Numerical Simulation on Perforation of Conical Nose Rigid Projectile into Thick Aluminum Alloy Target

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Abstract. In this paper, the penetration and perforation process of the conical nose rigid projectile into thick aluminum alloy target was simulated numerically by using finite element method. The residual velocity was obtained by using numerical simulation. Time history of the projectile velocity is presented. Comparison of the present experimental results with numerical data from MSC.DYTRAN code indicates validity of the proposed simulation. The simulation results indicate that in the same conditions, the simulated residual velocity is in generally good agreement with the existing data. It shows the validity and exactness of the numerical simulation.

1. Introduction
Light weight aluminum alloy plates are often used in protective structures against projectile impact. Thus, analytical, experimental and numerical investigations on the ballistic resistance of metallic plates can be found in the literature. Due to the complex penetration process, analytical solutions is usually limited, and thus numerical simulations are frequently adopted [1-6].

To show the validity of the numerical simulation in this paper, it is necessary to compare the numerical simulation results with reliable experimental data in the same conditions, such as residual velocity, ballistic limit etc.

In Ref. [7], a set of experimental data for conical nose tungsten rods striking normally on thick 5083-H131 aluminum target plates were presented. In Ref. [7], post-perforation x-ray photographs showed that the tungsten projectile remained undeformed to impact velocities of about 1200m/s. Thus the major approximations assumed that the projectiles were rigid bodies.

A numerical investigation on the penetration and perforation of thick aluminium targets struck normally by rigid conical nose projectile over a wide range of striking velocities (less than 1200m/s) was conducted in this paper.

2. Numerical Simulation

2.1. Numerical Models
The initial finite element mesh of the conical projectile and 76.2 mm thick 5083-H131 target and the geometry of projectile are shown in Fig.1-2.

The geometries of the targets and projectile were the same as those used in the experiment for comparison.

The projectile material is rigid (MATRIG). In the simulations, the projectile was given an initial striking velocity, the target was perforated and the residual velocity of the projectile was calculated.
Non-linear finite element simulations were carried out using MSC-DYTRAN commercial software. The target material was modeled with elastic-plastic constitutive relation (DYMAT24). Target element fails when effective plastic strain equals to 0.4 in the simulation and is then removed from the rest of calculation.

In Ref. [7], the mass of the projectiles was 0.0257 kg. For that experiment, $\rho_t=2660 \text{ kg/m}^3$, $2a=8.31 \text{ mm}$, $L=20.7 \text{ mm}$, $l=14.8 \text{ mm}$, $\tan \phi=0.281$, and $\rho_p=18500 \text{ kg/m}^3$. The wideness of the target plate is 0.2 m and the thickness is 76.2 mm.

The element size in the target plates was 1 mm. There are 77 elements over the plate thickness. The number of plate elements is 280000, the number of projectile elements is 684. Coarsening of the element mesh towards the target boundaries was used to lower the number of elements of the target. It is believed that the chosen number of elements across the targets’ thicknesses is large enough to have a positive solution. The mesh of the target was taken coarser than that of the rigid projectile.

The eroding master-slave contact algorithm in MSC-DYTRAN is adopted to simulate the interaction of the projectile and plate during penetration.

For simplicity, the small friction effect between the target and projectile was neglected in all simulations, and temperature and strain rate effects of target material’s constitutive relation were also small and neglected.

**Figure 1.** The initial finite element mesh showing the projectile and target

**Figure 2.** Geometry of a conical nose projectile.

Target material is elastic–plastic material with power law strain hardening in the simulation. The one dimension compressive response is $\sigma=\varepsilon E$ in the elastic region and $\sigma=\gamma\varepsilon E (\gamma/\gamma_0)^n$ in the plastic region. In this paper’s simulation, $E=70.3 \text{ GPa}$, $\gamma=276 \text{ MPa}$, $\nu=0.33$, $n=0.084$ for 5083-H131 aluminium alloy target[7].

### 2.2. Numerical Results

In Fig. 3, the penetration image showing the projectile and 76.2 mm thick target is presented.

In Fig. 4, simulated velocity time history of the projectile at initial striking velocity of 1100 m/s is presented.

Simulation predictions in terms of residual velocity and ballistic limit are in generally good agreement with measurements (see Fig. 5). It shows the validity and exactness of the numerical simulation.
Figure 3. The penetration image showing the projectile and thick target (t=60.1μs, cycle=800, Vs=1100m/s).

Figure 4. Simulated velocity time history of the projectile (Vs=1100m/s).

Figure 5. Striking vs. residual velocity plots from experimental data[7] and simulations.

3. Conclusion
A numerical investigation on the penetration and perforation of thick aluminium targets struck normally by rigid conical nose projectile with high initial striking velocities(less than 1200m/s) was conducted.
The present simulation predictions are in generally good agreement with the test data for thick aluminium targets in terms of residual velocity and ballistic limits. It shows the validity and exactness of the numerical simulation.
The method and result of this paper is valuable for solving related impact engineering problems. It shows the strong effectiveness of simulation method when solving impact and penetration problems. In the future, detailed information and key penetration parameters and mechanism need to be investigated using numerical simulation method.

References

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