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Study on the analysis method on ballistic performance of deterred propellant with large web size in large caliber artillery

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ABSTRACT

As for the characteristics of combustibility of deterrent propellant with large web size which is used in large-caliber gun and interior ballistic performance, the combustion characteristics of deterrent propellant are obtained by using closed-bomb experiments. The combustion law of deterrent propellant and the classic interior ballistic model of composite charge are given. By simulation and analysis the results of the artillery firing test, the burning rate variation law and the interior ballistics simulation parameters of propellant A are determined, and the burning rate relationship between propellant A and propellant B obtained from closed-bomb, then the ballistic performance of propellant B is predicted. The results show that the predicted results are in good agreement with the experimental results. The study shows that the burning rate law of deterrent propellant with large web size can be obtained by closed-bomb experiment. Using the method provided in this paper can accurately predict the interior ballistic performance and provide an important basis for improving the accuracy of interior ballistic calculation.

1. Introduction

The change of pressure in bore is affected by two factors, one is the combustion gas from propellant which, whilst burning, makes the pressure continuously increasing, and the second is the motion of the projectile which increases the space behind the projectile and makes the pressure continuously decreasing. Under the combined effect of these two factors, the pressure-time curve in the chamber rises firstly and then decreases. The maximum pressure and the muzzle velocity of the projectile are important parameters of the interior ballistic process. The target of the interior ballistic design of gun is to achieve higher muzzle velocity under the smaller maximum chamber pressure. The burning law of the propellant directly affects the formation rate of burning gases, which affects the change of the chamber pressure and finally realize different muzzle velocity. Therefore, the technology of controlling the burning law of propellant has been an important part of interior ballistics design. In order to improve the performance of gun continuously, it cannot meet the requirements only by controlling the geometry shape of propellant in the maximum pressure limit, so more investigators use the technology of deterrent propellant which has a better progressive combustibility to achieve higher muzzle velocity in the maximum pressure limit.

The technology of deterred propellant is by infiltrating the slow burning material into a certain thickness on the surface of propellant, which can reduce the formation rate of burning gases during initial combustion of propellant. When the deterrent layers gradually finish the combustion to finish, the generation rate of burning gases is gradually increased by progressive burning, which can increase the chamber pressure to offset the decrease of chamber pressure because of the projectile motion. By using this principle, the chamber pressure drop down not too fast after the maximum chamber pressure and we can get the higher muzzle velocity of projectile. Therefore, it is generally believed that the muzzle velocity of projectile can be improved by using the technology of deterred propellant. The analysis of Li Jie [1] shows that the use of technology of deterred propellant in 35 mm antiaircraft gun is better than increasing the number of perforated propellant holes. Under the same maximum chamber pressure, the muzzle velocity can be increased 2% by using technology of deterred

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propellant with the same charge structure. At present, the technology of deterred propellant has been widely applied to small caliber gun, and applied to large caliber gun charge in some countries with advanced technology [2]. The prominent feature of technology of deterred propellant is the control of combustion law, which has a better progressive combustibility.

The application of deterred propellant for large caliber gun is studied in this paper, especially for the combustion law, combustion model and interior ballistic performance of deterred propellant. An interior ballistic simulation software has programed for deterred propellant in large caliber gun by establishing combustion model of deterred propellant, classic interior ballistic model of hybrid propellants and the method of combustion rate processing for different propellants. Through the comparative analysis of the test results, the software and the model can accurately simulate the ballistic performance of large caliber gun by using deterred propellant.

2. Experimental data processing of closed-bomb for propellant

In order to improve the muzzle velocity of the projectile at the limited maximum chamber pressure, the propellant with large web size is usually used in large caliber artillery. In this paper, the study of the combustion law and the interior ballistic performance analysis has been done for the charge with 19 perforated plum blossom deterred propellant, and the web size of this propellant is changing from 1.8 mm to 2.0 mm. The deterrent material was applied within the perforations and also on the surface of the propellant. The depth of deterrent layer was 20% of the web size. First of all, a closed-bomb experiment was carried out for two kinds of propellants to obtain the combustion law of the propellant under static combustion conditions. The parameters of propellant for the two kinds of propellants are shown in Table 1.

The process of the experiment is to ignite the propellants which are put into a closed bomb at a loading density of 0.35 kg/m^3, and record the change process of pressure and time (*P-T*) curve during burning. The relative combustion amount of propellant can be obtained at different times from the *P-T* curve, and then the change rate of burning distance can be obtained from the relative combustion amount and the geometric parameters of propellant. The burning rate of propellant u can be got by using the change rate of burning distance.

The relationship between burning rate and pressure is obtained by using the method of numerical fitting. At present, the exponential burning rate law is usually used to characterize the burning rate of propellant, the expression is as follows

$$u = u_1 p^n \tag{1}$$

In the formula, u_1 is the coefficient of burning rate, n is the exponent of burning rate, p is chamber pressure (Pa). Table 2 is the experiment results of the burning rate which was been fitted in 10%–70% of maximum pressure.

According to the burning rate of two kinds of propellants in Table 2, the contrast curve of burning rate for two kinds of propellants under the same chamber pressure is calculated and shown in Fig. 1, and the relative coefficient of burning rate for two kinds of propellants k_1 is given.

Table 2
Experiment results of burning rate for two kinds of propellant.

Propellant	Burning rate $u = u_1 p^n$ (m.s^{-1}Pa^{-n})	
	u_1	n
A deterred propellant-with 19perf	1.185×10^{-11}	1.2208
B deterred propellant-with 19perf	4.510×10^{-8}	0.8013

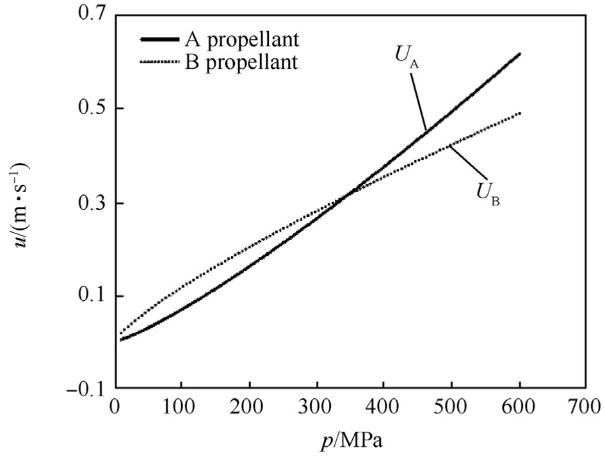

Fig. 1. Curves of burning rate for two kinds propellants.

$$k_1 = u_B / u_A \tag{2}$$

u_A, $u_B$are the burning rate of the propellant A and B at different pressures as formula (3), and show in Fig. 1. Fig. 2 shows the curve of $k_1$which obtains form curve A dividing by curve B in Fig. 1.

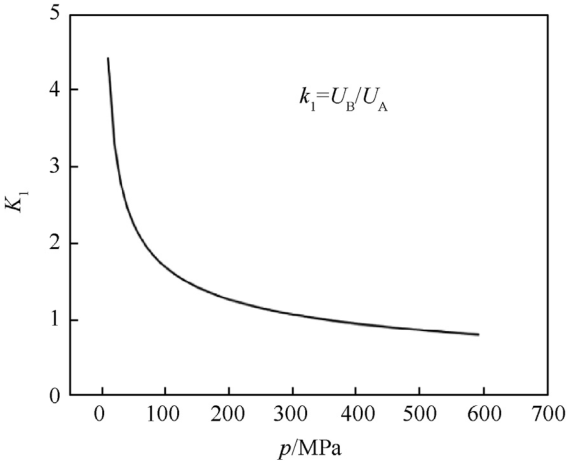

Fig. 2. Curve of relative coefficient of burning rate for two kinds propellants.

Table 1
Geometric parameters of two kinds of propellants.

Deterred propellant	Number of perf	Web size/mm	Stick length/mm	Internal diameter of grain perforation/mm	Density/(kg·m^{-3})
A propellant	19	1.95	13.55	0.36	1674.0
B propellant	19	1.83	13.41	0.35	1600.0