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Study on Shock Initiation of the Charge Covered by Metal Plate with Penetrated Notch

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Problem description and Challenges

The study on the safety of the covered charge structure under strong external loading is of great significance to the development of weapons and ammunition. Shock waves and high-speed fragments are the two most common threats in battlefield environments. At present, as an important aspect of ammunition security research, the response of charge covered by metal plate with defect under the action of super close field intensity shock wave is rarely researched.

Theoretical analysis

The shock initiation model of the charge covered by metal plate with defects studied in this paper is shown in Fig. 1. This charge covered by steel plate with defects includes donor charge, covered plate with penetrating notch and acceptor charge, the donor charge radius is r, the covered plate is in close contact with the acceptor charge, the thickness of the covered plate is H and the gradient is α. In this paper, the cylindrical charge is equivalent to the spherical charge structure of equal mass. Based on the two-dimensional assumption of shock wave plane and neglecting the influence of sparse wave, we analyze the evolution process of shock wave by using the reflection and superposition principle of shock wave. This model can represent the shock initiation of the charge covered by metal plate with penetrated notch, and can reflect the influence of the above parameters.

Numerical simulation

In order to study the shock initiation process with the charge covered by metal plate with defects, the nonlinear finite element program AUTODYN-2D is used to simulate the shock initiation of the charge covered by steel plate with penetrated notch. The finite element calculation model includes: donor charge, defective covered plate, acceptor charge and air domain. Both the donor and the acceptor charge are cylindrical pressed TNT with the same diameter 35mm and height 30mm, the thickness of the covered plate is 3mm, and the upper and lower sizes of the notch are different. The numerical calculation uses a pure Euler algorithm, and the initiation point is set at the midpoint of the donor charge surface.

Test Verification

In order to analyze the effectiveness of the numerical simulation， a verification test is carried out by taking the shock initiation of the covered charge as an example in Fig.2. The witness plate deformation comparison chart of the experiment and numerical simulation at 12mm interval is shown in Fig. 3. After the acceptor charge is exploded, the pit depth of Q235 witness plate obtained by numerical calculation is 4.3mm and the pit diameter is 43.0mm. The test results show that the pit depth is 4.20mm and the diameter is 40.0mm. The error between the numerical simulation and the test results of the witness plate pit depth is no more than 2.38%. The error between the numerical simulation and the experimental results of the diameter of the witness plate is not more than 7.50%. The numerical simulation results agree well with the experimental results.

Analysis and Discussion

Keep the diameter of the lower notch unchanged, change the slope of the covered plate by adjusting the diameter of the upper notch, and analyze the influence of the covered charge on the detonation under six different working conditions. Compare the pressure of reflection and superposition in numerical simulation with theoretical calculations. The maximum error between the attenuation pressure and theoretical value is 11.55%, the maximum error between the reflection pressure and the theoretical value is 7.45%. the covered plate with the upper and lower notch diameters of 7 mm and 1mm, 4 mm and 1mm respectively is taken as an example to analyze the detonation growth process and the incomplete detonation process of the acceptor charge in Fig.4-6. For the pressed TNT with and without 45# steel covered plate with the thickness 3 millimeters, the critical detonation distance of non-contact explosion was 13 millimeters and 81 millimeters.

Conclusions

(1) the numerical simulation results accord well with the experimental results. It shows that the calculation model can effectively describe the shock initiation test of the covered charge by using ALE algorithm.

(2) the second form of the shock initiation criterion $p^n\tau$ =K is adopted. n=2.12, K=1.24e12 (International System of Units) are obtained by the least squares method yields.

(3) For the covered plate with a cylindrical notch, the critical detonation distance of the pressed TNT increases with increase of the diameter of the covered plate. For the covered plate has a frustum notch, the critical detonation distance of the pressed TNT decreases with increase of the slope in normal reflection.

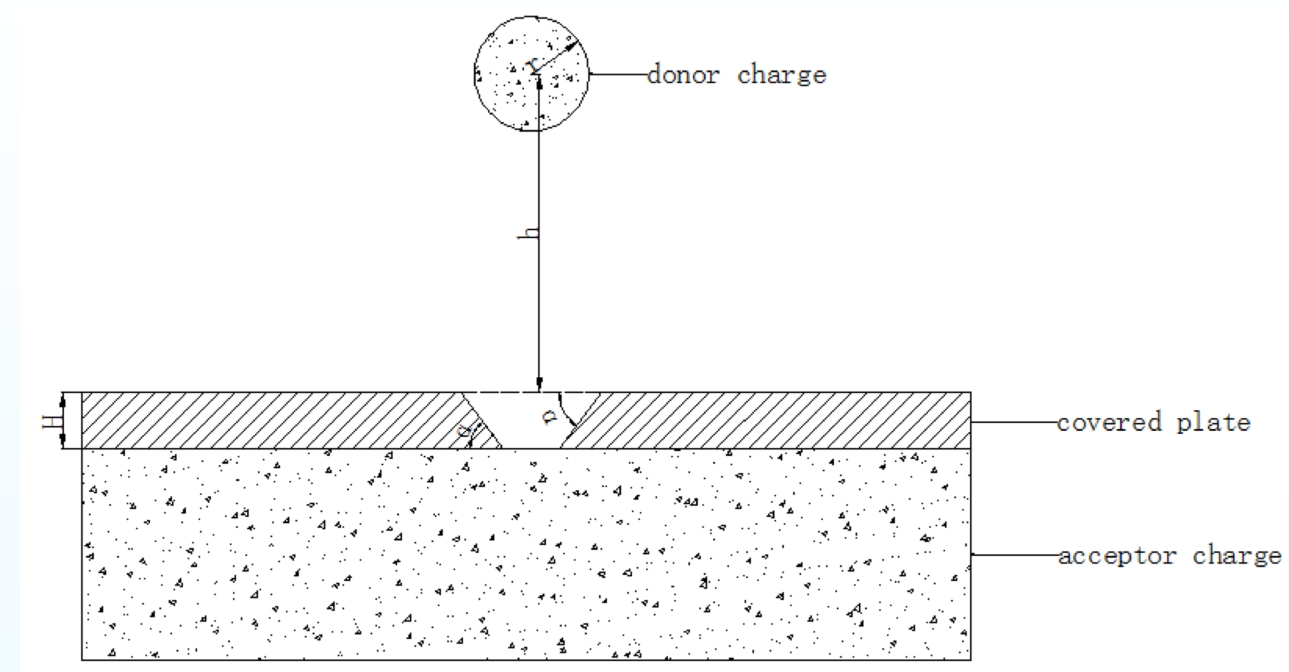


Fig. 1. Schematic of shock initiation of the charge covered by metal plate with defects.

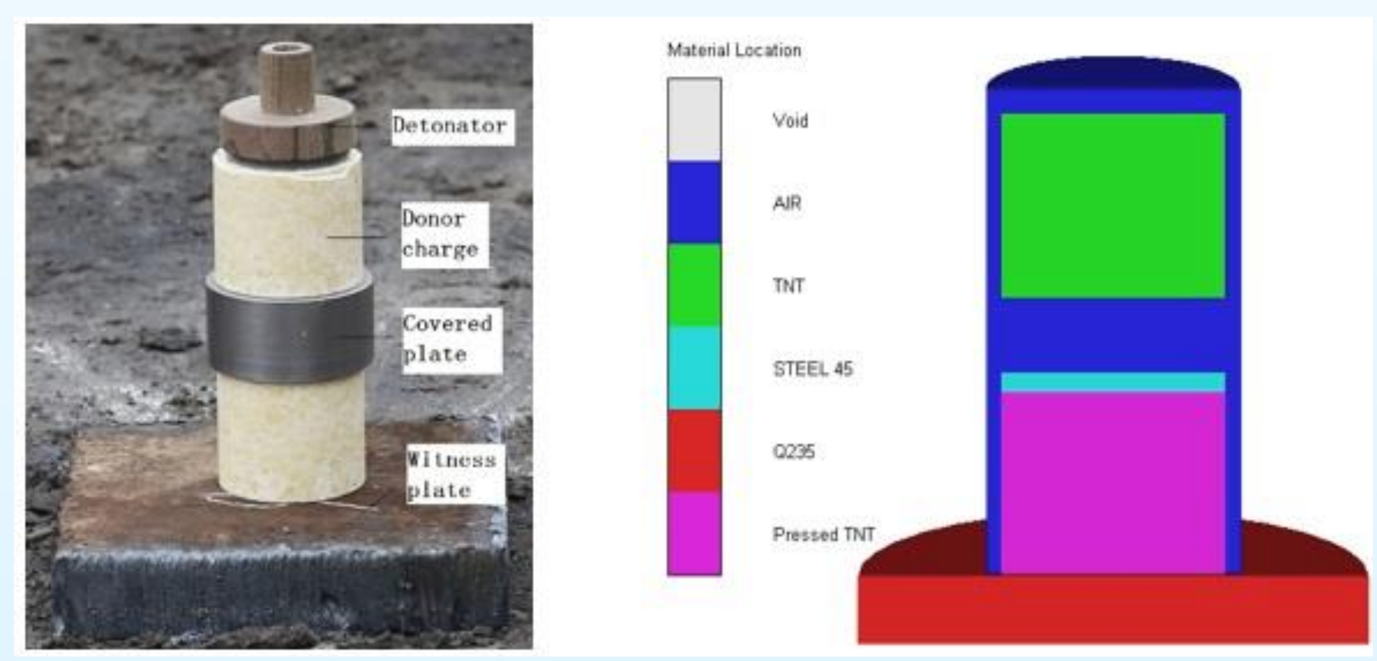
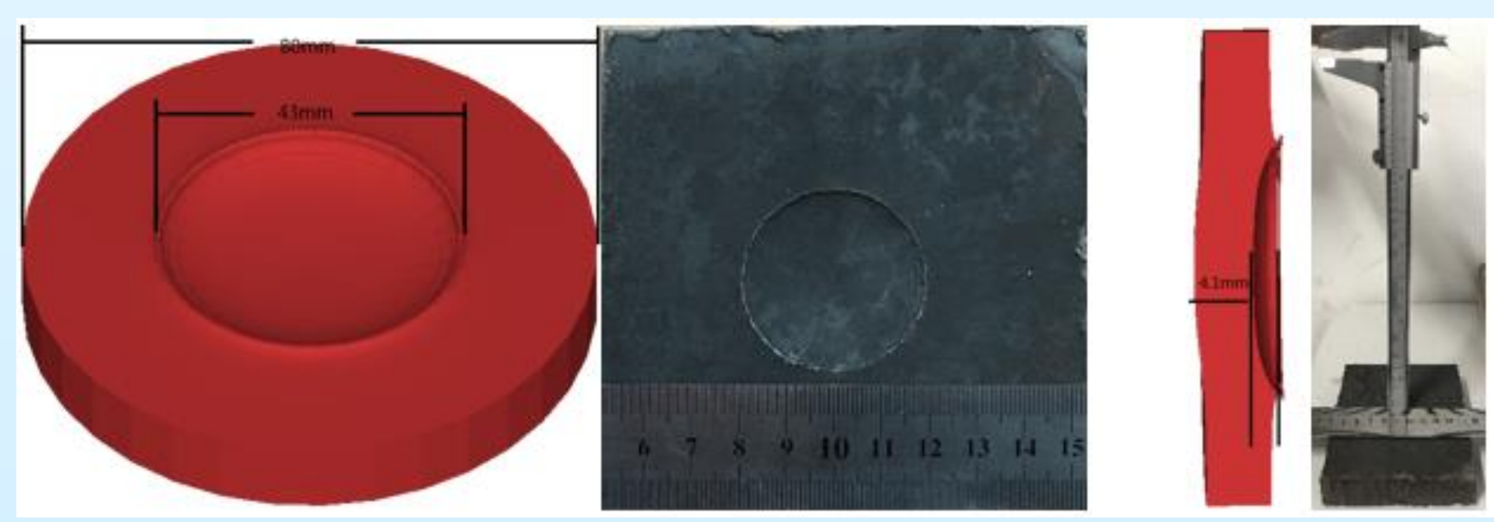


Fig. 2. The picture of the shock initiation on the covered charge and the numerical model.



a. Top view of witness plate b. Sectional view of witness plate

Fig. 3. Witness plate deformation comparison chart of the experiment and numerical simulation.

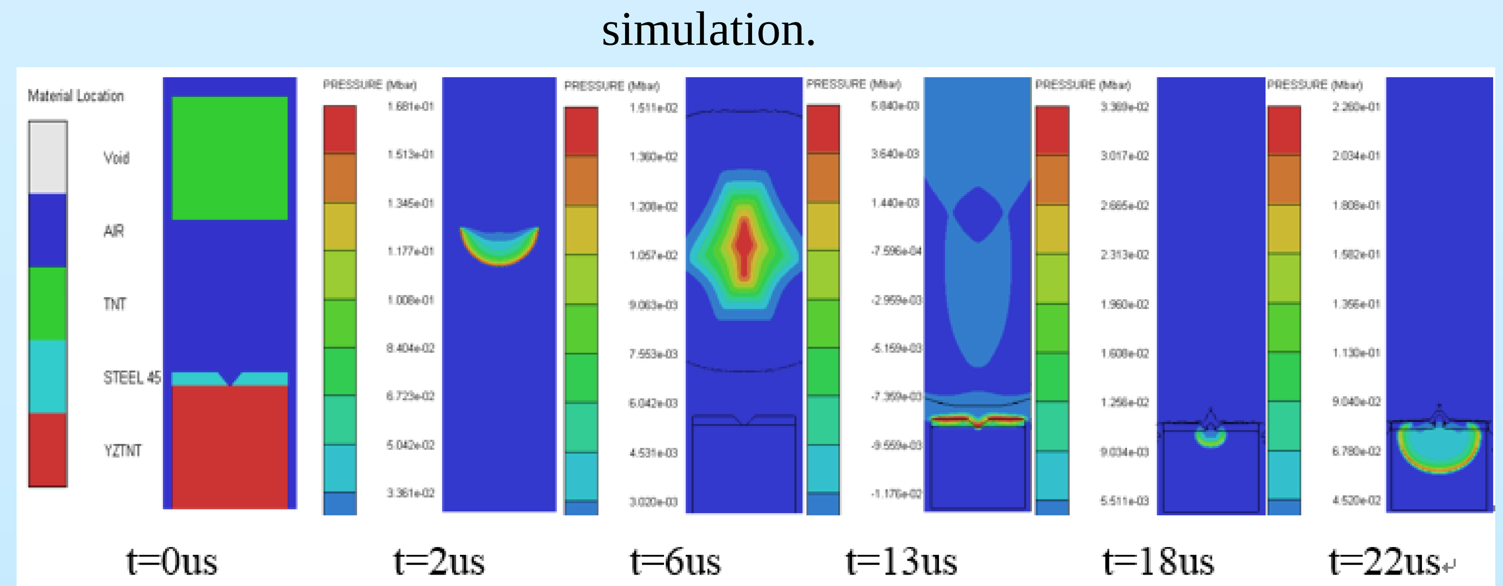


Fig. 4. Cloud chart of the acceptor charge on shock initiation when the upper and lower notch diameters of the covered plate is 7 mm and 1 mm at a height of 40 mm.

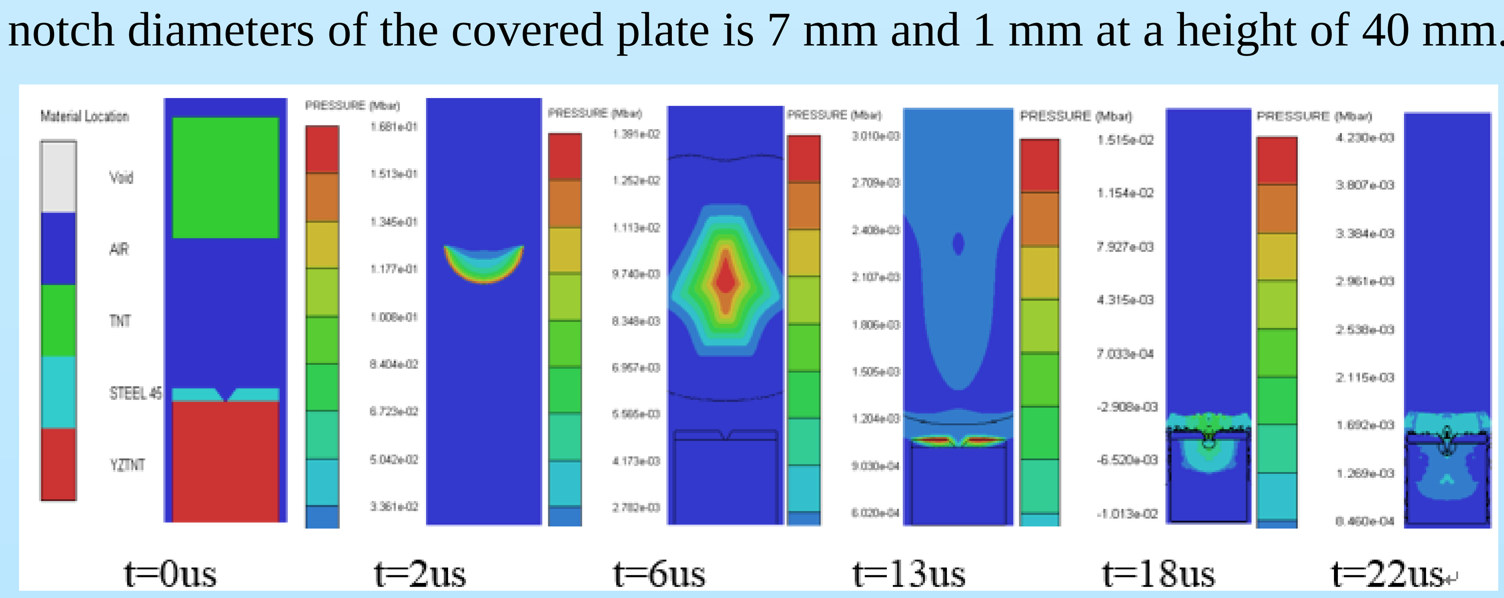


Fig. 5. Cloud chart of the acceptor charge on shock initiation when the upper and lower notch diameters of the covered plate is 4 mm and 1 mm at a height of 40 mm.

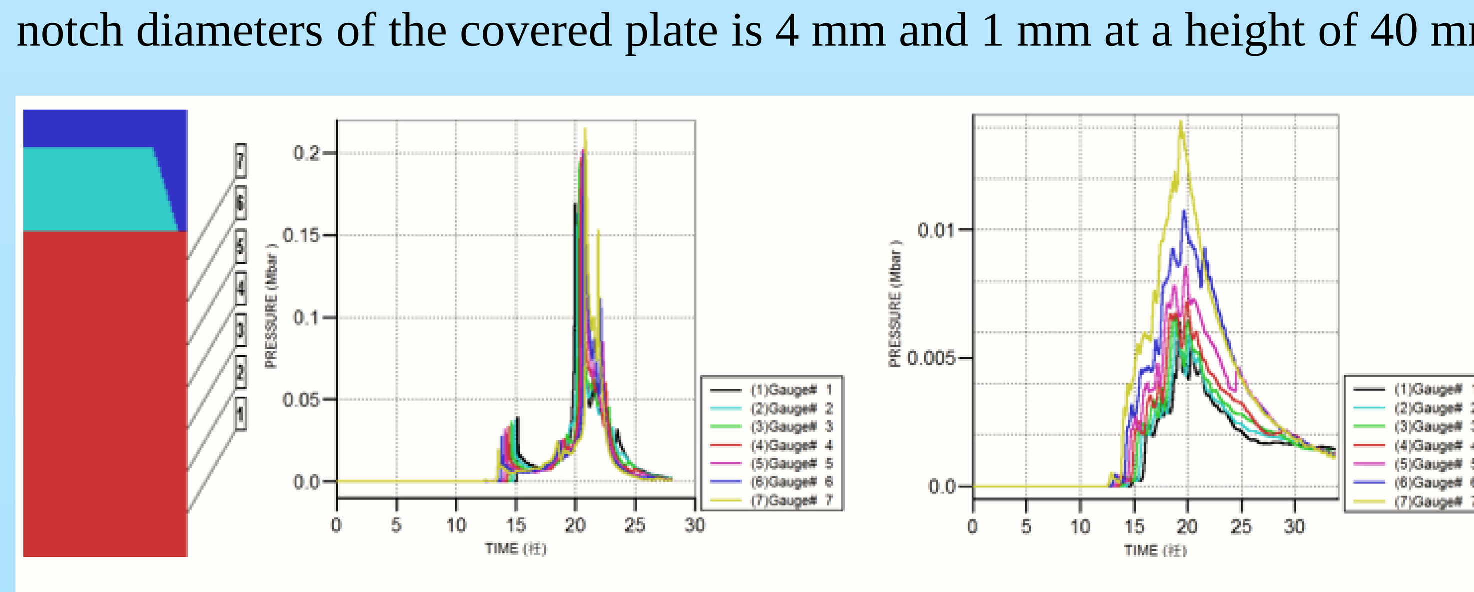


Fig. 6. The pressure change of the acceptor charge (a) Gauges point distribution, (b) complete detonation process of the charge and (c) incomplete detonation process of the charge.

Acknowledgments

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