PARAMETRIC STUDIES OF THE PENETRATION INTO MULTILAYER TARGETS

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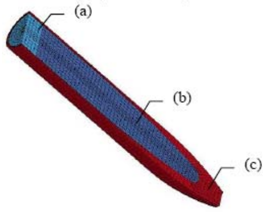
Summary A numerical screening study of the interaction between a penetrator and a multilayer geological target has been carried out to identify the main parameters affecting the ballistic responses. The multilayer was consisted with two concrete layers with different strengths and two soil layers with different densities. The planning of the numerical experiment was based on the orthogonal array OA(9,4,3), which allows 9 simulation runs with 4 parameters at 3 levels each. The four parameters chosen for this study are: velocity, oblique angle, yaw angle and the strength of the second layer. The analysis of the simulation has been based on main effects plots and analysis of variance, and it has been performed using three metrics: the residual velocity, the maximum value of the deceleration and the last state of the penetrator. The last state is defined as the rotation angle of the penetrator axis. This screening study shows that: under the given condition, the velocity and the oblique angle have a major influence on the deceleration, and that the velocity, the oblique angle and the strength of the second layer are the main effects on the residual velocity, and that the yaw angle and the oblique angle have strongest effect on the deflection of penetrator.

INTRODUCTION

Airstrip is a typically multilayer with four layers, which is composed of concrete, aggregate and two earth layers with different density. Due to its importance in military field, the destruction of the airstrip by the EPW (Earth Penetration Weapon) has been studied extensively through theory method, experimental method and numerical method [1-5]. The explosive destruction of the airstrip is the main one, which is influenced or decided by the penetration status and the penetration destruction. The penetration status is referred to the penetrator gesture at the explosive position. The explosive gesture is affected by the impact conditions and the material properties of target and penetrator. The studies of pre-researcher [1-5] were based on some given conditions, but the impact conditions were probability distributions. To study the affection on the explosive gesture, the paper was presented on the base of reference [5]. The influent parameters were initial velocity, oblique angle, yaw angle and the strength of the second layer.

ANALYSIS MODEL

The problem was studied by Ls-Dyna. Because of the symmetry of the load and the geometric shape, the analysis model was half of the penetration system (such as Fig.1 and Fig.2). The factors were shown in the Table 1 with their levels gained by the experiments. Based on the orthogonal array OA(9,4,3), nine cases (Table 2) were gained to study the influence of the factors on the penetration responses, such as the velocity curves, acceleration curves, deflection angle curves with final angle when out of targets. The normal penetration model was validated by the model of C.W.Young [4] (Table 3 and Fig.3), which was founded by many experiments. Because of the same control equations in all penetration problems, the normal penetration FEM model could be used to solve the oblique problems by only changing the initial conditions.



(a) Fuse; (b) Filler; (c) Missile
Fig. 1 the FEM model of missile

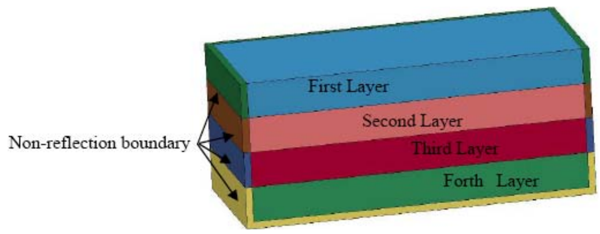


Fig.2 the FEM model of target

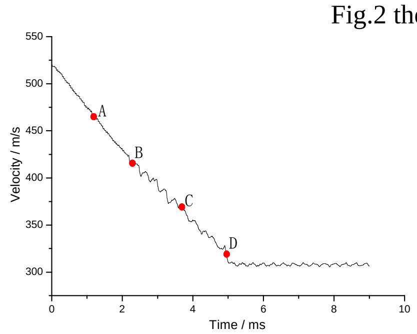


Fig.3 Velocity curve of normal penetration

Table 1 Factors and levels for parametric studies

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Factor	Level		
	1	2	3
A-Initial Velocity(m/s)	520	620	720
B-Oblique Angle(°)	0	25	50
C-Yaw Angle(°)	-3	0	3
D-Strength of the second layer (MPa)	30	35	40

Table 2 Orthogonal Array used for screening study

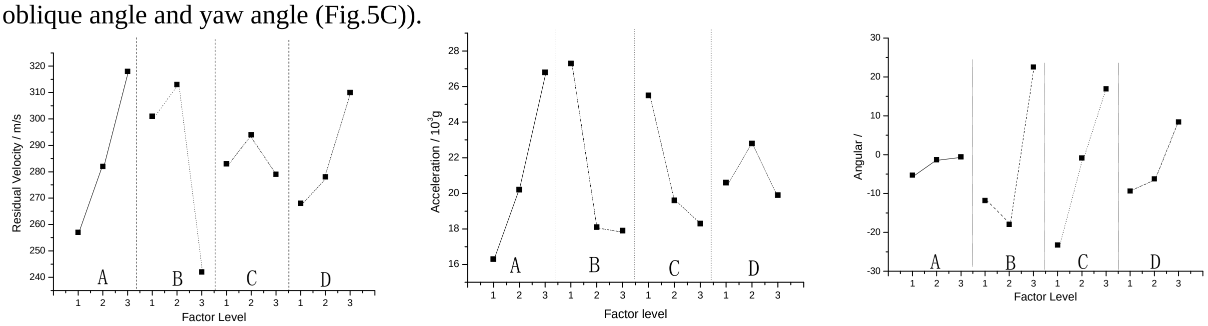
CASE	Initial Velocity Ms^{-1}	Oblique Angle °	Yaw Angle °	Strength of the Second Layer MPa
M1	520	0	-3	30
M2	520	25	0	35
M3	520	50	3	40
M4	620	0	0	40
M5	620	25	-3	30
M6	620	50	3	35
M7	720	0	-3	35
M8	720	25	3	40
M9	720	50	0	30

Table 3 Resultant velocity of every layer m/s

Layer/Moment in Fig.4	1/A	2/B	3/C	4/D
C.W.Young	473	430	393	350
Numerical	466	415	369	320
Error	1.5%	3.5%	6.1%	8.5%

ANALYSIS RESULTS

Based on Orthogonal Design and the data processing, the following results could be gained (Fig.5), and the followings could be concluded: under the conditions in the presented paper, 1) velocity was strongly affected by the oblique angle, initial velocity and the strength of the second layer (Fig.5A)); 2) initial velocity and oblique angle were the main factors on the accelerations, and the yaw angle was the second (Fig.5B)); 3) the deflection angle was mainly influenced by the oblique angle and yaw angle (Fig.5C)).



A) Resultant Velocity B) Acceleration C) Final Angle

Fig.5 Main effect plots for penetration responses

CONCLUSIONS

From the studies in the presented paper, the main factors on the penetration responses of airstrip were gained. The conclusions were relatively reasonable because of validation of the analysis model. The following could be concluded: the main factors on the velocity were oblique angle, initial velocity, strength of the second layer and yaw angle in sequence; and that on acceleration were initial velocity, oblique angle, yaw angle and the second layer strength in turn; and that on deflection angle were oblique angle, yaw angle, the second layer strength and initial velocity sequently.

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