

Simulating Perforation of Thin Plates Using Molecular Dynamics Approach

Anton M. Krivtsov

*Department of Theoretical Mechanics, St.-Petersburg State Technical University,
Polytekhnicheskaya 29, 195251, St.-Petersburg, Russia,
e-mail: krivtsov@AK5744.spb.edu*

The penetration of rod projectiles has been studied extensively during the past decade [1,2,3]. The understanding of the constitutive properties of materials is sufficiently mature so that simulation of the penetration-time behavior is in good agreements with experimental data. On the other hand, computational modeling of failure is not as well developed. Incorporation of the existing models of failure into general release hydrocodes usually cause problems because of difficulties in determining the micromechanical damage constants and drastic sophistication of the computation schemes. These problems are discussed thoroughly in [1].

Molecular dynamics (MD) approach allows avoiding many of the mentioned above problems because MD does not require theoretical failure models as such. The failure in MD simulation is automatically incorporated in the model by the limited distance of interaction between atoms or molecules. This method has been used extensively for nanoscale computations, where realistic interatomic potentials allow to model microscopic material properties close to reality. The same technique can be also applied to the macroscopic modeling if the representative particles are considered not as atoms or molecules, but as elements of the mesoscale level, such as material grains [4,5].

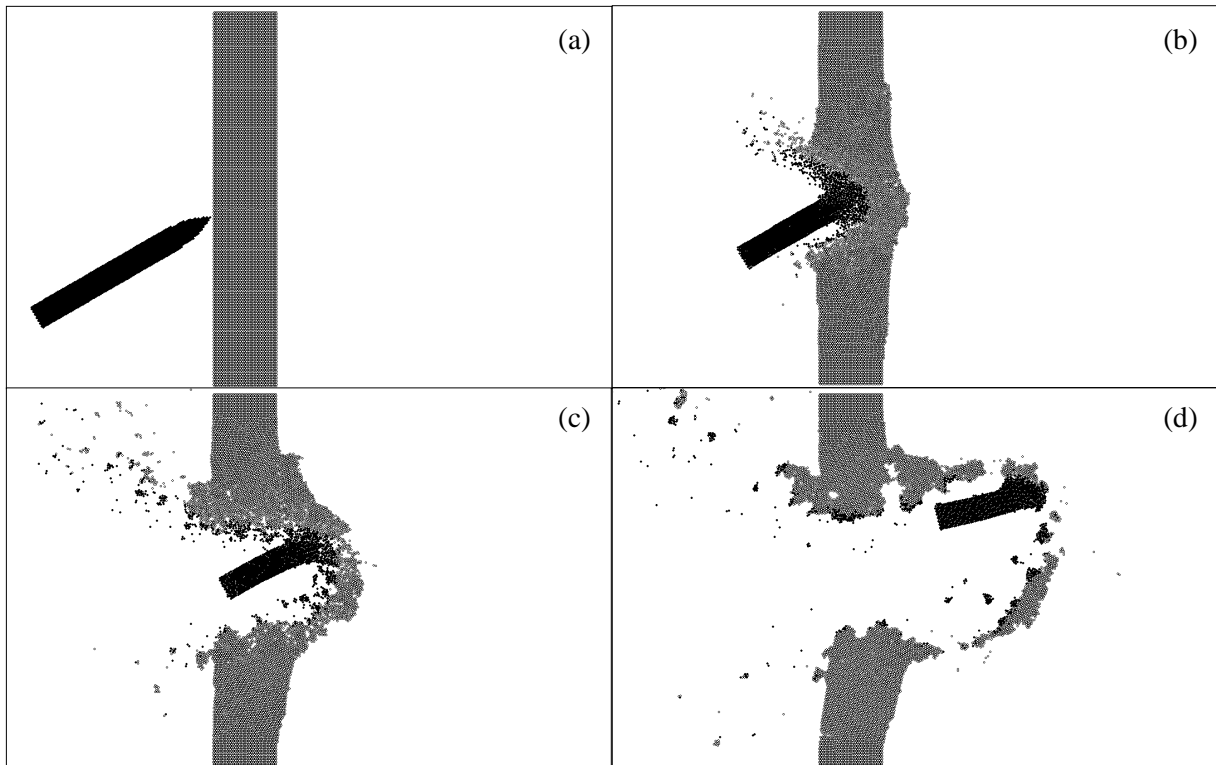


Fig.1: Oblique perforation of plate by ogive-nose projectile.

This approach is used in the current work to simulate perforation of plate targets by rod projectiles. Fig.1a shows the set-up of 2D computer experiment simulating oblique perforation. In the initial position ogive-nose projectile (black color) is nearly touching the target (gray color). The velocity of the projectile is directed along its axis of symmetry, which is 30 degrees inclined from the direction, orthogonal to the target. The impact velocity is 1.3 km/s,

length-to-diameter (L/D) ratio of the projectile is 8.6, and target thickness divided by the original projectile length (T/L) is 0.32. Figs.1a-d show sequential stages of the impact corresponding to 0, 8, 19, and 42 mks after the impact beginning. Wear of the projectile, crater formation, debris sputtering, and the projectile yaw are clearly visible and they are in a good agreement with well-known experimental results.

The simulation technique is close to conventional molecular dynamics simulation [6] and is described in details in [4,5]. The similarity to the experimental data in Fig.1 is astonishing because the material, which is used for the simulation is simple Lennard-Jones solid, that is 2D hexagonal crystal containing about 10000 particles interacting via Lennard-Jones potential. The only one control parameter – the depth of the potential well was set to fit the spall strength of the material to the one of titanium [5,7].

Example of 3D simulation using MD is depicted in Fig.2, where short sharp-nose projectile penetrates a thin plate made from the same material. Fig.2a shows initial state of the system, which contains about 14000 particles. Fig.2b corresponds to the moment of time just after the perforation when the projectile still is not completely separated from the target. Fig.3b shows the experiment at the same moment as Fig.2a, but from a different direction. Small thickness of the plate and low velocity of impact allows clear observation of elastic waves, which are excited in the plate due to the projectile impact.

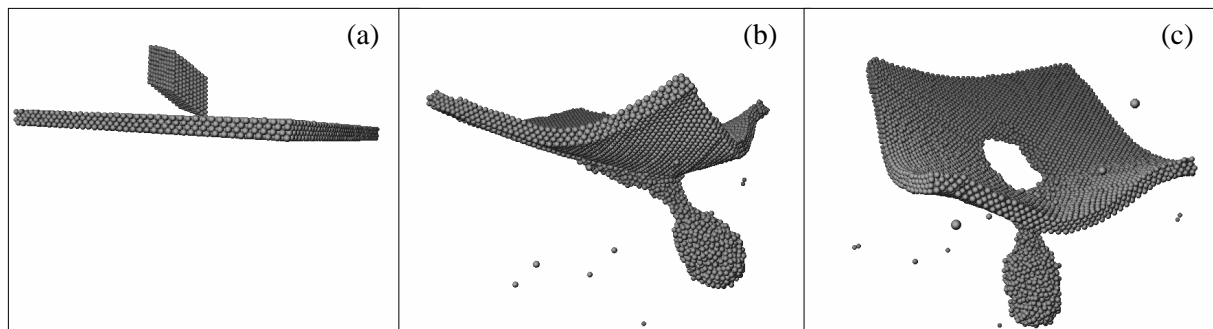


Fig.2: 3D simulation of oblique perforation of thin plate by a short projectile.

Use of empirical interparticle potentials and polycrystalline particle packing for more precise simulation of the penetration process is described in the presentation. Comparison with experimental data is considered.

1. C. E. Anderson, Jr, V. Hohler, J. D. Walker and A. J. Stilp. Time-resolved penetration of long rods into steel targets, *International Journal of Impact Engineering*, **16**(1), 1-18 (1995).
2. W. A. Gooch, M. S. Burkins, K. Frank, Ballistic performance of titanium against laboratory penetrators. *1st Australian congress on Applied Mechanics '96*, Melbourne (1996).
3. A. M. Rajendran, Penetration of tungsten alloy rods into shallow-cavity steel targets, *International Journal of Impact Engineering*, **21**(6), 451-460 (1998).
4. A. M. Krivtsov. Relation between Spall Strength and Mesoparticle Velocity Dispersion. *International Journal of Impact Engineering*, **23**(1), 466-476 (1999).
5. A. M. Krivtsov, Y. I. Mescheryakov. Molecular Dynamics Investigation of the Spall Fracture. *Proceedings of SPIE*, **3687**, 205-212 (1999).
6. B. L. Holian, R. Ravelo, Fracture Simulations Using Large-Scale Molecular-Dynamics, *Phys Rev B* **51**(17) 11275-11288 (1995).
7. Y. I. Mescheryakov, A. K. Divakov, N. I. Zhigacheva. Shock-induced phase transformation and vortex instabilities in shock loaded titanium alloys, *Shock Waves*, **10**(1) 43-56 (2000).