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MICROCALORIMETRIC COMPATIBILITY TESTING OF THE CONSTITUENTS OF COMBUSTIBLE MATERIALS AND CASTING COMPOSITE EXPLOSIVES

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Abstract

The method of microcalorimetric compatibility testing of the constituents of combustible materials and casting composite explosives is based on the change in power when separately measuring the different materials involved, and their mixture, during isothermal treatment. The experimental power–time curve for the mixture was compared to the hypothetical curve constructed from the results of the measurements of individual materials.

Keywords: casting composite explosives, combustible material, compatibility, hexogen, microcalorimetry, nitrocellulose-cellulose sheet

Introduction

Combustible materials, composite explosives and pyrotechnics contain polymeric materials as binding components. These polymeric materials must be compatible with the explosive materials.

All physical and chemical reactions are accompanied by heat exchange. Consequently, it is possible to analyze to compatibility of polymeric and explosive materials, and their stabilities [1–3].

It is important to make clear that during a long-term microcalorimetric compatibility test, only heat exchange effects are observed, not the effects arising from gases leaving through the explosive materials, gases which are formed during the degradation of explosive materials (they influence the deterioration of the mechanical properties, etc.).

The results of the microcalorimetric compatibility measurements of the constituent of combustible materials, nitrocellulose-cellulose (NC-C) sheet and phenol-formaldehyde resins, including: BOROFEN DL-702, BOROFEN BPF-70 and REZOFEN CS, as well as the compatibility test of casting composite explosives composed of hexogen (RDX), stabilized and recrystallized and three types of polyurethane binders are shown in this paper.

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Experimental

The microcalorimetric method enables the monitoring of very small heat flows released from the sample. The instrument has high sensitivity. It can measure a heat exchange of 0.1 μW.

A sample of one composition is exposed to constant temperature, up to 80°C, and the heat absorbed or evolved is monitored. The heat produced from the constituents of that composition, exposed to the same temperature, is also noted. A theoretical curve is drawn for the case when there is no chemical interaction between the constituents. The theoretical curve represents a linear combination of the curves of the heat flows of the constituents, multiplied by the mass ratio of the constituents.

The difference of the time integral between the experimental and theoretical curves represents the chemical interaction of that system [1].

All the experiments were performed on an LKB 2277 BIOACTIVITY MONITOR, Bromma, Sweden, a four-channel microcalorimeter, which allowed the simultaneous measurement of four samples [4].

All the samples studied and their symbols are listed in Table 1.

Samples of combustible materials were placed in stainless steel ampoules. Samples of composite explosives were placed in glass ampoules, closed with standard caps. The sample masses were always about 1.5 g, and they were conditioned for two days in a chamber at 20°C and 65% RH. Before the samples were

Table 1

A_1	nitrocellulose-cellulose sheet (NC-C, 70 mass%, NC+30 mass% C)
A_2	hexogen, stabilized (RDX)
A_3	hexogen (RDX; 2 parts of stabilized + 1 part of recrystallized)
A_4	combustible material, composition 1 (92.5 mass% A_1 + 7.5 mass% B_1)
A_5	combustible material, composition 2 (92.5 mass% A_1 + 7.5 mass% B_2)
A_6	combustible material, composition 3 (90 mass% A_1 + 10 mass% B_3)
A_7	composite explosive [5], composition 4 (77 mass% A_3 + 23 mass% B_4)
A_8	composite explosive, composition 5 (80 mass% A_3 + 20 mass% B_5)
A_9	composite explosive, composition 6 (77 mass% A_2 + 23 mass% B_5)
A_{10}	composite explosive, composition 7 (80 mass% A_3 + 20 mass% B_6)
B_1	phenol formaldehyde resin BOROFEN KL-702
B_2	phenol formaldehyde resin BOROFEN BPF-70
B_3	phenol formaldehyde resin REZOFEN CS
B_4	polyurethane binder, composition 1
B_5	polyurethane binder, composition 2
B_6	polyurethane binder, composition 3

placed in the microcalorimeter, they were exposed to the working temperature of the microcalorimeter for two hours. The reference materials were glass beads, of a total mass of 1.5 g, placed in the same type of ampoules as the samples.

Results and discussion

During all the microcalorimetric measurements (Figs 1 and 2) at the beginning of the experiments the heat effects were high, and after one day they reached steady levels. These parts of the curves are not discussed here, because they are not related to the samples [6].

The combustible materials studied were composed of nitrocellulose, cellulose, diphenylamine as a nitrocellulose stabilizer, added to the NC-C sheet, and phenol formaldehyde resin. The resins were crosslinked. The phenol rings were crosslinked with methylene groups. The free OH groups of the phenol ring can form secondary links with the OH groups of cellulose, or with the OH groups of nitrocellulose which were not nitrated. If primary chemical bonds had been formed between nitrocellulose and the resin, the curve of heat flow would have been increased or a peak would have been formed to characterize the reaction. Based on the energy of interaction, (Fig. 1) the difference of the time integrals between the experimental and theoretical curve for one composition, it is possi-

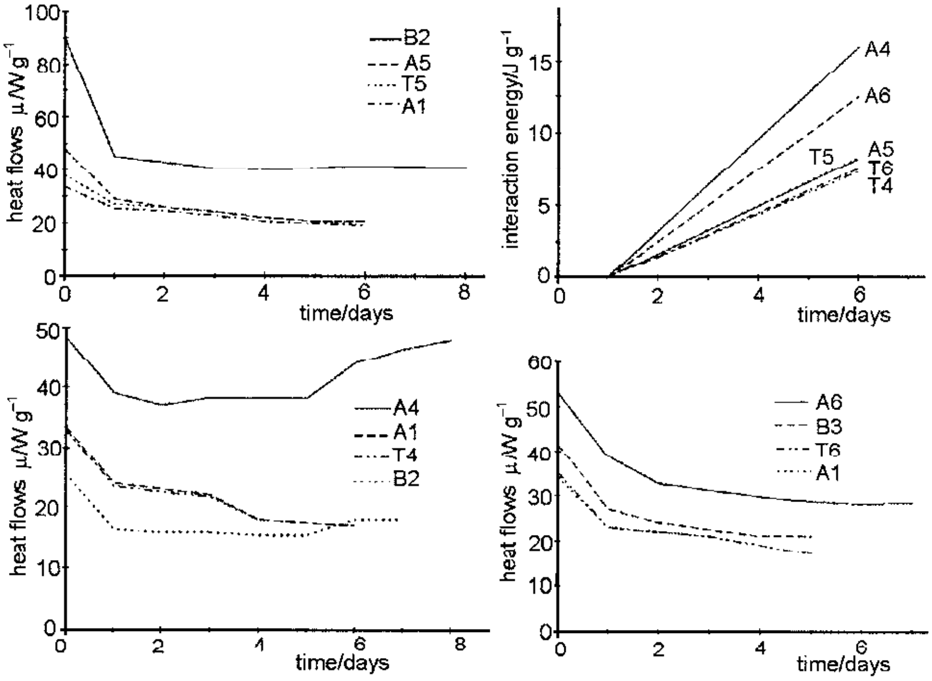

Fig. 1 Heat flows and interaction energies for combustible materials at 80°C

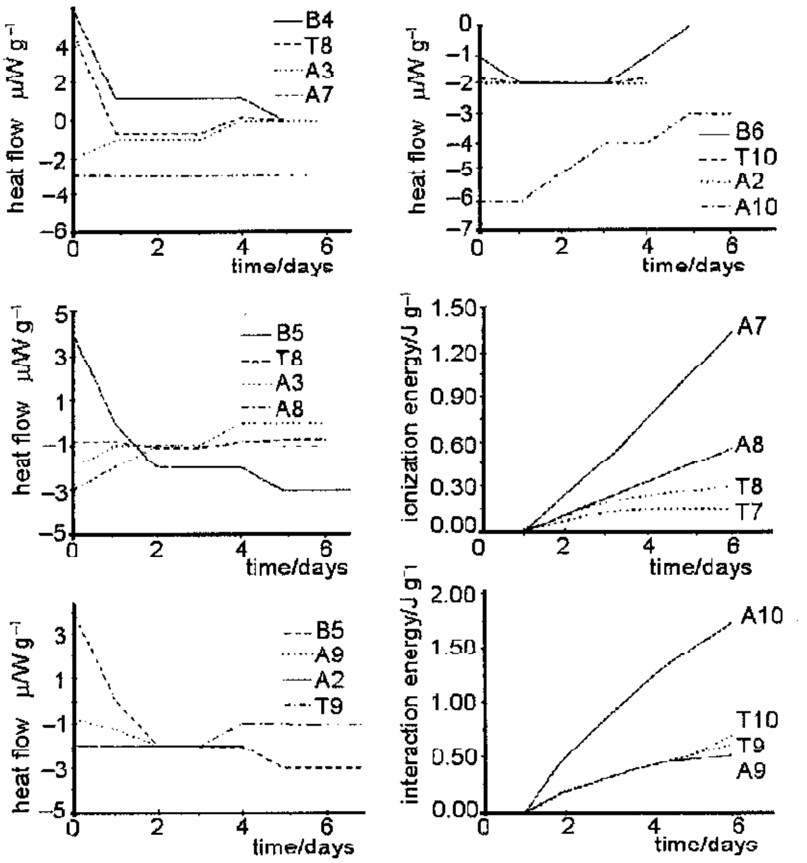

Fig. 2 Heat flows and interaction energies for casting composite explosives at 80°C

ble to conclude that the phenol formaldehyde resins, B_2 and B_3 are compatible with nitrocellulose. Experiments with composition A_4 will be continued in the future to confirm this conclusion.

The casting composite explosives were formed from RDX, stabilized, or a mixture of stabilized and recrystallized material and polyurethane binder. When stabilized RDX was used, (Fig. 2), the heat flow curve was slightly endothermic. When the stabilized and recrystallized mixture of RDX was monitored, the heat flow was so endothermic that it could be neglected, and after four days the curve merged with the baseline. The linearity of these curves with measured heat flows, indicated that these structures are very stable. The small absorption is probably the result of some physical processes in the system, which can be neglected in comparison with the absorbed heat.

During the exposure of polyurethane binder to 80°C, there were no considerable heat changes, because the binders were completely cured. In the case of casting composite explosives, secondary chemical bonds were formed between the RDX and polyurethane binders, and according to their heat flows, there were no later chemical reactions, which could influence the formation of primary bonds. This was confirmed by the low energy of chemical interaction which was less than 1.5 J g^{-1}.

Conclusions

The microcalorimetric method can be successfully used for studying the compatibility of the constituents of combustible materials and casting composite explosives. When considering compatibility, the chemical structure of every component of the material and the possible interaction between them should be included.

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