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A comparative study of combustible cartridge case materials

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ABSTRACT

Foamed combustible material based on polymer bonded RDX was fabricated using CO_2 as foaming agent. The inner structures of felted and foamed combustible materials were presented by SEM. The two materials presented different formulations and inner porous structures. The combustion behaviors of felted and foamed materials were investigated by closed vessel test. Simultaneously, the co-combustion behavior of combustible cartridge case with 7-perf consolidated propellants was also investigated. The results of closed vessel test is applicable to gun system which is made of the foamed combustible material as component.

1. Introduction

In the past, the porous combustible materials for combustible cartridge case or caseless ammunitions were fabricated by various methods, such as felt-moulding, winding or impregnation of resin in the felted combustible components, in which nitrocellulose were used as energetic ingredient [1–5]. The materials can burn out in a shortened time due to a giant internal surface area, leaving no burning residue. The material is easily ignited and misfires due to the inflammable property of nitrocellulose component when it leaves in hot gun chamber. Hence, the foamed combustible materials based on polymer bonded RDX, which present better heat resistance, were fabricated [6,7]. The foamed combustible materials have the advantages of adjustable energy content, high burn rate, improved heat resistance and low vulnerability [7–12].

In the weapon systems, the presence of combustible material complicates the interior ballistic performance, in that the combustible material differs in its combustion characteristics from the propellant. Its burning characteristics have significant effect on the interior ballistic cycle. Early attempts at investigating the combustion of the porous combustible materials in closed vessel were not entirely successful since the discrepancies of combustion behavior were noted in measured and predicted pressures in the gun chamber [8]. In fact, the dependence of combustion behavior on porous structure, sample size and loading density on combustion behavior were also noticed when a porous material was burned in a closed bomb. In addition, the material may be ignited by varied ignition pressures for different applications. Consequently, the energy output will not follow the desired way.

In this paper, a comparison of the foamed material with the felted combustible material was investigated. What's more, the effects of two kinds of cartridge case on consolidated propellants were tested by closed bomb test. The results of this study will be primarily used for the further development of combustible cartridge case. The findings may also be applicable to other applications in which the foamed combustible materials are used.

2. Experiment

The combustion properties of combustible materials in 109 ml closed vessel were tested, and the data sampling interval was 0.001 ms. Sample size was 10 × 10 × 6 mm. The output of closed vessel test data acquisition system was fed to a computer, and the pressure histories were recorded. Nitrocellulose with nitrogen content of 12.0% was used as ignition powder, of which the force constant and co-volume of ignition powder are 883 J/g and 1.0 cm^3/g, respectively.

The mass of ignition powder was calculated according to Eq.(1)

$$m_{ig} = \frac{V_0(1-\Delta)/\rho)p_{ig}}{f_{ig} + p_{ig}\alpha_{ig}} \quad (1)$$

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where V_0 is the volume of closed vessel; m_{ig} is the mass of ignition powder; Δ is the loading density; ρ is the density of sample; p_{ig} is the ignition pressure; f_{ig} is the force constant of ignition powder; α is the co-volume of ignition powder.

The mass of tested sample, m, is calculated according to Eq.(2)

$$m = (V_0 - m_{ig}\alpha_{ig}) \tag{2}$$

3. Results and discussion

3.1. Inner structures

The two types of combustible materials, i.e. felted combustible cartridge case material and foamed combustible material were observed by SEM. Felted combustible cartridge case material was felted and moulded from a mixture of nitrocellulose fibers, cellulose fibers and binder. The nitrocellulose content is 62%, and the density of the material is 1.0 g/cm^3. The foamed combustible components were blended, kneaded, moulded and dried by traditional method. The dried materials were placed in a high pressure vessel, and CO2 in the vessel was pumped to 15 MPa. After the sample was exposed in SC-CO2 at 50 °C for 10 h, the pressure was quenched rapidly to atmospheric pressure. The details of foaming equipment was described in Ref. [6]. RDX content of the formulation is 70% in weight, and the density of the foamed sample is 1.34 g/cm3. The density of sample before foaming is 1.61 g/cm3. Hence, the relative densities of sample before and after foaming are 0.83, or the expansion ratio is 1.2.

Different inner structures were obtained using two different methods. The inner structures were observed by scanning electron microscope (SEM). Fig. 1 and Fig. 2 show the inner structures of the felted and foamed materials. As shown in the Fig. 1, the felted case is composed of fibers which were piled up and bonded. The average diameter of fibers was about 20 μm. In Fig. 2, the cross section of foamed sample presents a micro foamed structure, which is composed of RDX particles and micro pores with diameter < 10 μm.

3.2. Combustion characteristics of felted and micro foamed combustible materials

The burning behaviors of combustible materials are influenced by the formulations as well as the inner structure. A comparison of pressure histories, dp/dt curves and L-B curves of felted and foamed samples are shown in Fig. 3, Fig. 4 and Fig. 5, respectively. The initial temperature of tested samples was 25 °C. Table 1 presents the maximum pressure (p_m), burning time (t_k), peaks of dp/dt-t curves, maximum dynamic vivacity and corresponding value of B.

Obvious differences in combustion behavior were observed from the profiles of pressure histories and dp/dt-t curves in Figs. 3 and 4. The maximum pressure of foamed propellant is higher than

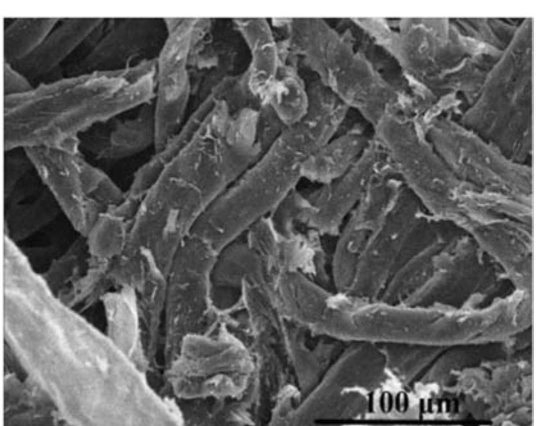

Fig. 1. SEM micrograph of felted combustible material.

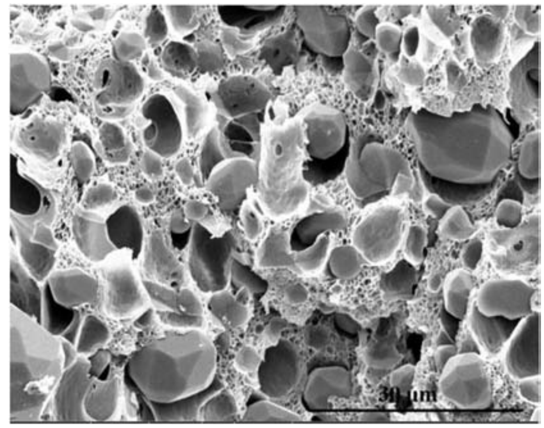

Fig. 2. SEM micrograph of foamed combustible materials.

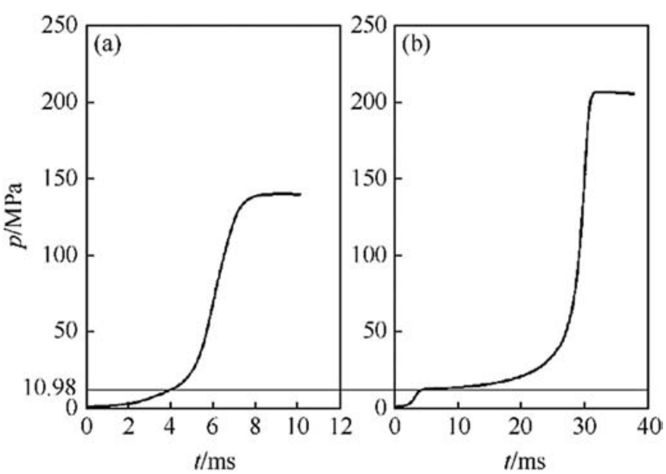

Fig. 3. *p*-*t* curves of (a) felted and (b) foamed combustibles materials.

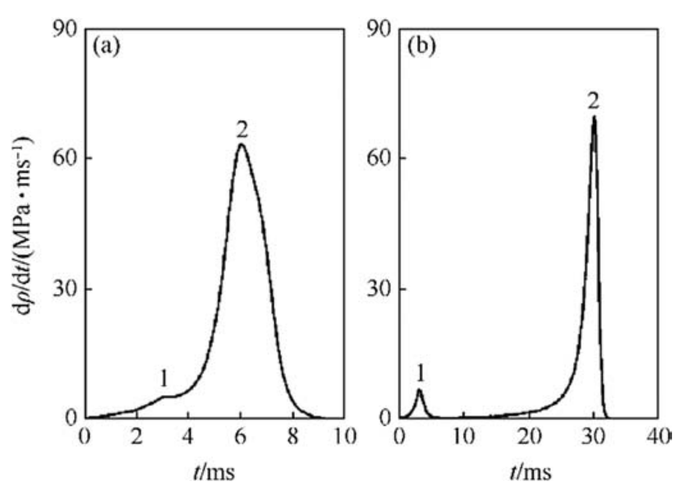

Fig. 4. dp/dt-t curves of (a) felted and (b) foamed combustible materials.

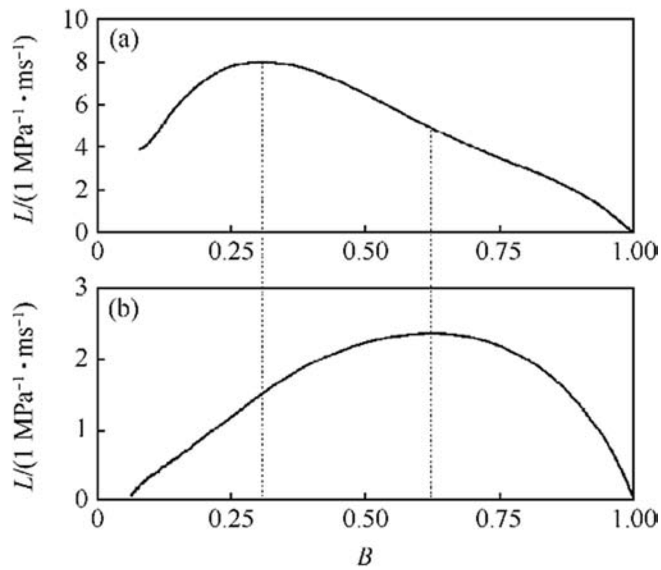

Fig. 5. *L-B* curves of (a) felted and (b) foamed combustible materials.

that of the felted one under the same loading, thus indicating that the foamed material contains more energy. Simultaneously, the felted sample got ignited due to its inflammability before the ignition powder burned out. Hence, the pressure increased smoothly from atmospheric pressure to pm. Since the foamed material was hard to ignite, the pressure history of foamed sample contained an initial pressure rise of ignition powder combustion and the pressure rise of tested sample. The pressure increased slowly at the initial burning period and started to rise rapidly when t was about 25 ms. Compared with felted sample, dp/dt value of foamed sample increased to peak 2 after dp/dt value dropped to zero.

Fig. 5 shows L-B curves of felted and foamed combustible materials. As shown in Fig. 5, the vivacity of felted sample is higher than that of foamed sample. Since the felted sample was easy to ignite and the flame penetrated in the felted sample in ignition, the burning area was giant at initial period. Therefore, the maximum vivacity of felted sample was obtained at lower relative pressure ($B = 0.31$). Since the foamed sample was hard to get ignited and penetrated, its initial combustion area was small, and the maximum vivacity was obtained during later combustion ($B = 0.62$). The significant difference of dynamic vivacity between the felted and foamed materials in the closed vessel tests indicates that the two case types have different burning mechanisms.

3.3. Co-combustion behavior

The double-base oblate spherical propellants were foamed using CO_2 as the blowing agent by a batch foaming process. The consolidated propellants were molded using energetic adhesive. To

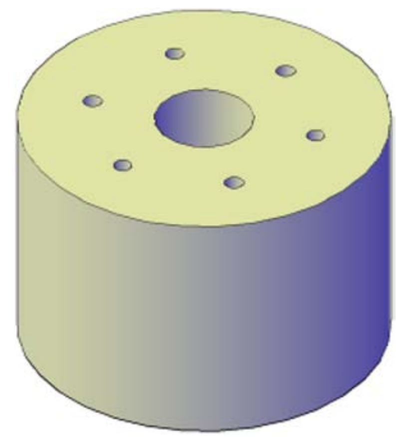

Fig. 6. Schematic diagram of molded 7-perf propellant.

achieve the high burning progressivity of consolidated propellants, a propellant geometry with 7-perforation structure was used (see Fig. 6). More detail about consolidated propellants is shown in Ref. [13].

As can be seen from Fig. 7, the curve shape of consolidated propellant is similar to that of 7-perforation propellant with lower dynamic vivacity value. The dynamic vivacity of consolidated propellant starts to fall slowly for $B = 0.5$, and *L-B* curve is flat before $B = 0.5$.

Figs. 8 and 9 show L-B curves of felted and foamed combustible materials with consolidated propellants, respectively. The mass ratio of cartridge case and 7-perf propellant is 1:1, and the loading density is 0.2 g/cm3. As shown in Fig. 8, the maximum dynamic vivacity of felted case + 7-perf propellant is higher than that of the

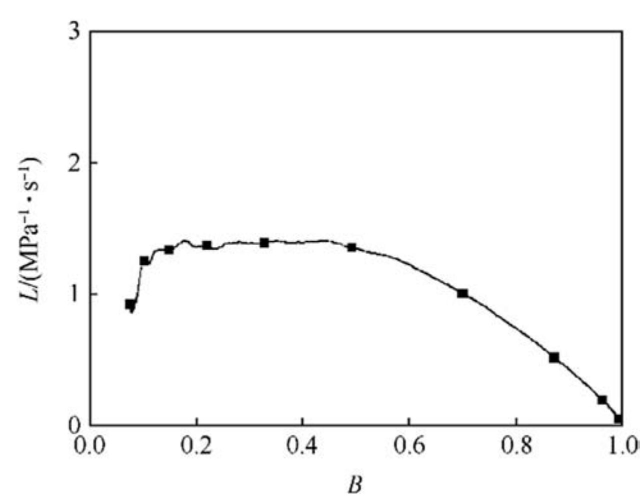

Fig. 7. *L-B* curve of consolidated propellant.

Table 1
Characteristic points of *p-t* curves, d*p*/d*t*-*t* curves and *L-B* curves.

Sample	*p-t*		d*p*/d*t*-*t*				*L-B*	
	p_m/ MPa	t_k/ ms	$(dp/dt)_1$ /MPa/ms	t_1 /ms	$(dp/dt)_m$ /MPa/ms	t_m /ms	L_m /1/(MPa ms)	B_m
Felted	140.04	9.13	5.08	3.12	63.23	6.03	7.97	0.31
Foamed	206.42	32.31	6.73	3.16	69.73	30.04	2.36	0.62

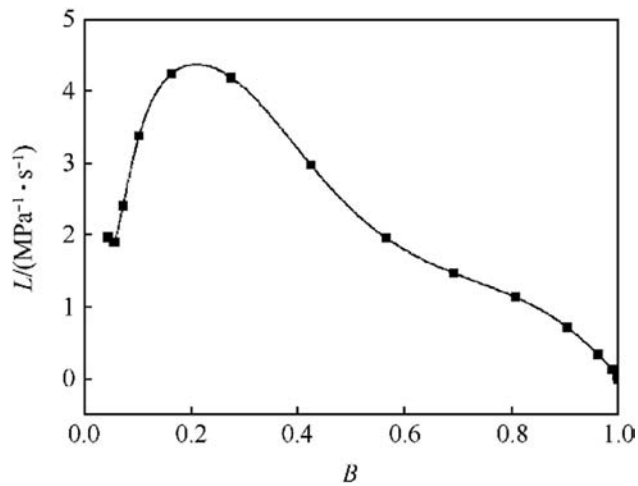

Fig. 8. *L-B* curve of consolidated propellants with felted cartridge case.

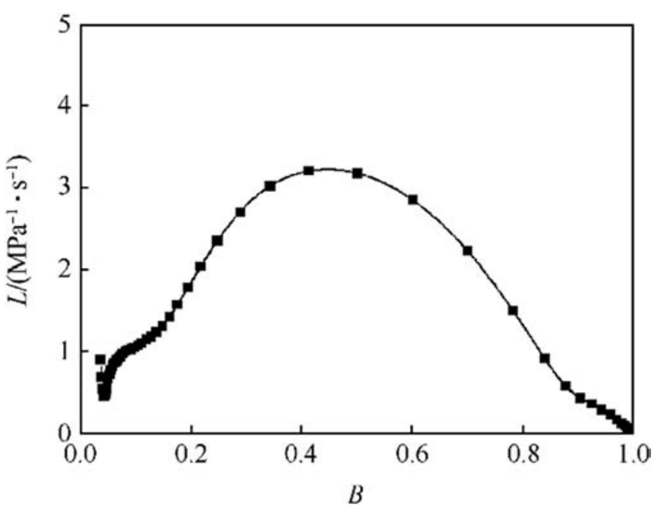

Fig. 9. *L-B* curve of consolidated propellants with foamed cartridge case.

foamed one + 7-perf propellant. The maximum vivacity in Fig. 8 was obtained at lower relative pressure ($B = 0.21$). Since the foamed sample was hard to get ignited and penetrated, the initial combustion area was small and the maximum vivacity was obtained during later combustion ($B = 0.45$). Figs. 8 and 9 indicate that the co-combustion of foamed case and 7-perf propellant shows better combustion progressivity and smaller initial burning area.

4. Conclusions

The new type of combustible material presents a significant difference in inner structure and burning characteristics in comparison with the traditional felted case material. The new combustible material has good combustible behavior, including heat resistance (long ignition delay time), burning progressivity and consistency under different conditions of loading. This material has great potential for application in combustible cartridge case, modular charge in the near future.

References

[1] Shedge MT, Patel CH, Tadkod SK, et al. Polyvinyl acetate resin as a binder effecting mechanical and combustion properties of combustible cartridge case formulations. Def Sci J 2008;58(3):390–7.

[2] K. Johnson, S. Levine, M. Nusbaum, et al. Duplex combustible cartridge case[P]. U.S. Patent: 3,823,668; 1974. 7–16.

[3] K. O. Jacobsen, E. Troen. Combustible cartridge casings and method for making same[P]. U.S. Patent: 3,977,325; 1976. 8–31.

[4] W. S. Baker. Method of making combustible cartridge cases[P]. U.S. Patent: 3,282,146; 1966. 11-1.

[5] F. J. Zimmerman. The development of small caliber combustible cartridge case ammunition[A], In: ICRPG/AIAA 3rd Solid Propulsion Conference; 1968.

[6] Yang W, Li Y, Ying S. An investigation of the preparation and performance of microcellular combustible material. Central Eur J Energ Mater 2014;11(2):257–69.

[7] Yang W, Ying S. Burning characteristics of microcellular combustible ordnance materials. Propellants, Explos Pyrotech 2016;41(1):136–41.

[8] Yang W, Li Y, Ying S. Burning characteristics of microcellular combustible objects fabricated by a confined foaming process. Propellants, Explos Pyrotech 2015;40(1):27–32.

[9] Yang W, Li Y, Ying S. Burning characteristics of microcellular combustible objects. Def Technol 2014;10(2):106–10.

[10] Yang W, Li Y, Ying S. Fabrication of graded porous and skin-core structure RDX-based propellants via supercritical CO2 concentration profile. J Energ Mater 2015;33(2):91–101.

[11] Yang W, Ying S. Microcellular foaming of CA/RDX composites in a batch supercritical CO2 process. Chin J Explos propellants 2016;39(2):22–6.

[12] Robbins FW, Colburn JW, Zoltani CK. Combustible cartridge cases: current status and future prospects[R]. Aberdeen: ARMY BALLISTIC RESEARCH LAB ABERDEEN PROVING GROUND MD; 1992.

[13] Li Y, Yang W, Ying S. Burning characteristics of consolidated gun propellants. Propellants, Explos Pyrotech 2015;40(1):33–8.