Influence of Isopropyl Nitrate on Combustion Characteristics of Triple-base Propellant

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***Abstract*—In order to study the influence of Isopropyl Nitrate on combustion characteristics of triple-base propellant, the combustion of triple-base propellant was tested with closed bomb. Combustion characteristic parameters including maximum pressure, combustion time, gas generated brisance, pressure impulse, the percentage of gunpowder burned out, impetus and covolume were obtained by analyzing pressure-time curves. And law of combustion rate was calculated. It is shown that the combustion rate is slower, combustion time is longer, combustion rate coefficient is lower and pressure index is higher.**

Keywords-combustion; closed bomb; isopropyl nitrate; propellant

I. INTRODUCTION

Because of the limits of the characteristics of isopropyl nitrate and the processing technology, isopropyl nitrate can inevitably leak into the ammunition and around the environment in the process of storage. The feature of isopropyl nitrate is easily volatile, flammable, explosive, and strong solubility. The combustion performance of propellants can be influenced by isopropyl nitrate. In order to study the influence of Isopropyl Nitrate on combustion characteristics of triple-base propellant, closed bomb (differential method) [1] is used to test the performance of triple-base propellant combustion. The parameters of combustion properties are calculated in order to determine the performance of triple-base propellant combustion.

II. TESTING PART

A. *Testing Device*

Closed bomb is a constant volume, gas closed, high pressure resistant container. Figure 1 is a schematic diagram of the structure of closed bomb [2].

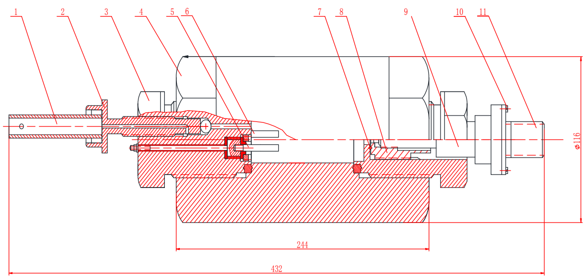

Figure 1. Schematic of the closed bomb test apparatus

1-ehaust pipe; 2-exhaust bolt; 3-igniter plug; 4-noumenon; 5-fire-guiding connecting rod; 6-fire-guiding pillar; 7-washer;8-pressure sensor joint; 9-manometry plug; 10-screw; 11-connector socket

B. *Sample Preparation and Dose Calculation*

Test sample is single base propellant. Igniter gunpowder is nitrocellulose. The calculation formula of the igniter gunpowder amount [2] is:

$$m_{ig} = V_0\left(1-\Delta/\rho\right)p_{ig}/f_{ig} \qquad (1)$$

Where: mig is the amount of igniter gunpowder (g); V0 is closed bomb volume (106.1mL); Δ is charge density (g•cm-3); ρ is the density of igniter gunpowder (1.6g•cm-3); pig is ignition pressure (10MPa); fig is gunpowder force of igniter gunpowder (882J•g-1).

The amount of propellant is calculated as:

$$m = \Delta\left(V_0 - m_{ig}\alpha_{ig}\right) \qquad (2)$$

Where: m is propellant amount (g); αig is the covolume of igniter gunpowder (1cm3•g-1).

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Charge density take Δ1=0.10g•cm-3 and Δ2=0.16g•cm-3, the amount of igniter gunpowder and sample are mig1=1.13g, m1=10.50g; mig2=1.08g, m2=16.80g.

III. Test Result

C. Combustion Test

The P-t curves and dP/dt curves of Δ2 are shown in Figure 2 and 3. The corresponding parameters including maximum combustion pressure and time are calculated through the test curves, as shown in Table I.

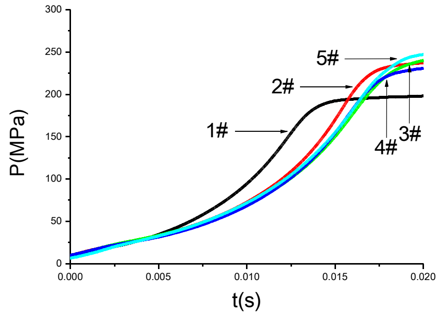

Figure 2. P-t curves of Δ_2

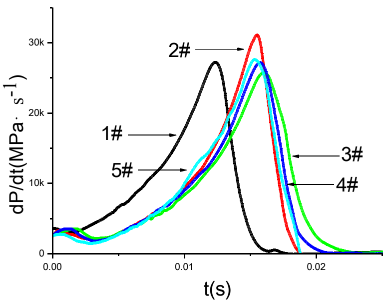

Figure 3. dP / dt-t curve of Δ_2

TABLE I. Maximun Pressure and Combustion Time of Samples

	Δ_1		Δ_2	
	P_m/MPa	*t*/ms	P_m/MPa	*t*/ms
1#	80.72	19.33	165.78	16.50
2#	91.80	24.10	167.55	17.07
3#	92.35	25.10	169.31	19.40
4#	93.02	25.15	165.89	19.37
5#	92.98	23.83	168.97	17.33

Note: Pm is maximum pressure, t is combustion time.

After adding isopropyl nitrate, maximum pressure increases because of the combustion of isopropyl nitrate. Combustion time of triple-base propellant with isopropyl nitrate becomes longer.

D. Gunpowder Force and Covolume

Covolume and gunpowder propellant force are important parameters in the ballistic performance, which are calculated [3] as follows:

$$\alpha = \frac{P_{m2}/\Delta_2 - P_{m1}/\Delta_1}{P_{m2} - P_{m1}} \quad (3)$$

$$f = \frac{P_{m2}}{\Delta_2} - \alpha \cdot P_{m2} \quad (4)$$

Where: f is force powder (J•g-1); α is covolume; Pm1 is the average maximum pressure corresponding to Δ1; Pm2 is the average maximum pressure corresponding to Δ2.

The test results in Table I are calculated through the formula (3) and (4). The covolume and gunpowder force of the measured propellant are showed in table II.

TABLE II. Impetus and Covolume of Samples

	1#	2#	3#	4#	5#
$f/(J\cdot g^{-1})$	596.197	759.289	769.875	776.123	783.460
$\alpha/(cm^3\cdot g^{-1})$	2.719	1.838	1.769	1.703	1.679

After adding isopropyl nitrate, the impetus increases because of the combustion of isopropyl nitrate. The covolume reduces because isopropyl nitrate burns and creates gases.

E. Combustion Rate Laws

Gunpowder combustion is a very complex physical and chemical process, factors that affect the speed of burning gunpowder are too much, and the combustion rate of gunpowder cannot be calculated accurately with theoretical method. Usually the gunpowder combustion rate is measured by test method. In the closed bomb test, for given gunpowder, under certain initial temperature conditions, selecting the appropriate charge density, the P-t curves can be measured. The combustion rate laws are the relationship between combustion rate and pressure which obtained through P-t curves.

Table III is the result of combustion rate coefficient and the index of samples.

After adding isopropyl nitrate, Combustion rate coefficient is lower and pressure index becomes higher.

TABLE III. THE COMBUSTION RATE COEFFICIENT AND PRESSURE INDEX OF SAMPLES

	Δ_1		Δ_2	
	A（$m \cdot s^{-1} \cdot MPa^{-1} \times 10^{-4}$）	v	A（$m \cdot s^{-1} \cdot MPa^{-1} \times 10^{-4}$）	v
1#	8.573	0.60	6.327	0.61
2#	5.776	0.73	5.736	0.67
3#	2.162	0.89	2.276	0.84
4#	2.512	0.86	3.082	0.80
5#	2.772	0.83	3.828	0.74

IV. CONCLUSION

The closed bomb is used to test the ballistic performance of triple-base propellant. The test shows that the combustion rate is slower, combustion time is longer, combustion rate coefficient is lower and pressure index is higher.

REFERENCES

[1] GJB770A-1997 closed bomb test - differential pressure method.

[2] J.Z. Ming, “Interior Ballistics,” Beijing: Beijing Institute of Technology Press, 2004.

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