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The thermal behaviors and safety characteristics of composition B explosive

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Abstract

The explosive composition B is an old explosive. It was developed by Britishers during World War I and World War II. It was also used by the United States in World War II. The differential scanning calorimetry (DSC) curves of mixtures that of the explosive composition B show a significant change in recent manufacture batches. In order to understand the effect of the mixtures on DSC data, the thermal behaviors and safety characteristics were reevaluated in this work.

Keywords: Composition B explosive; RDX; TNT; Melt casting; Press casting

1. Introduction

There are two major methods in dealing with casting explosives in a shell. One is melt casting and the other one is press casting. Melt-cast loading of explosives in a shell is more economical and suitable for mass production, such as explosive composition B, which is composed of RDX (cyclo-tri-methylene tri-nitro-amine) and TNT (tri-nitro toluene). It is normally performed by heating the explosive composition B to a temperature exceeding the liquidized temperature of TNT, and then pouring the explosive composition B into a shell. A solidification process, by controlling temperature to room temperature, is needed in order to obtain a good casting explosive in the shell. Thermal analysis is a useful technique for the characterization of explosives. Differential thermal analysis (DTA) and differential scanning calorimetry (DSC) yield a great deal of information about the thermal properties of explosives, e.g., phase transformation (involving absorption or release of heat), melting point, and the compatibility of explosive. Thermogravimetric analysis (TGA) data can determine the thermal stability and decomposition temperatures, it is a complementary technique of DTA/DSC. Explosive composition B is a mixture of RDX, TNT and a small amount of wax in this work. We found that the DSC curves of mixtures based on extractions from explosive composition B have changed in recent manufacture lots. Therefore, it is interesting to know how the presence of the different mixtures influences the thermal behaviors and safety characteristics of the explosive composition B.

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Table 1
Composition of explosive composition B for different manufacture batches

Explosives	Weight (%)		
	RDX	TNT	Wax
Old composition B	58.7	40.3	1
New composition B	60.2	38.9	0.9
MIL-C-401E	59.5 ± 2	39.5 ± 2.3	1.0 ± 0.3

2. Experimental

The compositions of explosive composition B from different manufacture lots are listed in Table 1. The mixture was extracted by acetone, and then dried to obtain the samples for DSC experiments. Perkin-Elmer 7 series thermal analysis system (TGA/DSC) were used in this work. The auto-ignition temperature, ignition temperature within 5 s and the decomposition kinetic parameters were also investigated following MIL-STD-650-T514.1, MIL-STD-650-T515.1 and dynamic TG/DSC techniques.

3. Results and discussion

DSC/TG curves of explosive composition B for different manufacture lots are shown in Fig. 1. DSC curves of explosive composition B from different manufacture lots show a sharp endothermic peak around 80°C and the endothermic heat of fusion ranged from 36 to 38 J/g. The next DSC event is the decomposition as a board exothermic peak at 235°C. These results agree with Krein's report [1]. For TG curves, mass loss started at 90°C, and the residue was 2–3 wt.%, when the temperature was above 310°C. Fig. 2 shows the DSC curves of a mixture from the extractions from different manufacture lots for explosive composition B. The old batch possess two individual endothermic peaks at 77 and 88°C, respectively, but the new batch has only appeared as an endothermic peak at 91°C in DSC curve. Although the melting temperature of mixture is low, it may play a role on the decomposition and "the sensitivity" of explosive composition B.

The decomposition kinetic parameters of explosive composition B were determined via DSC

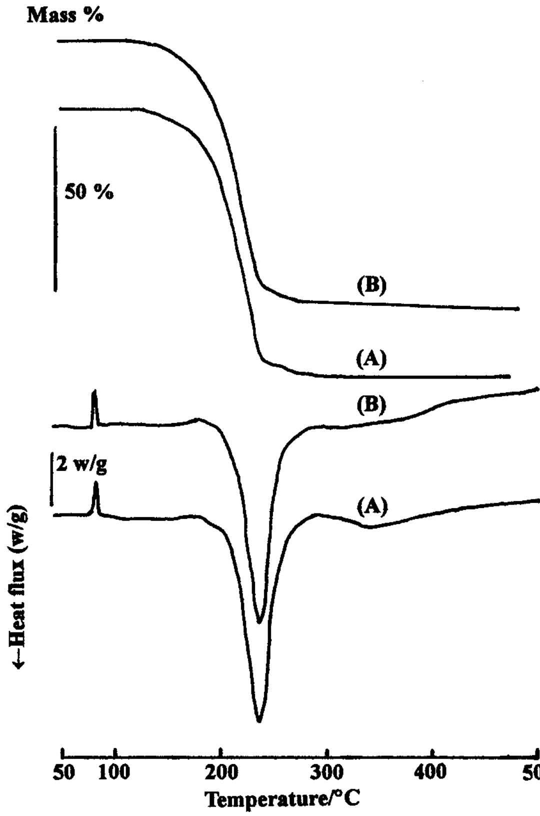

Fig. 1. DSC/TG curves of explosive composition B, with a 10°C min^{-1} heating rate, and in a nitrogen atmosphere: (A) old, (B) new.

using Kissinger's method [2]. This method is based on the equation

$$-\frac{E}{R} = \frac{\mathrm{d}\ln(\beta/T_{\mathrm{p}}^{2})}{\mathrm{d}(1/T_{\mathrm{p}})} \qquad (1)$$

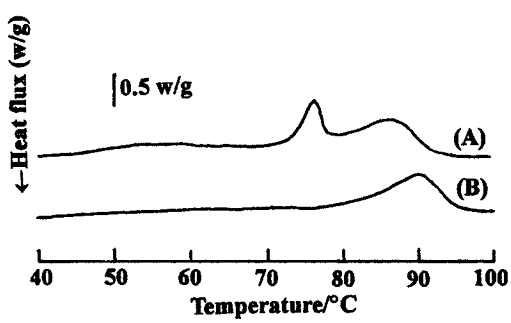

Fig. 2. DSC curves of a mixture extracted from explosive composition B, with a heating rate of 10°C min^{-1}, and in a nitrogen atmosphere: (A) old, (B) new.

Table 2
Activation energies of ignition within 5 s and the activation energies of decomposition for explosive composition B

	Old composition B	New composition B	Value in the literatures
A (s^{-1})	4.07×10^{12}	6.32×10^{13}	3.9×10^{8} for TNT (287–333°C), 5.02×10^{14} for RDX (220–248°C) [8]
Activation energy of decomposition (dynamic DSC), kJ mol^{-1}	$159 \pm 3\%$ (0.998)[a]	$156 \pm 5\%$ (0.996)[a]	163.2 for explosive composition B (MIL-C-401) [7]
Activation energy of decomposition (dynamic TG), kJ mol^{-1}	$74 \pm 3\%$ (0.997)[a]	$37.4 \pm 4\%$ (0.995)[a]	87.7 (Kissinger), 148.3 (Piloyan and Novikava) for TNT [6]
Activation energy of ignition, kJ mol^{-1}	$67 \pm 2\%$ (0.999)[a]	$66.7 \pm 3.6\%$ (0.998)[a]	34.8 (Coats and Redferm) for TNT [6]

[a] Correlation coefficient.

where β is the heating rate, and T_p the peak temperature of a DSC scan at that rate. When $\ln(\beta/T_p^2)$ is plotted against $1/T_p$, a straight line is obtained, and the activation energy is calculated from the slope $-E/R$. In the method of Ozawa [3,4] the activation energy is determined graphically from the equation

$$\log \beta + 0.4567 \frac{E}{RT} = C \tag{2}$$

The methods proposed by Ozawa have shown that the activation energy of a thermal decomposition process can be directly determined from a series of TG curves carried out at different heating rates. The activation energy of decomposition is obtained by plotting log β versus the reciprocal of the absolute temperature at an identical mass loss. The measurement of time-to-ignition is often assumed for the purpose of modeling and estimating safety. The deflagration or detonation is described by a first-order Arrhenius equation. Many energetic materials appear to obey such a law except for a region at long ignition delays [5]

$$\ln(t_{ign}) = \frac{E_a}{RT} + C \tag{3}$$

Table 2 listed the activation energy of decomposition and the activation energy of ignition within 5 s for explosive composition B. In explosive composition B, TNT was mixed with RDX and a small amount of wax, and the freezing point of TNT is 80.4°C. Therefore, the activation energies of decomposition for explosive composition B should be close to the value of pure TNT or RDX. (The apparent activation energy of TNT is 100.4 and 142.3 kJ mol^{-1} of RDX for Harries [7] investigation. The decomposition activation energy of TNT is 143.9 and 197.1 kJ mol^{-1} of RDX in Skinner's [8] studies.) The ignition properties and sensitivity of explosive composition B are listed in Table 3. New explosive composition B appears to show slightly higher sensitivity than the old batch.

4. Conclusion

The activation energy of decomposition for explosive composition B is from 35 to 170 kJ mol^{-1}. Our dynamic DSC data is close to the value of the activation energy of decomposition that is presented by Harries [7]. TNT is the major component of explosive composition B. When casting TNT or examining

Table 3
The auto-ignition temperature, ignition temperature within 5 s and sensitivity of explosive composition B

	Old composition B	New composition B
Auto-ignition temperature (°C)	224	227
Ignition temperature within 5 s (°C)	286	286
Friction sensitivity, kg (N)	128 (12.8)	120 (12)
Impact sensitivity, kg/cm (J)	15 (5×30)	10 (5×20)

explosives containing TNT, we must consider the appropriate melting point and good fluidity. In this work new explosive composition B shows slightly lower activation energy of decomposition but slightly higher sensitivity than that of old batch. The changes on the thermal behaviors and on the sensitivity of explosive composition B may be induced by adding different types of wax, and the thermal properties, the sensitivities of composition B are invaluable for the processing of explosive composition B and other solid explosives.

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