Design of Ablation Test Device for Brick Coating of Gun

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Abstract. As a result of the live ammunition test conditions, the barrel resistance of the barrel coating has high cost, time consuming, low efficiency and high test site requirements. This article designed a simple, convenient and efficient test device. Through the internal trajectory calculation by Matlab, the ablation environment produced by the ablation test device has achieved the expected effect, which is consistent with the working condition of the tube in the launching state, which can better reflect the ablation of the coating.

1. Test principle of ablation test device
The whole ablation test device mainly consists of three parts: gun barrel, new coating ablation test device and connecting device. The working principle is as follows: Before the test, first flat tube and unscrew the muzzle brake, will try to spin the embedded high pressure cylinder connected to the barrel. Loading pressure controlled bomb in high-pressure cylinder chamber, then in a certain amount of gunpowder, and then screwed sealing plug in high pressure cylinder is connected with the 24V electrode, DC. In experiments, the powder is ignited by the current and burned to produce a propellant gas with a certain pressure. When the pressure control was forced to play into high-pressure cylinder chamber and forward movement. At the same time, the gunpowder continued to burn and the pressure of gunpowder and gas increased. When the pressure bomb through the specimen, the propellant gas pressure reaches the maximum value, resulting in the best effect of using ablation treatment. After the pressure controlled projectile is released from the test piece, it continues to fly forward in the barrel until it hits the breech. The propellant gas ejected from the specimen expands in the tube, resulting in a sharp drop in temperature and pressure, eventually leaking from the gap between the breech and the tube in the atmosphere. Repeat these actions, the multiple ablation test of the test piece can be realized. At the end of the test, the test specimen is removed from the high pressure cylinder, and the ablation condition of the coating specimen can be studied by using relevant instruments to test the specimen.

2. Design of ablation test device
Based on the above test ideas and experimental principle, a test device for the ablation performance of a large caliber gun is designed. The device can be used for many ablative tests on the coated specimens. The inner environment generated by the ablation environment test device is similar to the firing conditions, the coating specimen after ablation can detect the ablation condition through various methods, so as to assess the prepared coating erosion resistance. In addition, a number of specimens can be placed at the same time during the ablation test to compare the ablative properties of the coated
Figure 1. The coating erosion test device

Figure 1. is a coating erosion test device machined by machining. The test device is screwed on the muzzle connecting device and connected with the gun barrel. Figure 2. is a muzzle connection device, and Figure 3. is the actual installation mode of the test device. The ablation test device is connected to the muzzle, the coating can be fixed ablation test device effectively, reduce the impact of combustion on the test device, but also can make the control from the test pressure of projectile impact of gun breech and stop, improve safety. On the other hand, the gas produced by the burning of the gunpowder can be stored in the barrel of the gun to dissipate slowly, and the smoke produced in the test can be slowed down. Furthermore, the noise produced in the test can be reduced.

Figure 2. The gun barrel connector

Figure 3. The install pattern of erosion device

In order to explain the specific internal structure of the coating erosion test device intuitively, a three-dimensional model of the coating ablation test device is established by using the Pro-E three-dimensional modeling software, as shown in figure 4.. Coating device ablation test in Figure 4. connection device connected with the muzzle through threaded connection, the ignition device and the pressure cylinder also adopts threaded connection, the ablation test device through the connecting device and the muzzle of gun tube. The control pressure bomb is a copper material similar to the shape of a bullet. The chamber were used for powder grains after installing pressure controlled bomb and electric ignition device, the chamber for closed environment.
The coating device can be placed up to one-time ablation test of 4 specimens, 4 specimens of the ablation test, installation can be convenient for ablation of a plurality of test pieces were analyzed to evaluate the coating erosion resistance. The coating specimens are installed in the retaining ring, and the standard coating specimen size is 11mm * 7mm * 9mm. Figure 5 shows how the mounting rings and coated specimens will be fitted.

3. Internal ballistic calculation of ablation test equipment

The test process of an ablativo test device can be approximated as an internal ballistic process. By solving the ablation test device of internal elastic coating problems can reflect the ballistic characteristics accurately and directly, the main parameters of internal ballistics are obtained and can directly reflect the powder gas pressure ablation test unit condition in the ablation process and coated specimens are in test. In addition, by comparing the interior ballistic parameters of the gun under the condition of live ammunition shooting, the simulation of ablation process of the ablation test device can be further described. During the calculation of the ballistic problem in the ablation test apparatus, the following basic assumptions are made [1]: (1) the combustion of propellant follows the law of geometrical combustion. (2) the particles are burned at average pressure and follow the law of burning speed. (3) the surface heat dissipation of the ablation device is indirectly corrected by reducing the powder force f or increasing the specific heat k. (4) use the coefficient $\varphi$ to consider various secondary functions. (5) the propellant gas obeys the Nobel Abel equation of state. (6) the f, residual $\alpha$ and specific heat ratio k are constant in the whole combustion process.
3.1. Basic equations of interior ballistics

In the internal ballistic process of the ablation device, the following basic interior ballistic equations [2]:

\[
\begin{align*}
\psi &= \chi Z \left(1 + \lambda Z + \mu Z^2\right) \\
\frac{dZ}{dt} &= \frac{p}{I_k} \\
Sp &= \varphi m_q \frac{dv}{dt} \\
Sp(l_\psi + l) &= fm_q \psi - \frac{\theta}{2} \varphi m_q v^2 \\
\frac{dl}{dt} &= v
\end{align*}
\]

(3-1)

Among: \(\psi\) — The percentage of gunpowder burned out. \(Z\) — The percentage of gunpowder burned out. \(\chi\), \(\lambda\), \(\mu\) — The shape characteristic quantity of propellant grain. \(P\) — Propellant gas pressure. \(I_k\) — Total pressure impulse. \(S\) — Bore cross-sectional area. \(\varphi\) — Coefficient of resistance is also called secondary work coefficient. \(v\) — Projectile velocity. \(l_\psi\) — Free chamber volume shrinkage long.

3.2. Initial conditions of internal ballistic calculation for ablative test equipment

3.2.1. Charge parameters of ablative test equipment.

Charge quantity \(m_\omega = 10\) g .

Grain thickness \(2\epsilon_1 = 0.78\times 10^{-2}\) dm. Gunpowder \(f = 950000\) kg.dm/kg. Coefficient of surface burning \(\chi_1 = 0.72347956, \lambda_1 = 0.3311631\). Surface burning coefficient \(\chi_s = 1.4872194, \lambda_s = -0.3685706\). Gas volume \(\alpha = 1.0\) dm3/kg. Propellant density \(\delta = 1.6\) kg/dm3 . Ignition charge \(\omega_B = 10\) g. Effects of ignition \(f = 300,000\) kg.dm/kg.

3.2.2. Related internal ballistic parameters of ablation test equipment.

(a) chamber volume.

According to the specific size, Figure 6. Figure 7. pressure cylinder pressure control pipe size and assembly relation between chamber volume can be calculated approximately \(V = 7.84\times 10^{-2}\) dm3. (b) cross-sectional area of a pressure control tube. The pressure control pipe cross-sectional area is similar to the internal ballistic gun bore transverse area from Figure 7. pressure tube size can be calculated to control the pressure pipe cross-sectional area of \(= 28.26\) mm2.

3.2.3. The length of the projectile, the mass of the projectile and the pressure of the projectile.

The length of the projectile is the length of the control tube. As shown in Figure 7., the stroke length of the projectile is \(= 46\) mm. The projectile is made of brass, and the quality is \(10\) g. The projectile is squeezed into the pressure reference gun and the barrel of the gun is squeezed into the pressure (30 Mpa).
3.3. Internal ballistic solution of ablation test device

Based on the known interior ballistic condition, the internal ballistic solution of the ablation test device can be obtained by using the internal ballistic solver. Because the test uses the powder as the porous propellant, therefore the gunpowder combustion has the enhancement stage and the reduction surface stage. The sign at which the end of the combustion is increased, i.e., $Z=1$. Gunpowder reduced surface combustion. At the end, $\Psi=1$. Table 1 is the internal ballistic table of the test device calculated, and Figure 8. is the relevant internal ballistic parameter curve. From the results of internal ballistics calculation, the theoretical maximum pressure point position and the maximum point of pressure control projectile velocity are all located at the end face of the pressure control pipe. The maximum pressure at the bottom of the projectile is 186MPa, and the maximum velocity of the control projectile is 192.8m/s. It can be seen that the position of the coating specimen is the maximum pressure point position, and the maximum propellant gas pressure at the moment of the test piece is 186MPa. In addition, the coated specimen is also affected by the action of the powder gas and the mechanical wear of the powder residue. Working conditions of bore contrast during gun firing, the ablation ablation test device and the actual environmental emission is close to that of the coated specimens are close to ablation ablation and bore gun steel. According to the theoretical calculation results, the ablation environment produced by the ablation test device has achieved the desired results.
Table 1. The internal trajectory of erosion

| Time t/m | Propellant Burning Coefficient Z1 | Ignition Coefficient of Propellant Z2 | Length of Projectile Travel l/m | Projectile Velocity v/m*s⁻¹ | Bottom Pressure pd/MPa |
|----------|----------------------------------|---------------------------------------|-------------------------------|-------------------------------|-----------------------|
| 0.0000000 | 0.13855                          | 0.03626                               | 0.000                         | 0.00                          | 30.0000               |
| 0.0000300 | 0.14507                          | 0.61428                               | 0.000                         | 6.05                          | 158.2328              |
| 0.0000409 | 0.14910                          | 1.00000                               | 0.000                         | 10.09                         | 167.9846              |
| 0.0000409 | 0.14910                          | 1.00000                               | 0.000                         | 10.09                         | 167.9846              |
| 0.0000709 | 0.16038                          | 1.00000                               | 0.001                         | 21.43                         | 169.3717              |
| 0.0001009 | 0.17173                          | 1.00000                               | 0.001                         | 32.87                         | 170.7353              |
| 0.0001309 | 0.18317                          | 1.00000                               | 0.003                         | 44.39                         | 172.0740              |
| 0.0001609 | 0.19467                          | 1.00000                               | 0.004                         | 56.01                         | 173.3866              |
| 0.0001909 | 0.20626                          | 1.00000                               | 0.006                         | 67.71                         | 174.6716              |
| 0.0002209 | 0.21791                          | 1.00000                               | 0.008                         | 79.50                         | 175.9279              |
| 0.0002509 | 0.22963                          | 1.00000                               | 0.011                         | 91.37                         | 177.1541              |
| 0.0002809 | 0.24142                          | 1.00000                               | 0.014                         | 103.33                        | 178.3491              |
| 0.0003109 | 0.25328                          | 1.00000                               | 0.017                         | 115.36                        | 179.5117              |
| 0.0003409 | 0.26520                          | 1.00000                               | 0.021                         | 127.47                        | 180.6406              |
| 0.0003709 | 0.27719                          | 1.00000                               | 0.025                         | 139.65                        | 181.7348              |
| 0.0004309 | 0.30134                          | 1.00000                               | 0.034                         | 164.24                        | 183.8150              |
| 0.0004609 | 0.31350                          | 1.00000                               | 0.039                         | 176.63                        | 184.7990              |
| 0.0004909 | 0.32571                          | 1.00000                               | 0.044                         | 189.09                        | 185.7443              |
| 0.0004998 | 0.32936                          | 1.00000                               | 0.046                         | 192.81                        | 186.0179              |
4. Conclusion
The design of a new type of coating erosion test device is described. The device can approximately simulate the bore condition when the gun is fired, and explain the working principle and test method of the ablation test device. The calculation of internal ballistic related problems of ablation test device, the internal ballistic solution of the test device is obtained, and the ablation condition of the ablation test device is basically consistent with the actual launching conditions.

Reference
[1] Wang Lianrong, Zhang Peicheng. Artillery Interior Trajectory Calculation Manual [M]. Beijing: National Defense Industry Press, 1987(6)pp37-39.
[2] Jin Zhiming, Yuan Yaxiong, Song Ming. Modern Interior Ballistics [M]. Beijing: Beijing Institute of Technology press, 1992(3)pp113-129.

Figure 8. The curve graph of internal trajectory parameters