Simulation on the Equivalent Relation Between Different Armour Plates Penetrated a Tungsten Sphere

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Abstract. To research on the equivalent of perforating through LY12CZ aluminum alloy plates and 2π armor steel, based on the rule that the ultimate velocity, the penetration process of tungsten sphere into LY12CZ aluminum alloy plate and 2π armor steel plate was simulated with LS-DYNA finite element code, the numerical results corresponded well to previous experimental observation. The expression between LY12CZ aluminum alloy plate and 2π armor steel plate impacted by a tungsten sphere was presented through analyzing the numerical results.

Introduction

A lot of experiments often were required to target vulnerability research, and a lot of time and cost to adopt the whole true experiment, if the various armor protection level could be substituted by equivalent target, a lot of the experimental expenses and costs will be saved. In view of the two common armor materials, the protection level of aluminum alloy was equivalent by standard homogeneous steel. Numerical simulation is one of the main means of this kind of problem, It can greatly save the cost and shorten the research period by means of numerical simulation and the experimental correction[1]. Based on the principle of the equal ultimate velocity, the numerical simulation was used to the aluminum alloy target and the homogeneous target penetrated by the fragment through the finite element software LS-DYNA, and the equivalent relations of the aluminum alloy target and the homogeneous steel target was preliminary study.

Equivalence Principle

The two kinds of principle can be chosen for the equivalent of the plate impacted by fragment: the ultimate velocity method and the residual penetration method. From the evaluation of the power of ammunition, the ultimate velocity method was chosen, from the evaluation of the ability of target anti-damage, the residual penetration method was generally chosen. The ultimate velocity method was selected in this paper.

The H1 thickness of aluminum alloy target and the H2 thickness of homogeneous steel target was penetrated by spherical fragment, and the same V50 of ultimate velocity was obtained on two kinds of target, so the H1 thickness of aluminum alloy target and the H2 thickness of homogeneous target was equivalent. The equivalent diagram of aluminum alloy target and homogeneous target as shown in Fig.1.

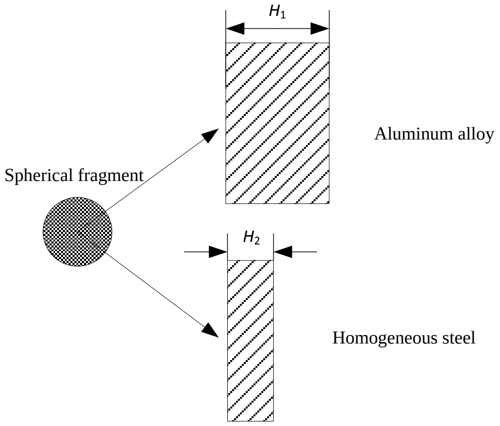
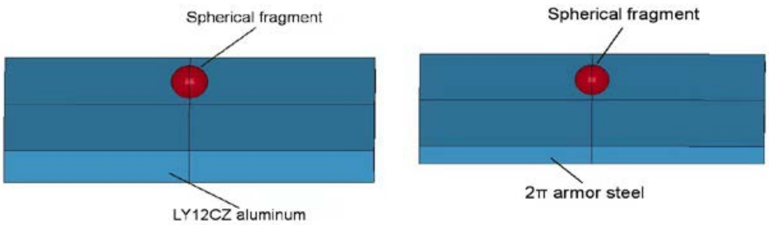


Fig. 1 Equivalent diagram of aluminum alloy target and homogeneous target

Numerical simulation

Geometric modeling

Experiment for reference to construct equivalent target model, material and size of fragment based on the literature[2], and combining the model shown in Fig. 1: (a)Target model: the materials of spherical fragment was tungsten alloy, the diameter was 10mm; The materials of plate was LY12CZ aluminum, the size was 100mm×100mm×10mm; (b)Equivalent target model: the size and material of fragment was the same as the target model, the materials of the plate was 2π armor steel, the size was 100mm×100mm×6mm. The constitutive model of fragment was Plastic_Kinematic[3], and the LY12CZ aluminum alloy and 2π armor steel was Johnson_Cook[3]. The symmetric plane was applied by boundary conditions, and a quarter of the overall model was used calculated based on the symmetry of the model. The nonreflect boundary condition was applied on the border around based on ignored the influence of boundary of stress wave. The meshing model was adopted by the 3d Solid164, and the target contact part of the unit was fine in order to reduce the computing time. The finite element calculation model was shown in Fig. 2.



(a) Target model (b) Equivalent target model

Fig. 2 Finite element model of calculation

Results and analysis of simulation

The 10mm diameter spherical tungsten alloy fragment with 440 m/s and the 450 m/s vertically impacted on 6mm thickness armor steel plates, the curve and the impact process of the fragment velocity as shown in Fig. 3 and Fig. 4.

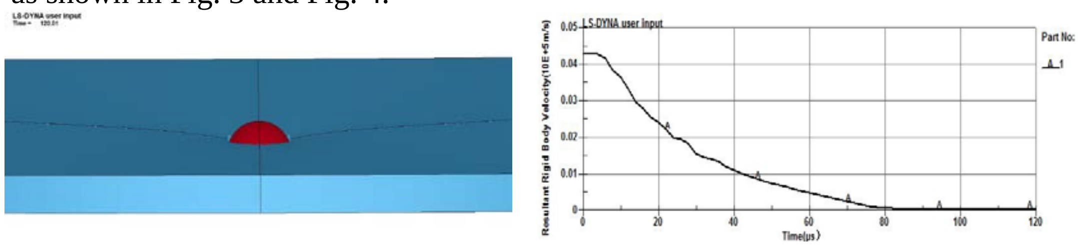


Fig. 3 State and velocity curve of spherical tungsten alloy fragment vertically impacted on 6mm thickness armor steel at 440m/s

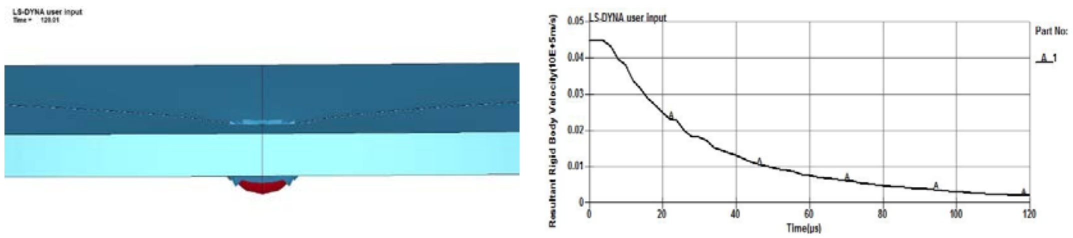


Fig. 4 State and velocity curve of spherical tungsten alloy fragment vertically impacted on 6mm thickness armor steel at 450m/s

As shown in Fig. 3, when the impact velocity was 440m/s, t=80μs, the velocity of tungsten alloy spherical fragment was zero, and the armor steel plate was not penetrated by fragment.

As shown in Fig. 4, when the impact velocity was 440m/s, t=120μs, the velocity of tungsten alloy spherical fragment was not zero, and the armor steel plate was penetrated by fragment; So, the ultimate velocity of 6mm thickness armor steel plates was 450 m/s by tungsten alloy spherical fragment.

According to the above method and the fragment's size, plate's thickness in literature[3], 4 kinds of scheme of the numerical simulation were calculated, the results of simulation and the experimental data in literature[3] were compared, as shown in Table 1.

The results of simulation and calculation from the Table 1 were found that the error of numerical simulation and experimental data was small, all within 6%, so the finite element material model, parameters, the algorithm, the results of simulation were all reliable, this model can be used for the calculation of equivalent relationship.

Table 1 Comparison of the simulation and the experiment of the ultimate velocity of armor steel

H_1/mm	Diameter/mm	Experiment/m/s	Simulation/m/s	Error
6	7.6	606	620	+2.3%
6	10	453	450	-0.6%
10	7.6	881	850	-3.5%
10	10	666	710	+5.1%

In accordance with the above method, the results of simulation of aluminum alloy plate penetrated by fragment and the experimental data in literature[3] were compared, as shown in Table 1.

The results of simulation and experiment from the Table 2 were found that the error of numerical simulation and experimental data was small, all within 9%, so the finite element material model, parameters, the algorithm, the results of simulation were all reliable, this model can be used for the calculation of equivalent relationship.

Table 2 Comparison of the simulation and the experiment of the ultimate velocity of aluminum alloy

H_2/mm	Diameter/mm	Experiment/m/s	Simulation/m/s	error
8	10	306	330	+7.8%
8	7	419	430	+2.6%
8	3	809	850	+5.1%
10	7	487	470	-3.4%
10	10	377.5	370	-2.0%
2	4.4	230	210	-8.7%

The finite element model(a) for calculation, in the case of 10mm diameter fragment, the ultimate velocity of the different thickness of aluminum alloy plate penetrated by fragment was obtained, the results as shown in Table 3.

Table 3 The ultimate velocity of different thickness of aluminum alloy plate penetrated by 10mm diameter fragment

H_1/mm	Diameter /mm	V_1/m/s
6	10	280
7	10	310
8	10	330
9	10	350
10	10	370

The relationship between the thickness H1 and the ultimate velocity V1 was fitted without considering the diameter of fragment, the fitted formula as shown in Fig. 5:

$$V_1 = 22H_1 + 152 \tag{1}$$

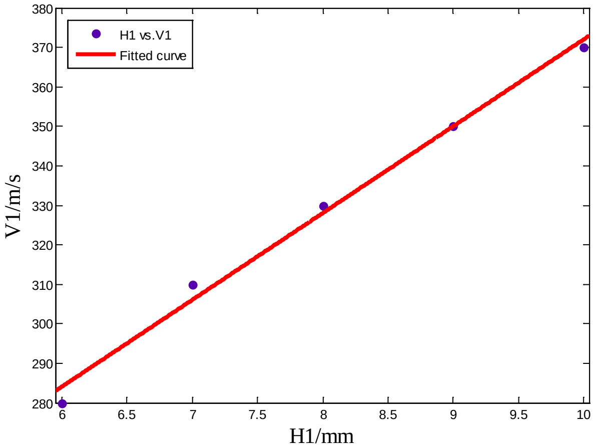


Fig. 5 Diagram of the thickness of aluminum alloy target and the ultimate velocity of fragment

The finite element model(b) for calculation, in the case of 10mm diameter fragment, the ultimate velocity of the different thickness of steel plate penetrated by fragment was obtained, the results as shown in Table 4.

Table 4 The ultimate velocity of different thickness of steel plate penetrated by 10mm diameter fragment

H_2/mm	Diameter/mm	V_2/m/s/
6	10	450
7	10	490
8	10	540
9	10	630
10	10	710

The relationship between the thickness H2 and the ultimate velocity V2 was fitted, and the fitted formula as shown in Fig. 6:

$$V_2 = 66H_2 + 36 \tag{2}$$

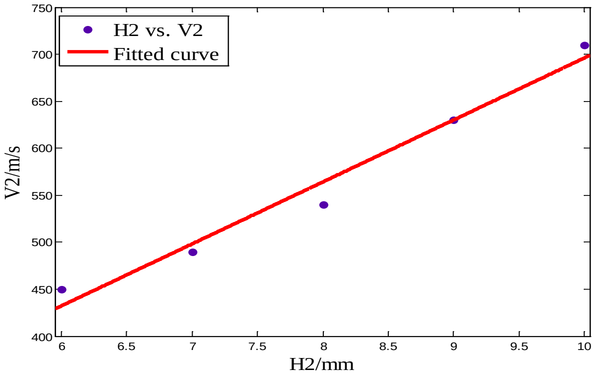


Fig. 6 Diagram of the thickness of steel plate and the ultimate velocity of fragment

The equivalent principle shows that when the ultimate velocity V1 and V2 were equal, the thickness H1 of aluminum alloy target and thickness H2 of homogeneous steel target were equivalent.

Therefore, Through Eq. (1) and Eq. (2), the equivalent relation of the aluminum alloy target and the steel plate target penetrated by fragment can be obtained:

$$H_2 = 0.333H_1 + 1.758 \tag{3}$$

The ultimate velocity from Table 2 and Table 3 in the contrast, when the same of the diameter fragment penetrated the same total thickness of the aluminum alloy target and homogeneous steel target, the ultimate velocityV2 is greater than the V1, which can indicate that the H1 is greater than the H2 in Eq. (3), so the H1>2.64mm.

Conclusion

(1)Based on the rule that the ultimate velocity, the simulation model of tungsten sphere into LY12CZ aluminum alloy plate and 2π armor steel plate was established, and the ultimate velocity of aluminum alloy plate and steel plate penetrated by spherical fragment was obtained through the simulation calculation, and fitted the formula. Based on the equivalent principle and through the Eq. (1) and Eq. (2), the equivalent relations Eq. (3) of aluminum alloy plate and steel plate penetrated by fragment was obtained.

(2)The equivalent relations of this paper was based on the experimental data, and the engineering practical requirement can be satisfied, the equivalent relations of protective armor of other materials and structure was also effective by using the equivalent method of the ultimate velocity combined with the fitting formula.

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