Effects of Charge Type and Structure Parameters on Armor Protection Performance

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Abstract. In order to improve the reaction armor protection, this paper armours of interlayer charge and the thickness of the steel plate and charging ratio analysis, based on the reaction between armor and jet interaction, established the reactive armor and shaped charge of finite element model, using AUTODYN software, adopt the method of fluid-structure interaction for numerical simulation research. The results show that compared with other explosives, CL-20 has an ideal interference effect on jet flow. In the designed structure, the reactive armor with a steel plate thickness of 4 mm and a charge thickness of 8 mm achieves the best protective performance.

1. Introduction
Explosive reactive armor was first proposed by M. Held, that is, the structure of a sandwiched explosive between two steel plates. When the jet penetrates the explosive reaction armor, it will detonate the explosive in the middle structure. The detonation wave generated by the explosive will drive the upper and lower steel plates to move, interact with the jet, and then reduce the jet velocity and cause the jet to bend and break. Good protective effect [1-3]. Since M. Held invented explosive reactive armor in 1970, it has been widely used on armored targets such as tanks because of its advantages of convenient carrying, easy replacement, low cost, and effective resistance to armor-piercing and armor-piercing bombs. With the continuous development of explosive reactive armor-related technologies, its ability to protect armored targets has been recognized by all countries, and has become the main protective means for armored targets in all countries in the world [4-5]. The factors that affect the protective performance of reactive armor include the type of charge and the structure of the charge. These two factors also play a key role. Therefore, it is worth analyzing and studying the impact of the type and structure of the charge on the effect of the reactive armor on the jet interference [6].
Based on the interaction between the jet and the reactive armor, the factors that affect the protective capability of the reactive armor under different types of interlayer charges and structural parameters are studied. The AUTODYN software is used for numerical simulation, and 6 groups of different sandwich charges and 5 groups of reactive armor schemes with different structures are respectively set to analyze the interference process of the reactive armor on the jet, and to compare the simulation results.

2. Model establishment

2.1. Geometric model establishment
First, use CAD drawing software to draw the geometric model diagrams of the armor-piercing warhead, the reactive armor, and the main target board, as shown in Figures 1 and 2.

![Figure 1. The geometric model of the armor-piercing warhead.](image)

![Figure 2. Geometric model of reactive armor and main target plate.](image)

The specific model parameters are as follows: the diameter of the armor-piercing warhead is 60 mm, the cone angle is 60°, the shell thickness is 2 mm, and the charge height is 90 mm; the reactive armor panel and backplane are both 4 mm, and the thickness of the sandwich charge is determined according to different structures.; The length of the after-effect target board is 200 mm and the height is 100 mm. The distance between the armor-breaking warhead and the reactive armor is 180 mm, that is, the explosive height is set to 3 times the caliber of the charge, and the reactive armor is 10 mm from the main target plate.

2.2. Finite element model
The jet part and the interlayer charge can be regarded as fluids for calculation during the action process. Therefore, the jet part and the interlayer charge adopt Euler grids, and the front plate, back plate and main target plate of the reactive armor are regarded as Solids are used for processing, so Lagrange grids are used. The two grids are coupled together by fluid-structure coupling, and the two-dimensional fluid-structure coupling algorithm is used for calculation[7]. The AUTODYN software is used for numerical simulation calculation. The structure of the medicine cover is an axisymmetric structure. In order to reduce the amount of calculation and improve the efficiency, a 1/2
two-dimensional model is established. Establish an air domain to simulate the working environment under real conditions. The grid size is 0.5 mm × 0.5 mm. The boundary effect is eliminated by adding the “FLOW-OUT” boundary condition on the air boundary [8], because the numerical simulation involves The impact of explosives is detonated, so the unit system adopted is cm-g-μs, and the finite element model diagram is shown in Figure 3.

![Finite element model diagram](image)

**Figure 3.** Finite element model diagram.

### 2.3. Material parameters

In the numerical simulation of jet penetration of reactive armor, the main components involved in the armor-breaking warhead are explosives, shells, and charge-type covers. The reactive armor has panels, back plates, and sandwich charges. Use the materials in the AUTODYN material library. The charge uses COMP B explosives, the shell uses 1006 steel, the charge type cover material uses red copper, the reaction armor panels, backplanes and main target plates all use 4340 steel, and the reaction armor sandwich charges using COMP B, CL20, H6, LX10, PBX9404, TNAZ and other explosives, the specific material parameter model is shown in Table 1.

| Part          | Material     | Equation of State | Strength Model       | Failure Model       |
|---------------|--------------|-------------------|----------------------|---------------------|
| Warhead Charge| COMP B       | JWL                | None                 | None                |
| Case          | STEEL 1006   | Shock              | Johnson Cook         | None                |
| Medicine Mask | COPPER       | Shock              | None                 | None                |
| Reactive Armor| STEEL 4340   | Linear             | Johnson Cook         | None                |
| Main Target   | STEEL 4340   | Linear             | Johnson Cook         | Plastic Strain      |
|               | COMP B       | Lee-Tarver         | von Mises            | None                |
|               | CL20         | Lee-Tarver         | von Mises            | None                |
| Sandwich Charge| H6          | Lee-Tarver         | von Mises            | None                |
|               | LX10         | Lee-Tarver         | von Mises            | None                |
|               | PBX9404      | Lee-Tarver         | von Mises            | None                |
|               | TNAZ         | Lee-Tarver         | von Mises            | None                |

### 2.4. Set Gauss point

In order to better analyze and compare the interference process of different sandwich charges and reactive armor under different structures on the jet flow, and obtain more accurate parameters, 25 Gauss points are set in the jet axial direction, and each Gauss point is separated by 10 mm for analysis.
The jet is disturbed and the action process of the reaction armor [9], the set Gauss point is shown in Figure 4.

![Figure 4. Gaussian point distribution map.](image)

3. Simulation results and analysis

3.1. Interference process of reactive armor on jet

Choose the sandwich charge as COMP B explosive, the reactive armor panel and back plate are both 4 mm, and the sandwich charge is 7 mm. The simulation calculation is carried out, and the interference process of the reactive armor on the jet is analyzed. The process of jet penetration of reactive armor is shown in Figure 5.

![Figure 5. Jet penetrating the reactive armor.](image)

From 10 μs to 50 μs is the moment when the jet does not touch the reactive armor. At this stage, the jet is still forming, and the charge type cover is crushed and elongated under the explosive load; at 60 μs, the jet penetrates into the reactive armor, but the reaction The armored charge did not completely explode; at 70 μs, the jet penetrated the reactive armor and touched the main target plate, and the
The explosive of the reactive armor had begun to explode and began to interfere with the jet; at 100μs, the jet head penetrated the main target plate and reacted. The armored explosives are completely detonated, cutting off the interference of the rear jet and affecting the jet’s penetration ability.

3.2. Simulation and analysis of different types of charges

3.2.1 Scheme design

In order to compare the different types of reactive armors and their effects on the protective performance of reactive armors, 6 sets of plans were designed, and the sandwich charges used COMP B, CL20, H6, LX10, PBX9404, and TNAZ explosives. The specific plans are shown in Table 2.

| Scheme | Sandwich charge |
|--------|----------------|
| I      | COMP B         |
| II     | CL20           |
| III    | H6             |
| IV     | LX10           |
| V      | PBX9404        |
| VI     | TNAZ           |

3.2.2 Jet velocity analysis

When the jet passes through the reactive armor, the interlayer charge is detonated, and the undisturbed jet continues to penetrate the main target plate. In this paper, the 150μs time is selected to compare the jet velocity of different schemes when it penetrates the main target plate to evaluate the interference effect of the reactive armor on the jet. Figure 6 shows the jet velocity cloud diagram of 6 groups of different types of charges.

![Figure 6. Cloud diagram of jet velocity.](image-url)
In order to get more accurate speed data, you can observe and analyze through the set Gauss point. Call the Gauss point data graph in AUTODYN, as shown in Figure 7.

![Gauss point velocity diagram](image)

**Figure 7.** Gauss point velocity diagram.

The lines of different colors in the figure represent the speeds of different points at different times. The speed data at this time can be obtained by comparing the Gauss point reached by the jet head at 150 μs. The jet speeds of the 6 groups of plans are shown in Table 3.

| Scheme | I  | II | III | IV  | V   | VI  |
|--------|----|----|-----|-----|-----|-----|
| Speed  | 1841 | 1647 | 1742 | 1760 | 1867 | 2127 |

From the data analysis in the table, it can be seen that the jet head speed of Scheme II is the smallest and the remaining penetration ability is small; while the jet head speed of Scheme VI is the largest and the remaining penetration ability is large. The jet head velocity of Scheme I and Scheme V is similar, the velocity is concentrated at about 1850 m/s; Scheme III and Scheme IV have similar interference effects on the jet velocity, with the velocity concentrated at about 1750 m/s.

### 3.2.3 Analysis of penetration depth of main target

After being disturbed by the reactive armor, the remaining jet still has a certain amount of kinetic energy and has the ability to penetrate. At this time, it can still penetrate the main target to a certain depth. The penetration depth of the jet on the main target plate at 150 μs is selected to judge the interference effect of the reaction armor. The penetration of the main target plate by 6 groups of different types of charges is shown in Figure 8.
Figure 8. Penetration diagram of the main target. The corresponding penetration depth of the main target is shown in Table 4.

Table 4. Penetration depth of the main target plate under different charging schemes (mm).

| Scheme | I   | II  | III | IV  | V   | VI  |
|--------|-----|-----|-----|-----|-----|-----|
| Penetration Depth | 80.55 | 76.68 | 83.41 | 82.27 | 79.06 | 84.09 |

According to the analysis of the penetration depth of the main target in the table, the penetration depth of the main target in Scheme II is the smallest compared with other schemes, and the remaining penetration capacity of the jet is small; the penetration depth of the main target in Scheme VI is the largest, and the remaining jet Great penetration ability. The penetration depth of the main target plate in Scheme V, Scheme I, Scheme IV, and Scheme III increased in turn.

By analyzing the jet head velocity and the penetration depth of the main target plate, it is concluded that the jet head velocity of Scheme II is the smallest, the penetration depth to the main target plate is the smallest, and the reaction armor has the best interference effect on the jet, that is, the interlayer
Compared with the other five explosives, CL20 has the best effect as the charge, and the reactive armor under this charge has the best protective performance.

3.3. Simulation and analysis of different structures

3.3.1. Scheme design

In order to compare the effects of different explosive structures of reactive armor on the protective performance of reactive armor, five sets of plans were designed. The specific parameters of the armor-piercing warhead and the main target plate were kept the same. The sandwich charge of the reactive armor used COMP B explosives. The thickness of the front and back plates of the reactive armor remains unchanged at 4mm, only the thickness of the interlayer charge is changed, and the unit increase is 1mm. The specific plan is shown in Table 5.

Table 5. Design of different charge structure schemes.

| Scheme | Charge Structure (Panel/Sandwich Charge/Back Plate) |
|--------|----------------------------------------------------|
| A      | 4/5/4                                              |
| B      | 4/6/4                                              |
| C      | 4/7/4                                              |
| D      | 4/8/4                                              |
| E      | 4/9/4                                              |

3.3.2. Jet velocity analysis

At the same time, 150μs is selected to compare the velocity of the jet when it penetrates the main target under different charge structure schemes to evaluate the interference effect of the reactive armor on the jet. The jet velocity cloud diagram of 5 groups of different charge structure schemes is shown in Figure 9.

Figure 9. Jet velocity cloud diagram.
The corresponding velocity data is obtained through the corresponding Gaussian point at 150 μs. The specific values of the jet head velocity of the 5 groups of schemes are shown in Table 6.

Table 6. Jet head velocity under different charge structure schemes (m/s).

| Scheme | A    | B    | C    | D    | E    |
|--------|------|------|------|------|------|
| Speed  | 1933 | 1902 | 1841 | 1784 | 1897 |

From the data in the table, it can be seen that the jet head speed of scheme D is the smallest, and the remaining penetration capability of the jet is small; the jet head velocity of scheme A is the largest, and the remaining penetration capability of the jet is greater. At the same time, within a certain range, as the thickness of the sandwich charge increases, the jet head velocity decreases, and the interference effect of the reactive armor on the jet gradually increases.

3.3.3. Analysis of penetration depth of main target

The penetration of the jet into the main target plate is shown in Figure 10 when the five groups of different charge structures are at 150 μs.

The specific penetration depth of the five groups of programs is calculated, as shown in Table 7.
Table 7. Penetration depth of the main target plate under different charge structure schemes (mm).

| Scheme | A     | B     | C     | D     | E     |
|--------|-------|-------|-------|-------|-------|
| Penetration Depth | 83.34 | 82.85 | 80.55 | 74.70 | 82.77 |

From the analysis of the data in the table, it can be seen that the penetration depth of the plan D to the main target is the smallest, and the penetration ability of the jet is the smallest after being disturbed. The structure has a better response armor interference effect; while the penetration of the plan A to the main target The largest, the penetration ability after jet interference is greater, and the interference effect of the reactive armor of this structure is poor. In a certain range, as the thickness of the charge increases, the penetration depth into the main target plate decreases, and the interference effect of the reactive armor increases.

Through the analysis of the jet head velocity and the penetration depth of the main target plate, it is concluded that the jet head velocity of Scheme D is the smallest, the penetration depth to the main target plate is the smallest, and the reaction armor has the best interference effect on the jet, namely 4. Compared with the other four schemes, the 4/8/4 charge structure has the best effect, and the reactive armor under this charge structure has the best protective performance.

4. Conclusion

Using AUTODYN software, design 6 groups of reactive armors with different types of charges and 5 groups of different charges structures, simulate the interference effect of reactive armors on jets, study the effects of the types of charges and the structure of the charges on the protective performance of reactive armors, and obtain Reactive armor for optimal protection performance.

(1) After analyzing the simulation results of 6 groups of different types of charges, it is concluded that the reactive armor with the sandwich charge of CL20 has the best jet interference effect and the best protection performance; the reactive armor with the sandwich charge of TNAZ has the best jet interference effect Poor.

(2) After analyzing the simulation results of 5 groups of different charge structure schemes, it is concluded that the reactive armor with a charge structure of 4/8/4 has the best jet interference effect and the best protection performance; at the same time, within a certain range, As the thickness of the dressing agent increases, the interference effect of the reactive armor increases, and the protective performance is improved.

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6. Conflicts of Interest

The authors declare no conflict of interest.

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