Study on the burning of the modified single base gun propellant

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Abstract

The modified single base gun propellant (MSBP) was prepared from single base propellant grain by impregnation with blasting oil, followed by deterring with deterrent in water medium. The combustion performance of this propellant was investigated by means of closed-bomb, interior ballistic and barrel erosion test. The interior ballistic property of this propellant after accelerated aging at high temperature was researched, too. Compared with the single base gun propellant, the MSBP burns more progressively and the value of \( P_r \) increases from 0.035 to 0.445. The interior ballistic performance for this propellant charge is improved obviously. The muzzle velocity increases by 5.0% from 886.6 m/s to 931.3 m/s. The MSBP has the characteristic of low temperature sensitivity and the barrel erosion of this propellant decreases by 16.6% at least. The interior ballistic performance of the MSBP has slightly changes after long-term storage. The MSBP has the advantages of higher muzzle velocity, higher combustion progressivity, low temperature sensitivity, low erosion and it can be satisfied with the actual storage demand.

1. Introduction

The so called "extruded impregnated" EI-propellant were made successfully and applied widely to the secondary-caliber and the small-caliber artillery to overcome the drawbacks mentioned above obviously in Switzerland in the 1990s [1-3]. This propellant is produced from extruded one-, seven- or nineteen-perforated single base propellant grains by impregnation with blasting oil, followed by deterring with a polymer. This propellant can solve the drawbacks, such as the limiting by the restricted energy content or by the grain geometry, the reduction of shelf life by diffusion of some components, or the excessive gun barrel wear [1-4].

The modified single base gun propellant, which is similar to EI-propellant, has been conducted in China recent years. In this paper, the combustion performance of this modified single base gun propellant, which is part of these efforts, is reported.

2. Propellant sample

The sample, which labeled as MSBP, was home-made. It was of EI-type (extruded impregnated), and produced from the single base gun propellant grain by impregnation with blasting oil, followed by deterring with deterrent. The blasting oil was nitroglycerine (which is called NG in the following), and the deterrent was polymer esters (which is produced by ourselves and called NA in the following).
The concentration profiles of NG and NA in MSBP are studied by Fourier Transform Infrared Microspectroscopy and are given in Figure 1. It can be seen that the curve of NG concentration is just like a parabola along the radius and in the near surface of propellant the NA concentration decreases exponentially from the surface inwards.

![Figure 1](image)

**Figure 1.** Concentration profiles of NG and NA in MSBP propellant

### 3. Closed-bomb test

MSBP and the single base gun propellant (which is named blank for comparison in the following) were put into the closed-bomb and ignited by an igniter. The sample then started to burn and pressure was built up. The pressure \((p)\) – time \((t)\) data in the bomb were recorded by a pressure gauge and saved in a computer. The \(p-t\) curve is obtained and given in Figure 2. According to literature [5], the values of \(L\) and \(B\) are got from the value of \(p\) and \(t\). Then, the \(L-B\) curve is obtained and given in Figure 2, too. Next, \(Pr\), which reflected the progressivity of a real gun propellant, can be calculated based on the values of \(L\) and \(B\). The values of \(Pr\) for the two propellants are listed in Table 1.

![Figure 2](image)

**Figure 2.** \(p-t\) Curves (left) and \(L-B\) curves (right) of two propellants

<table>
<thead>
<tr>
<th>Sample</th>
<th>(L_s) (MPa(^{-1})·s(^{-1}))</th>
<th>(B_s)</th>
<th>(L_s\times B_s) (MPa(^{-1})·s(^{-1}))</th>
<th>(L_{0.1}) (MPa(^{-1})·s(^{-1}))</th>
<th>(L_{0.3}) (MPa(^{-1})·s(^{-1}))</th>
<th>(L_{0.1}+L_{0.3}) (MPa(^{-1})·s(^{-1}))</th>
<th>(Pr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>blank</td>
<td>4.048</td>
<td>0.053</td>
<td>0.215</td>
<td>2.793</td>
<td>3.286</td>
<td>6.079</td>
<td>0.035</td>
</tr>
<tr>
<td>MSBP</td>
<td>2.805</td>
<td>0.605</td>
<td>1.697</td>
<td>1.412</td>
<td>2.400</td>
<td>3.812</td>
<td>0.445</td>
</tr>
</tbody>
</table>

From Figure 2, compared with the blank, the burning of MSBP is slower in the initial process and the time to reach the maximum pressure is extended. The \(L\) value of MSBP is less than that of the blank at the earlier burning stage, especially when the \(B\) value is less than 0.4. With the progress of the burning, the \(L\) value of MSBP exceeds that of the blank. From Table 1, the value of \(Pr\) is become bigger significantly, from blank’s 0.035 to MSBP’s 0.445, because the value of \(L_s\times B_s\) increases and the value of \(L_{0.1}+L_{0.3}\) decreases.

### 4. 30mm Gun interior ballistic test
MSBP and blank were tested in a 30mm gun. The cartridge contained a DD-2 electronic igniter, an ignition enhancement with 2g BP, and a projectile with copper band. Test temperatures were -40°C, 20°C and 50°C, respectively. During the firing test, the maximum pressure (Pm) was recorded by a copper cylinder, and the muzzle velocity (Vg) was calculated by the distance and the touching time interval of the bullet between two electromagnetic targets.

The results of MSBP and blank by 30mm gun interior ballistic at three temperatures are listed in Table 2. Curves of Pm-T and Vg-T in MSBP and blank in Figure 3 are obtained when the temperature is taken as the horizontal axis and the maximum pressure or the muzzle velocity as the longitudinal axis.

### Table 2. Results of interior ballistic experiment in 30mm gun

<table>
<thead>
<tr>
<th>Sample</th>
<th>Charge mass (g)</th>
<th>Temperature (°C)</th>
<th>Maximum pressure Pm (MPa)</th>
<th>Muzzle velocity Vg (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>blank</td>
<td>96</td>
<td>-40</td>
<td>275.4</td>
<td>840.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>307.3</td>
<td>886.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50</td>
<td>318.8</td>
<td>905.7</td>
</tr>
<tr>
<td>MSBP</td>
<td>100</td>
<td>-40</td>
<td>289.6</td>
<td>906.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>308.7</td>
<td>931.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50</td>
<td>310.2</td>
<td>940.7</td>
</tr>
</tbody>
</table>

Note: maximum pressure and muzzle velocity was averaged by fifteen times.

From Table 2, the results of the experiments show that keeping the maximum chamber pressure almost constant, the muzzle velocity of MSBP increases by 5.0% from 886.6m/s to 931.3m/s at normal temperature. From the results given in Figure2, it is evident that the change of the maximum pressure and the muzzle velocity of blank following the temperature are bigger than that of MSBP. This allows the performance potential given by the limits of the weapon system to be fully exploited — the excellent performance is obtainable at service temperature.

### 5. Barrel erosion test

The barrel erosion was characterized by erosion tube test. Erosion quantity means the reduced quantity of the erosion tube specimen. As the erosion degree of the erosion tube was related to the gun powder gas pressure, this paper would try best to test under the same pressure.

The erosion property of the blank and MSBP is demonstrated in Table 3.

### Table 3. Results of erosion of two propellants

<table>
<thead>
<tr>
<th>Sample</th>
<th>Charge mass (g)</th>
<th>Amount of erosion (g)</th>
<th>Average pressure (MPa)</th>
<th>Heat of explosion (J/g)</th>
<th>Force (J/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>blank</td>
<td>11.0580</td>
<td>0.7436</td>
<td>291.8</td>
<td>3761</td>
<td>1011</td>
</tr>
<tr>
<td>MSBP</td>
<td>11.0591</td>
<td>0.6201</td>
<td>291.6</td>
<td>3993</td>
<td>1055</td>
</tr>
</tbody>
</table>
Although the heat of explosion and force of MSBP are larger than those of the blank, the barrel erosion of MSBP decreases 16.6% than that of the blank at least under the same pressure.

6. Long-term storage test

MSBP was storage 130 days under the conditions of grinding mouth flask sealed at the temperature of \((70 \pm 2) ^\circ C\). According to Arrhenius equation, this equals to 20 years at least at room temperature.

The results of interior ballistic test of the MSBP propellant before and after long-term storage are shown as Table 4.

Table 4. Interior ballistic of MSBP propellants before and after long-term storage

<table>
<thead>
<tr>
<th>Sample</th>
<th>Charge mass (g)</th>
<th>Maximum pressure (P_m) (MPa)</th>
<th>(\Delta P_m) (MPa)</th>
<th>Muzzle velocity (V_g) (m/s)</th>
<th>(\Delta V_g) (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>before long-term storage</td>
<td>100</td>
<td>308.7</td>
<td>7.4</td>
<td>931.3</td>
<td>8.7</td>
</tr>
<tr>
<td>after long-term storage</td>
<td>100</td>
<td>305.3</td>
<td>7.5</td>
<td>930.1</td>
<td>7.8</td>
</tr>
</tbody>
</table>

Note: maximum pressure and muzzle velocity was averaged by fifteen times; the temperature is 20\(^\circ\)C.

In Table 4, there has not significantly change in the maximum pressure and muzzle velocity. So, the MSBP propellant has a good ballistic stability and can be stored at room temperature for more than 20 years.

7. Conclusions

Compared with blank, the value of \(Pr\) of MSBP increases from 0.035 to 0.445. The modified single base gun propellant burns more progressively.

In the interior ballistic test, compared with blank, the muzzle velocity of MSBP increases by 5.0% from 886.6 m/s to 931.3 m/s accompanied by the increase of charge mass. At the same time, the muzzle velocity of MSBP increases too no matter at the low and high temperature. The change of the maximum pressure and the muzzle velocity of MSBP following the temperature are smaller than that of blank.

In the barrel erosion test, the barrel erosion of MSBP decreases by 16.6% at least.

After long-term storage, there has not significantly change in the maximum pressure and muzzle velocity. The MSBP propellant has a good ballistic stability and can be stored at room temperature for more than 20 years.

So, the modified single base gun propellant has the advantages of higher combustion progressivity, higher muzzle velocity, low erosion and the low temperature sensitivity. And it can be satisfied with the actual storage demand.

References


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