubricated Metal Sliding," *Journal of Tribology*, v. 108, p. 301-313, July 1988.
[5] W. Lortz, "A Model of the Cutting Mechanism in Grinding," *Wear*, v. 53, p. 115-128, 1979.
[6] J. M. Challen and P. L. B. Oxley, "An Explanation of the Different Regimes of Friction and Wear Using Asperity Deformation Models," *Wear*, v. 53, p. 229-243, 1979.
[7] M. J. Forrestal, D.J. Frew, S.J. Hanchak, and N.S. Brar, "Penetration of Grout and Concrete Targets with Ogive-Nose Steel Projectiles," *International Journal of Impact Engineering*, v. 18, No. 5, p. 465-476, 1996.