Establishment and Simulation Analysis on Internal Ballistics Equations for Artillery Shrapnel

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Abstract. Internal ballistic equations of artillery shrapnel are established on the basis of theoretical analysis, and equivalent method used for dealing with semi-combustible cartridge case, calculation program selects the Matlab software. The simulation results are accord with the experimental data, it shows design of equations and calculation program is reasonable and credible.

Introductions

With the requirements of development of artillery's technology, the emergence semi combustible cartridge case is a perfect combination of all advantages of combustible cartridge case and metal cartridge case. In this paper, we studied internal ballistic of lower chamber pressure artillery firing with semi-combustible cartridge case.

According to the tactical technical requirements, in order to increase the damage effect of projectiles, launch projectiles need larger firing range and enough large falling angle when hit the ground target, so it must obtain different firing velocity. It is obviously that only one kind of charge cannot meet the requirements, and it must be spited into several small parts of propellant charge with different mass and shapes. But the propellant charge is incomplete combustion under low pressure when the charge is reduced to a certain amount, then the velocity distribution increased and the less quality of charge, the more obviously phenomenon. In order to address this issue the method of mixed charge is adopted that is combination of thin and thick powder charging gunpowder. In the small charging it mainly is thin charging gunpowder which can maintain constant pressure for complete combustion and fuse can remove insurance.

Equivalent conversion for semi-combustible cartridge case

For the convenience of calculation, equivalent method is selected for semi-combustible cartridge case in the calculation of internal ballistic that is release of energy in combustible cartridge case can burn for fixed value, converts it to a part of the ordinary powder, the semi-combustible cartridge case calculation can be used in the calculation method of the ordinary powder.

In this paper, the ingredients of semi combustible cartridge case is same with the third generation cartridge case, the simplified physical model is shown in figure 1, and d is the outside diameter and h_1 is the thickness of semi-combustible cartridge case. Material at the bottom of semi-combustible cartridge case is metal.

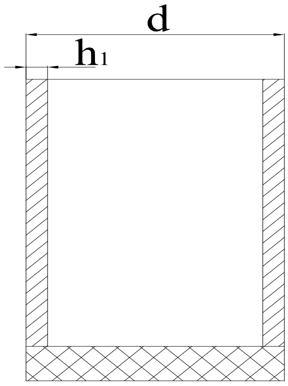

Figure 1: simplified physical model

For combustible cartridge case, composition and power are all very big different with ordinary powder, so it needs transformation quality and powder and makes it the same as ordinary powder.

$$\omega_1' = \frac{\omega_1 \cdot f_1}{f_2} \quad (1)$$

Meaning of parameters:

ω_1': quality of transformed semi- combustible cartridge case.

ω_1: mass of semi- combustible cartridge case.

f_1: power of semi- combustible cartridge case.

f_2: transformed power of semi- combustible cartridge case.

Shape function of main charge

Main charge of mixed charge is thin gunpowder and thick gunpowder. The shape function of thin gunpowder is:

$$\psi_2 = \chi_2 Z_2 (1 + \lambda_2 Z_2 + \mu_2 Z_2{}^2) \quad (2)$$

Meaning of parameters:

ψ_2: relative burning capacity of thin gunpowder

Z_2: relative burning thickness of thin gunpowder

χ_2 、 λ_2 、 μ_2: shape structure characteristics of thin gunpowder

Thick gunpowder usually is multi-perforated propellants, and its shape function is:

$$\psi_3 = \begin{cases} \chi_3 Z_3 (1 + \lambda_3 Z_3 + \mu_3 Z_3{}^2) & 0 \le Z_3 < 1 \\ \chi_s Z_3 (1 + \lambda_s Z_3) & 1 \le Z_3 < Z_s \\ 1 & Z_3 \ge Z_s \end{cases} \quad (3)$$

Meaning of parameters:

ψ_3: relative burning capacity of thick gunpowder

χ_3 、 λ_3 、 μ_3: shape structure characteristics of thick gunpowder

χ_s 、 λ_s: shape structure characteristics when the gunpowder divide

Z_3: relative burning thickness of thick gunpowder

Z_s: relative burning thickness of thick gunpowder when it burned

$Z_s = \frac{e_{13} + \rho}{e_{13}}$

$2e_{13}$: is thickness of gunpowder

$\rho = a(d/2 + e_{13})$

d :aperture of gunpowder

$a = 0.2956$

Deflagration velocities of main charge and projectile kinematics equations

Deflagration velocity equations contain pressure form function type, as following:

$$\frac{dZ_2}{dt} = \frac{\mu_2}{e_{12}} p^{n_2} \tag{4}$$

$$\frac{dZ_3}{dt} = \frac{\mu_3}{e_{13}} p^{n_3} \tag{5}$$

Meaning of parameters:

μ_2 、 μ_3: deflagration velocity coefficient of two kinds of main charge

e_{12} 、 e_{13}: half thickness of two kinds of main charge

p :pressure of mixed gas

n_2 、 n_3: pressure index of two kinds of main charge

According to the semi-combustible cartridge case interior ballistic basic assumptions, considering various minor functions and then obtained the Newton's laws of motion:

$$\varphi q \frac{dv}{dt} = Sp \tag{6}$$

$$\frac{dl}{dt} = v \tag{7}$$

Meaning of parameters:

q: mass of projectile

φ: minor function coefficient

v: velocity of projectile motion

S :gun cross-sectional area

l :projectile trip

Internal ballistic energy equations of main charge

In the bore considering semi combustible cartridge case can complete combustion and release energy to drive the projectile movement, so the semi-combustible cartridge case as part of the propellant, according to the law of conservation of energy can get energy equation of artillery grenade launch:

$$Sp(l + l_\psi) = f_2\omega_2\psi_2 + f_3\omega_3\psi_3 - \frac{\theta}{2}\varphi q v^2 \tag{8}$$

Meaning of parameters:

$l_\psi = l_0[1 - \frac{\omega_2}{\omega}\frac{\Delta}{\rho_p}(1-\psi_2) - \frac{\omega_3}{\omega}\frac{\Delta}{\rho_p}(1-\psi_3) - \frac{\omega_2}{\omega}\Delta\alpha_2\psi_2 - \frac{\omega_3}{\omega}\Delta\alpha_3\psi_3]$,

l_ψ :hole shrinkage of chamber length

l_0 :volume of chamber

ω_2' : sum of thin gunpowder and transformed mass of semi-combustible cartridge case

$\omega_2' = \omega_2 + \omega_1'$

ω_2 :mass of thin gunpowder

ω: sum of all kinds of gunpowder

$\omega = \omega_1' + \omega_2 + \omega_3$

ω_3 :mass of thick gunpowder

Δ :mean fraction of losses load density

ρ_p :density of gunpowder

α_2 、 α_3: covolume of two kinds of gunpowder

Simulation analysis for internal ballistic equations

Write internal ballistic program by Matlab software accord to equations (1)-(8) and simulation analysis for internal ballistic, in this paper, the 18/19 and 21/1 projectile mixed charge are selected, the minimum charge by loading a single number 21/1 of gunpowder. Obtain the results of simulation analysis and get the $p-t$ 、 $p-l$ 、 $v-l$ 、 $v-t$ 4 curves as shown in Figure 2.

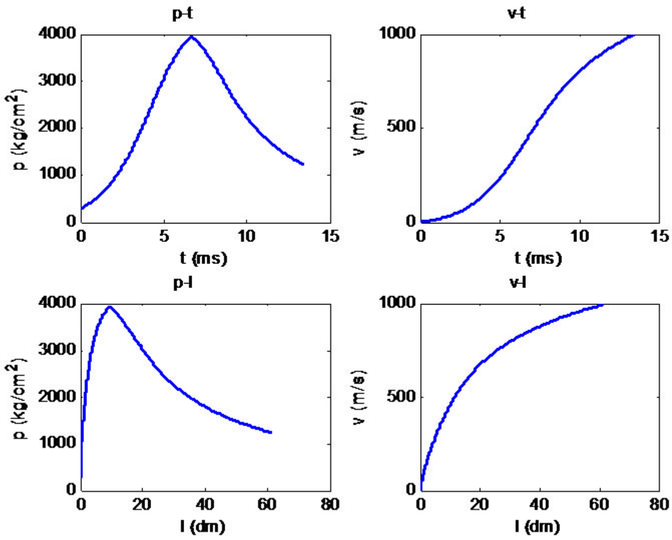

Figure 2: Results of simulation analysis

Compared with the experimental data, results of simulation analysis of the maximum insole pressure differ with the experimental results is about 1%, the velocity and the experimental results is about 2%, the simulation results is in the error range.

Conclusions

Based on internal ballistic theory analysis, established model of the equations of internal ballistic and detailed analysis basic theory was made, reasonable modeling from the theory, calculation method and program implementation process, the input parameter, initial value, special point calculation, and on the basis of experiments, respectively established projectile internal ballistic model is verified, the results are accurate feasible.

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