Simulation Study on the Safety of the Explosion of a Certain Type of Dyeing Bomb

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Keywords: Dyeing shell; Shell deformation; Simulation; Static explosion test

Abstract: Based on the structure of a certain type of dyeing projectile, the mathematical simulation model was established, and the simulation of the shell deformation in Ansys/LS-DYNA software was carried out by using the FEM/SPH method. The explosion process of the shell shell in different time displacement nephogram and the equivalent stress nephogram analysis, the maximum displacement and the maximum equivalent stress. Through the static explosion test, get the maximum deformation of the shell, the test results are in good agreement with the simulation results (the error is only 0.3cm), prove the correctness of the model, provides an important reference for further research on throwing stain.

1. Introduction

The bomb is dyeing dyeing agent from the explosion energy will be loaded on the projectile throwing out, in a target skin, clothing is not easy to leave the decontamination stain marks, in order to provide the basis for the afterwards or non lethal ammunition[1]. In order to realize the effective identification of the scene of the group events, we have developed a kind of hand cast. The play not only to do the dyeing dyeing effect is good, also must meet the requirements of non lethal bomb fragments, to avoid staining in accidental injury to personnel.

The design requirements for the realization of the above, the structure design of elastic dyeing cage structure, dyeing agent can quickly spilled out from the nozzle holes, but also can effectively relief[2], plastic deformation without breaking the shell fragments produced in the relatively small effect of shock wave, greatly improves the safety performance of ammunition.

The deformation process of dyeing shell very quickly, is not easy to be observed, and the explosion mechanics environment is complex[3], using theoretical analysis is very difficult. Therefore, this paper uses Ansys/LS-DYNA software [4] to simulate the explosion, and get the law of the deformation of the shell, the study of the dyeing bomb has a high practical value.

2. The Structure and Principle of the Dyeing Bomb

The dyeing bomb is composed of two parts, the firing mechanism and the projectile body. Firing mechanism and missile projectile body through the screw connection, the Aluminum Alloy material cage structure shell is provided with 6 symmetrical long holes along the shell axial loading; internal capsule staining and explosive expansion kit; improved grip handle and easy to throw, coat of 0.6mm thick paper shell casings. The structure diagram is shown in Fig. 1.

After the dye projectile is thrown, it is delayed (2.5~4 seconds), the dye projectile flies to the target area, the explosive charge is exploded, the instant pressure gas is generated, and the dyeing agent is ejected from the body spray hole. Aluminum Alloy shell deformation and not broken, do not produce metal fragments, only the formation of paper fragments and small flexible plastic fragments, will not cause harm to the staff, implementation of non lethal combat use.

  DOI: 10.25236/isrme.2019.021

Fig. 1 dye structure

3. Explosion Model and Simulation

3.1. Establishment of ammunition explosion model.

Because of the explosion may cause large deformation model, thus making the model grid serious deformation, the small deformation area after the explosion, the shell and PVC staining capsule by finite element method (FEM) modeling, and after the explosion of large deformation in the region, namely the explosives and the stain using smoothed particle method (SPH) modeling. This paper uses the shell can describe the material under high strain rate deformation behavior of thermal viscoplastic constitutive model of Johnson-Cook[5] capsule; dyeing using elastic-plastic linear kinematic hardening constitutive model; state equation of stain by shock wave (SHOCK) equation of state, which is actually a condensed medium state equation (Mie-Gruneisen) deformation booster; using Jones.Wilkins-Lee (JWL) equation of state, the state equation can describe accurately the product of explosion shock wave power, JWL equation of state is the dynamics equation of state.

The constitutive model of Johnson-Cook is as follows[6]:

$$\sigma=\left(1+C\ln\dot{\varepsilon}^{*}\right)\left(A+B\varepsilon^{\mathrm{n}}\right)\left(1-T^{*\mathrm{m}}\right) \tag{1}$$

A, B, C, m, n - the material parameter;

ε -Equivalent plastic strain;

$\dot{\varepsilon}^{*}=\dot{\varepsilon}/\dot{\varepsilon}_0$ -Non dimensional plastic strain rate. $\dot{\varepsilon}_0$ -Reference strain rate;

$T^{*}=\left(T-T_r\right)/\left(T_m-T_r\right)$. T -Actual temperature; T_m -Melting temperature of aterial; T_r -Reference temperature.

JWL equation of state:

$$P=A\left(1-\frac{\omega}{R_1V}\right)e^{-R_1V}+B\left(1-\frac{\omega}{R_2V}\right)e^{-R_2V}+\frac{\omega E}{V} \tag{2}$$

V is the relative volume of the formula, E is the initial internal energy of the unit volume of explosive; A、B、R_1、R_2、ω is the state equation parameters.

Elastoplastic constitutive model: elastoplastic constitutive model represents the relationship between stress and strain, in the stage of elastic deformation, stress and strain according to the variation of Young's modulus, the stress and strain of the ratio of Young's modulus of E; and exceed the yield limit, stress and strain in tangential modulus change at this time, the stress and strain ratio of tangential modulus E_{TAN}. The stress-strain curves of the elastoplastic constitutive model are shown in Fig. 2.

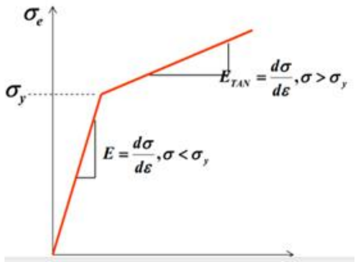


Fig. 2 stress-strain curves of elastoplastic constitutive model

The expression of Mie-Gruneisen state equation is as follows[7]:

$$P=\left(K_1\mu+K_2\mu^2+K_3\mu^3\right)\left(1\text{-}\Gamma\mu/2\right)+\Gamma e\left(1+\mu\right) \tag{3}$$

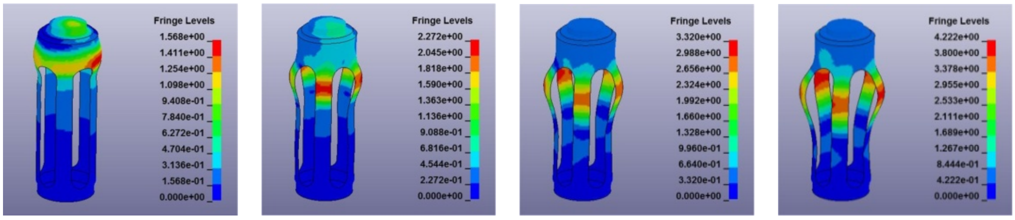
Volume change rate: $\mu=\rho/\rho_0-1$, e is Internal energy per unit volume, K_1、K_2、K_3 and Γ is Material parameters related to material impact compression. In addition, there is another expression for the Mie-Gruneisen equation of state.

$$P=\frac{\rho_0 C_s{}^2\eta}{\left(1-S\eta\right)^2}\left(1-\frac{1}{2}\Gamma\eta\right)+\Gamma\mathrm{e} \tag{4}$$

$\eta=1-\rho/\rho_0$, C_s is Volume sound velocity, S is Curve slope of U_S-U_P , Γ is constant of Gruneisen.

3.2. Simulation asalysis.

The displacement images of 95 us, 195 us, 295 us and 395 us are selected, as shown in Fig. 3. [8,9,10]

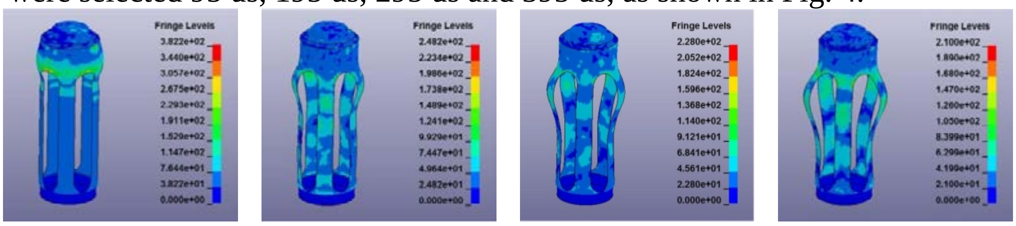


t=95us　　t=195 us　　t=295 us　　t=395 us

Fig. 3 the shell deformation displacement and moment

Fig. 3 we can see that, in the process of ammunition explosion, the shell due to the impact of the stress wave, will lead to severe deformation. The whole deformation process of very short duration, but due to plastic deformation of the shell, even after the explosion, the shell deformation can not be restored. With the explosion of the shell deformation, the maximum area continues to move down, the shell through hole of the middle region is the weakest and most serious deformation, at the same time, because of the shell with axial symmetry, and the shell after the explosion, the deformation of axial symmetry. Among them, the maximum displacement of the shell is 3.56cm.

Calculate the equivalent shell in the explosion stress in the process of using LS-DYNA software, renderings were selected 95 us, 195 us, 295 us and 395 us, as shown in Fig. 4.



t=95us　　t=195us　　t=295us　　t=395us

Fig. 4 von-mise stress shell after the explosion

Can be seen from Fig. 4, the shell stress is mainly concentrated in the through hole area, this area is the most easily broken shell region. According to Fig. 4, using PREPOST to deal with the maximum equivalent stress with time, and get the maximum equivalent pressure curve at different time, as shown in Fig. 5.

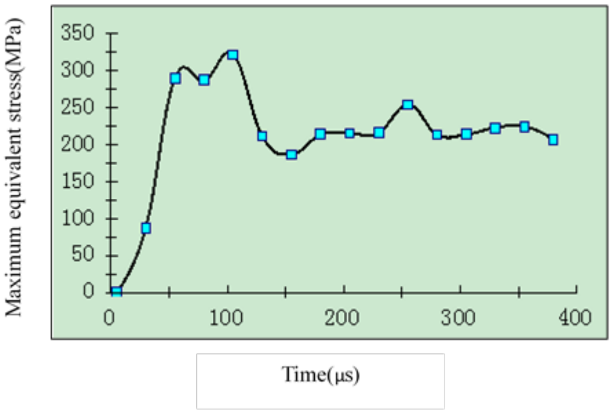


Fig. 5 von-mise shell stress curve

Data can be known, the yield limit of 2A11 aluminum alloy is 215MPa, tensile limit is 370MPa. We can see from Fig. 7, in 0~105 us, the maximum equivalent stress of the shell has been increased, the maximum value is 321Mpa; in 105-185us between the shell, the maximum equivalent stress gradually reduced to near 210MPa; in 185~380 us, the curve is flat, has been stable at around 210MPa. According to the fourth strength theory can be concluded as the maximum equivalent shell explosion in the stress in tensile and yield limit between the shell only plastic strain, without rupture, design in safety design is feasible.

4. Test

Ready to play the 12 hair, will be dyed in the cement ground flat on the static burst, and then collect the body debris. As shown in Fig. 6.

Fig. 6 static explosion test sample

Fig. 7 projectile debris after the explosion

The test results show that all samples of normal play, after the explosion of body integrity, no crack, no metal fragments. After the test, the deformation of the missile body is shown in Fig. 7. The maximum shell deformation measurement, the displacement error is 3.48cm, and the simulation results is very small, only 0.3cm, proved the correctness and rationality of the model establishment.

5. Conclusion

In this paper, the Ansys/LS-DYNA software is used to set up the explosion model of the dyeing bomb, the deformation process of the projectile is analyzed, and the simulation results are verified by experiments:

(1) For cage structure, booster is placed at the upper end of the projectile ammunition, in under the effect of shock wave, soon to produce plastic deformation, the maximum deformation area by moving down, the explosion at the end of the middle part of the maximum deformation through hole.

(2) Analysis of the projectile by the maximum equivalent stress regularity, the maximum equivalent body bomb type dyeing process by stress, according to the fourth strength theory can prove the scientific design of cage structure effectively, does not produce metal fragments, meet the requirements of non fatal, and the test results the simulation results are in good agreement.

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