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Study on Scattering Process of Preformed Rod Fragment

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Abstract. By theoretical analysis and simulation on the scattering process and characteristic parameter of preformed rod fragment, dynamitic and static dispersion angle of preformed rod fragment is derivate. The theoretical research shows: the velocity of warhead is a important influence factor in analysis the scattering process of preformed rod fragment. The results of theoretical model are validated by numerical simulation, which can be provided theoretical assessment to target damage.

Introduction

When preformed fragment explode, it forms many high-speed fragments, the shape, size, speed, and the spatial distribution law are the important parameters which influence its power. If the shape and the size of preformed fragment is unchanged, the speed and the spatial distribution law become the main factors which influence the power of the battle parts. This article conducts the analysis and research on the character of the speed and the spatial distribution law of the preformed rod fragment.

The Initial Speed of the Fragment

The Calculation of the Initial Speed of the Fragment

The initial speed of the fragment is the important performance parameter of the fragment, which influence the killing power of the fragment directly. Now, the calculation expression of the initial speed of the fragment is inferred from the basic relation of kinetic energy, among them, the Gurney formulation is the most important relational expression which express the initial speed of the fragment and the mass ratio of the explosive and the fragment, for cylindrical charge, Gurney formulation is:

$$\upsilon_0 = \sqrt{2E}\sqrt{\frac{\beta}{1+0.5\beta}} \tag{1}$$

Fragment Velocity Attenuation

The speed of the fragment decreases during exercise because of the air resistance, when the speed decreases to a certain figure, its kinetic energy will not meet the requirement of the killing power and have no killing energy. So the Fragment velocity attenuation influences the killing power of the pill directly. According to the aerodynamic, the resistance of fragment in the air is:

$$F = \frac{1}{2}\rho A C_x \upsilon^2 \tag{2}$$

In the formulation, p is air density; A is the front face area of fragment; C is resistance coefficient, which is related to the shape and the flying speed of fragment; V is the flying speed of fragment, we can get:

$$\upsilon = \upsilon_0 e^{-\frac{\rho c_x A}{2m}x}, \tag{3}$$

In the formulation, m is mass of the fragment. So the speed transformation due to the flying distance of the fragment in the air is shown in figure 1. From the figure we can see that the speed attenuation is very slow when in the air, when the flying distance is 10 meters, the loss of the speed is less than 60ms^{-1}. In the scatter radius of 10 meters, the speed attenuation of the fragment in the air can be ignored.

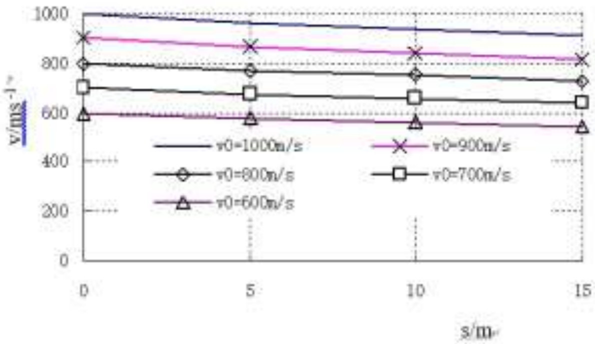

Figure 1. Relation between speed and distance of the fragment.

Scattering Angle Calculation

Static Scattering Angle

For cylindrical charge, the pellet can deviate the normal direction when flying, which forms scattering angle. The included angle α forms between the normal direction detonation wave front and the symmetry of the projectile bodies, supposing that there is no change and deformation of the material in terms of the length and thickness, when the detonation wave front arrives A, it starts deformation and moves to the direction of A, velocity vector of the pellet deviates the normal direction of the case is β, that is scattering angle of the fragment, as is shown in figure 2.

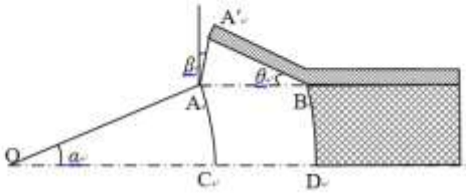

Figure 2. Scattering angle of the fragment.

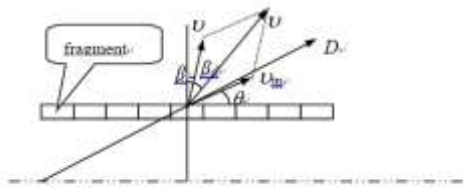

Figure 3. Scattering angles of fragments of the dynamic explosion.

Supposing the initiation position is O, take an infinitesimal of fragment from the case into research, during the time Δt, detonation wave front starts from AC to BD, so we can know scattering angle of the pellet is

$$\tan\beta = \frac{\upsilon_0}{2D}\cos\alpha \tag{4}$$

In the formulation: β is scattering angle of the pellet; υ_0 is limiting velocity of fragment; D is the speed of detonation. From the formulation (4) we can know that, scattering angle of the fragment is function about α, it indicates scattering angle of the fragment relates to the initial axial coordinate of the fragment. For cylindrical charge, if the fragments have no scattering angles, the fragments will take on approximately uniform distribution along the cylindrical surface. Due to the existence of the scattering angles, and is also the function about α, it leads to that the fragment distribution in cylinder changes along the axial, closer to the initiating point, the density of the fragment is larger.

Scattering Angles of Fragments of the Dynamic Explosion

If the battle parts have a kinematic velocity in the air, we should calculate the scattering angles of fragments according to the condition of motion state explosion, the scattering angles of fragments under dynamic explosion can get from the scattering angles of fragments under static explosion. Supposing the speed of the battle parts in the air is υ_m, the angle of attack between the velocity vector direction and the axis of the shell is θ, υ_0、υ_d is throwing speed of the static explosion and dynamic explosion, β、βd is scattering angles of fragments of the static explosion and dynamic explosion, as is shown in figure 3, from the geometrical relationship shown in the figure we can get the flight schedule of the fragment under the dynamic condition is:

$$\upsilon_d^2 = \upsilon_0^2 + \upsilon_m^2 - 2\upsilon_0\upsilon_m \cos\left(\frac{\pi}{2} - \beta - \theta\right) \quad (5)$$

The flight angle of the fragment under the dynamic condition is:

$$\sin\left(\beta_d - \beta\right) = \frac{\upsilon_m}{\upsilon_d}\sin\left(\frac{\pi}{2} - \beta - \theta\right) \quad (6)$$

when $\theta = 0$,

$$\upsilon_d^2 = \upsilon_0^2 + \upsilon_m^2 - 2\upsilon_0\upsilon_m \sin\beta \quad (7)$$

$$\sin\left(\beta_d - \beta\right) = \frac{\upsilon_m}{\upsilon_d}\cos\beta \quad (8)$$

Result of Numerical Simulation and Analysis

Take the cylindrical charge for example; we use LS-DYNA to analyze the motion of the preformed fragment. The model consists of explosive, lining, cylindrical particles and outer lining, the material of lining is aluminum metal, the material of outer lining is 45# steel, preformed fragment uses tungsten alloy, the diameter of the grain is 8cm, we put the cylindrical particles around the tungsten alloy, the diameter of the grain is 8mm, The initiation is 5cm away from the top in the axil, we build the model from the quarter of the model, the calculation model is shown in figure 4.

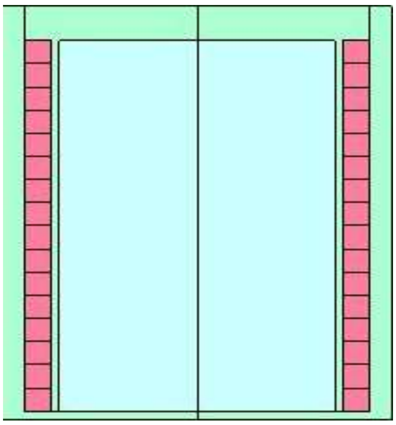

Figure 4. Model of simulation.

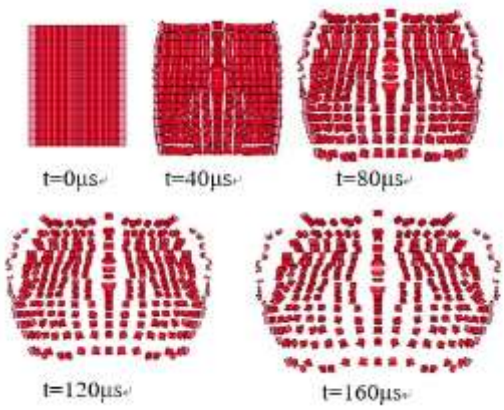

Figure 5. The physical process of flight of fragment.

Figure 5 is the result of numerical simulation of the physical process of flight of fragment, the density of the charge at both ends is small, in the middle is large, which is basically consistent with the theoretical analysis. The scattering density of fragment is not only related to the radius of cylindrical surface, but also related to the flight angle of the fragment, if the flight angle is bigger, the density of the flight area of the fragment is smaller.

Figure 6 introduces the law of the flight angle of fragment along with the change of the axial coordinate, from the figure we know, with the initiation point distance increases, the flight angle of fragment increases, numerical simulation is basically consistent with theoretical calculation, but in terms of the value, theoretical calculation is different from numerical simulation, especially at the ends of the powder charge, the gap is larger. The scattering area of pellet is determined by the flight angle at both ends. So, in terms of the flight angle of preformed fragment, the theoretical description should be further.

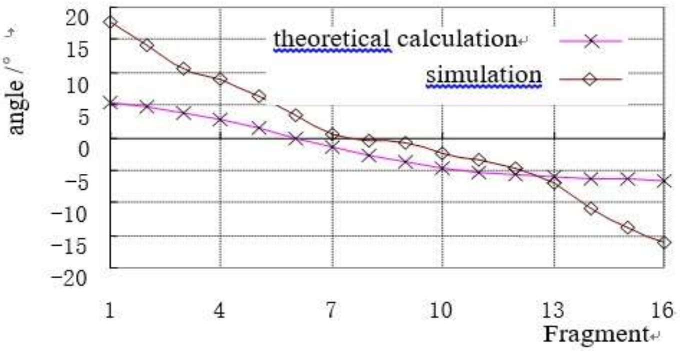

Figure 6. Flight angle of fragment along the axial.

Conclusion

The article conducts theoretical calculation and numerical simulation on the flight and characteristic parameter of the fragment of the cylindrical charge, and draw out the flight speed of fragment and the calculation formula of flight angle under dynamic and static condition and the law along the axial distribution, the result from the numerical simulation is consistent with the theoretical calculation, which provides important theoretical reference frame for the design and the performance parameter evaluation of the battle parts.

References

[1] Stobel, E. L. Review of DARPA segmented rod development efforts. Interferometrics, Inc., Document NO.91229. 1991.

[2] Bjerke, T. W., J. A. Zukas, and K. D. Kimsy. Penetration performance of disk shaped penetrators. International Journal of Impact Engineering, 1992, 12(2): 263-280.

[3] William S. de Rosset. An overview of novel penetrator technology. ARL-TR-2395. 2001.

[4] Frank, K., and J. Zook. Chunky metal penetrators act like constant mass penetrators. Proceedings of the 12th International Symposium on Ballistics. San Antonio, TX, 1990.

[5] N J Lynch, S. J. Bless, C. Brissenden, D. Berry, and B. Pedersen. Novel KE penetrator performance against a steel/ceramic/steel target at 00 over the velocity range 1800 to 2900m/s. International Journal of Impact Engineering. 2001, 26: 475-486.