Numerical study on kinetic energy projectile penetrating multilayer medium target
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ABSTRACT

This paper presents the numerical simulation on kinetic energy projectile penetrating multilayer medium target by finite element code. Before the numerical model was set up, the major issues which should be considered in simulation was discussed. Then the influences of impact angle and attack angle were numerically analyzed. The numerical results indicate that increasing impact angle or attack angle would reduce the penetration depth. For specified system in this paper, penetration depth reduces about 1.8 centimeters as impact angle increases 1 degree, while the depth reduces about 6.8 centimeters as attack angle increases 1 degree. Additionally, a new cognition was obtained that the projectile might deflect reversely during penetrating process.

INTRODUCTION

Kinetic energy projectile is one of the main tools to destroy airport runway. After the projectile intrudes into the runway, explosive is ignited and blasts, the runway will be destructed and form a crater with a certain extent depth and area, so as to impede battle plane taking off. Usually, the runway is made up of multilayer medium, such as concrete, cracked stone, and clay. The depth of blast spot and posture of projectile have directly influence on the destruction of runway. For evaluating the destruction of runway, it is important to study the issue of kinetic energy projectile penetrating multilayer medium target, and find out the relationship between impact condition and track of penetration. Currently, nonlinear dynamic finite element program is a significant tool to study this kind of problem systematically [1, 2].

PRIMARY ISSUES IN SIMULATION

In numerical simulation, these following important contents should be considered:
Firstly, physical problem should be reasonably simplified, effective tool and computational method is used to set up the numerical model.
Secondly, material constitutive equation which reflects the process of shock dynamics should be built up.
Thirdly, reasonable calculating parameters should be calibrated.

NUMERICAL MODEL OF PENETRATING MULTILAYER MEDIUM TARGET

Here, aimed at a typical system of kinetic energy projectile penetrating airport runway, numerical model was set up. Numerical model of kinetic energy projectile
penetrating multilayer target was built up using LS-DYNA program and LAGRANGE method.

To verify the simulation model and calibrate calculating parameters, experiments in the reference were simulated. For the first place, according to experiments by Hanchak[8], the test of projectile penetrating single target was simulated. Numerical results and experimental data are in good agreement as compared in Table I.

<table>
<thead>
<tr>
<th>Impact Velocity (m/s)</th>
<th>Residual Velocity (m/s)</th>
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</thead>
<tbody>
<tr>
<td>Numerical Results</td>
<td>Experimental Data</td>
</tr>
<tr>
<td>600</td>
<td>463</td>
</tr>
<tr>
<td>750</td>
<td>617</td>
</tr>
</tbody>
</table>

In the next place, referring to YANG's work [11], kinetic energy projectile with weight of 13kg impacts airport runway at a speed of 700m/s, and impact angle is 22°. The experimental data of penetration depth is 120cm. Figure 1 is three-dimensional image of penetrating process, and the numerical result of penetration is 137cm.

THE INFLUENCES OF IMPACT ANGLE AND ATTACK ANGLE

Through a series of simulations of penetrating process for the typical system, track of penetration, velocity, deceleration, and displacement were obtained. Then the influence of impact angle (θ) and attack angle (η) were numerically analyzed. Impact angle is the angle between projectile axis and normal line of the target in the beginning of contact, and attack angle is the angle between projectile axis and velocity vector, as showed in figure 2.

Computational Results of Various Impact Angles

Impact velocity of projectile is 620m/s, and attack angle is 0°. Penetrating processes at various impact angles (0°, 12.5°, 25°, 37.5°, 50°, 60° & 70°) were
simulated. The curves of velocity, displacement and deceleration at Z direction are showed in figure 3, 4 & 5.

Numerical results indicate that, penetration depth reduces as impact angle increases, the max deceleration occurs in the beginning of impact and then the deceleration reduces gradually. Penetration depth reduces about 1.8 centimeters as impact angle increases 1 degree. As the impact velocity at Z direction decreases from 620m/s to 399m/s, the deceleration reduces from 23000g to 15000g.

For various impact angle, penetrating images at 80000 µs are showed in figure 6. It can be seen that track of penetration deflects along counter-clockwise as impact angle \( \theta \) increases within 0° and 37.5°. While \( \theta \) is 50° & 60°, the track deflects along clockwise. While \( \theta \) is even more large, the phenomenon of ricocheting will take place as \( \theta \) is 70°.

Here, we define the angle between projectile axis and normal line of the target during penetration as track angle, and the change of track angle is listed in figure 7. As \( \theta \) is 50° & 60°, track angle increases slightly in the beginning, and then decreases
gradually, which says that the projectile deflects along counter-clockwise originally and then deflects along clockwise gradually. This phenomenon has not been recognized in previous research.

To demonstrate whether the inverse deflection is occurred by the interface effect of multilayer medium target, simulation was performed for projectile penetrating single target at impact angle of 50°. The result is plotted on figure 8. The track is similar as showed on figure 7, which indicates that interface effect is not the main reason for deflection of ballistic track.

**Computational Results of Various Attack Angles**

Impact velocity of projectile is 620m/s, and impact angle is 0°. Penetrating processes at various attack angles (-3°, -1.5°, 0°, 1.5° & 3°) were simulated.

The curves of velocity, displacement and deceleration at Z direction are showed in figure 9, 10 & 11. The curve of displacement at X direction is showed in figure 12. Numerical results indicate that penetration depth reduces about 6.8 centimeters as attack angle increases 1 degree. Compared with the case of zero attack angle, in other cases track of penetration has a little deflection at X direction.
REFERENCES