Journal of Thermal Analysis, Vol. 45 (1995) 289-296

THERMAL CHARACTERISTICS OF MIXTURES OF CYCLONITE AND NITROGLYCERINE OR DIAZIDONITRAZAPENTANE

Shenghui Li and Wenli Huang

Xian Modern Chemistry Research Institute, Xi'an 710061, Shaanxi, P. R. China

Abstract

The thermal characteristics of mixtures of cyclonite (RDX) and nitroglycerine (NG) and of RDX and diazidonitrazapentane (DIANP) were studied. The thermal decomposition processes of NG and RDX are not synchronous with those of RDX/NG mixtures. The DSC curves show two obviously exothermic peaks, one at 203°C for NG and the other at 240°C for RDX. However, there is only a single exothermic peak in the DSC curves of RDX/DIANP mixtures within certain ratio limits, due to the coincidence of the exothermic decomposition peaks for both RDX and DIANP and their mutual dissolution.

The effects of the different thermal characteristics of different explosives on the combustion performance are also discussed.

Keywords: azidonitramine, calorimetric analysis, cyclonite, nitroglycerine

Introduction

Modern war requires advanced performance weapons, and imposes higher demands on the energy, erosion and combustion performance of propellants. In the search for propellants with excellent comprehensive performance, scientists are attracted by the high nitramine explosives (such as cyclonite (RDX)) used as energetic additives. However, the nitramine propellants incorporated with nitrocellulose, nitroglycerine (NG) and RDX involve the combustion problem that the pressure exponent of the burning rate is greater than 1 in the range 30 to 150 MPa and there is an obvious turn in the curve of burning rate *vs.* pressure. These conditions limit the practical employment of the general nitramine propellants. Meanwhile, as a key technique, improvement of the combustion performance of nitramine propellants has been studied widely.

In recent years, the Xian Modern Chemistry Research Institute introduced diazidonitrazapentane (DIANP) as a plasticizer into propellants to take the place of NG, and incorporated the azidonitramine propellant with RDX. This kind of propellant has the characteristics of high energy and low erosivity. On proper incorporation, its burning rate pressure exponent is smaller than 1, and

0368–4466/95/ $ 4.00

John Wiley & Sons, Limited
Chichester

the curve of burning rate *vs.* pressure appears as a straight line. Thus, the limitation in general nitramine propellants is overcome and a technical method for improving their combustion performance has been found.

We have studied the thermal characteristics of the RDX/NG system and the RDX/DIANP system, and discuss here certain aspects of studies of the combustion mechanisms of nitramine and azidonitramine propellants, both containing RDX.

Experiment

Materials

RDX, NG and DIANP were purified materials.

Apparatus

The thermal characteristics of the mixture systems RDX/NG and RDX/DIANP were studied by means of differential scanning calorimetry (DSC) at a heating rate of 10 deg·min^{-1}.

Results and discussion

RDX/NG system

The RDX/NG mixture ratios were 100/0, 80/20, 60/40, 50/50, 40/60, 20/80 and 0/100. Their DSC curves are shown in Fig. 1. An obvious endothermic peak (205°C) is observed in the curve of pure RDX, followed by an exothermic decomposition peak (240°C). NG begins to decompose at 170°C, and its decomposition peak is at 203.3°C. The decomposition process of NG and the melting process of RDX occur in nearly same temperature range; the melting point of RDX is a little higher than the decomposition peak of NG. The two decomposition peaks are obviously different, with two exothermic decomposition peaks in the form of a saddle for the mixture RDX/NG. The decomposition of RDX and NG in the mixture is non-synchronous and heterogeneous: NG decomposes first, and RDX then begins to melt and decompose. The endothermic melting peak of RDX is offset by the exothermic decomposition peak of NG, because the two peaks are close to each other. On increase of the NG content in the RDX/NG mixture, the endothermic peak of RDX becomes smaller and the exothermic peak of NG becomes larger.

RDX/DIANP system

The ratios of the components in the RDX/DIANP mixtures were the same as those for RDX/NG. Their DSC curves are shown in Fig. 2. The temperatures of the thermal decomposition peaks are seen to be about the same. Even if the

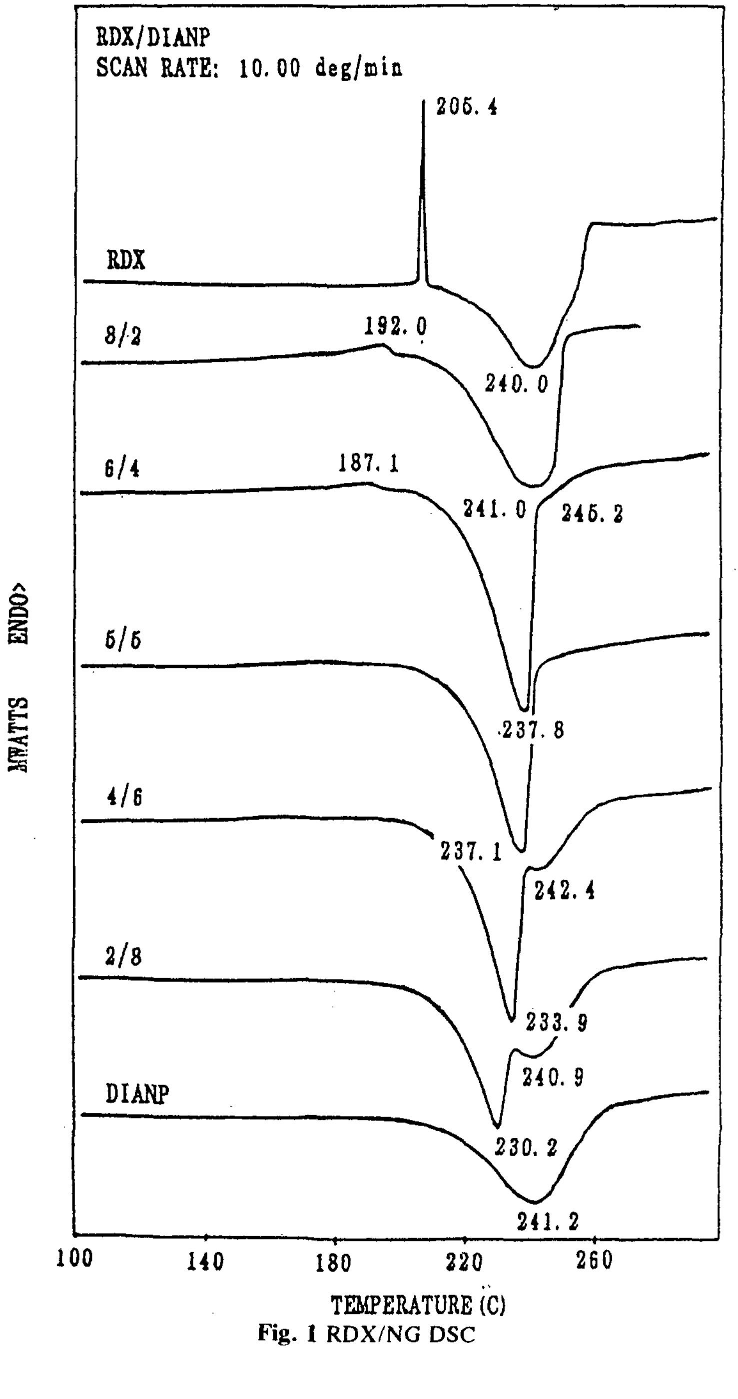

Fig. 1 RDX/NG DSC

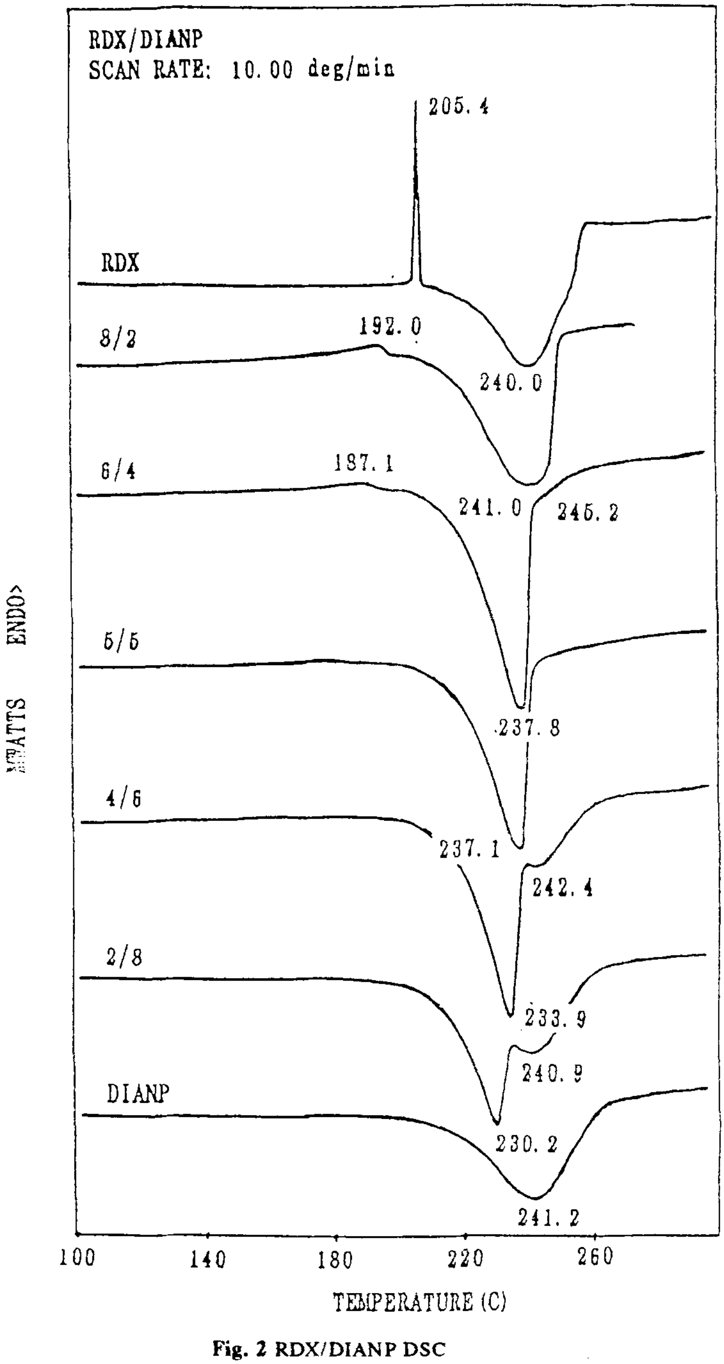

Fig. 2 RDX/DIANP DSC

content of DIANP is small, e.g. RDX/DIANP = 80/20, there is no obvious melting peak for RDX. Moreover, the melting point of the mixture shifts to lower temperature, and only a single exothermic decomposition peak appears. When the RDX/DIANP ratio is 50/50, the melting peak no longer appears and there is only a single exothermic peak. These phenomena indicate that all the RDX is dissolved in the DIANP during the heating process. The mixture becomes a homogeneous liquid, and the decomposition process for RDX and DIANP becomes synchronous in the liquid phase.

Effects of thermal characteristics of mixture systems on combustion performance of propellants

In general nitramine propellants containing NG as energetic plasticizer, the nitrocellulose and NG decompose first due to their lower decomposition temperatures. Thus, it is possible for the RDX crystals to be exposed and increased on the burning surface of the propellant, and the deflagration of RDX by heating then makes the burning surface sunken.

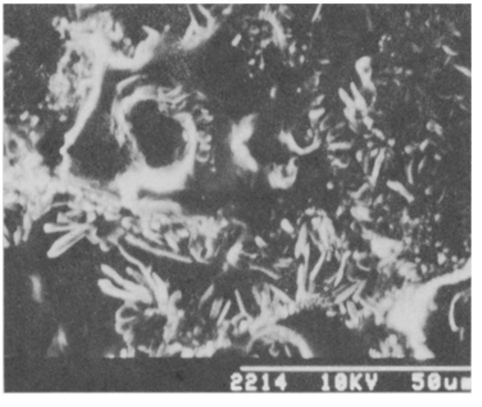

Fig. 3 GR5 Surface of interruption burning

This results in the burning surface being full of bumps and holes. Interruption of the propellant burning test and observation by scanning microscopy confirms such an analysis. Nitramine propellant GR5 consists of RDX (25% content) and NG, the latter used as an energetic plasticizer. As Fig. 3 shows, the result of interruption of the propellant burning test is that the exposed RDX crystals on the burned surface are clearly discernible, with hollows due to decomposition of the binder and "volcanic craters" due to deflagration of the RDX crystals everywhere. The area of the burning surface is actually increased, so

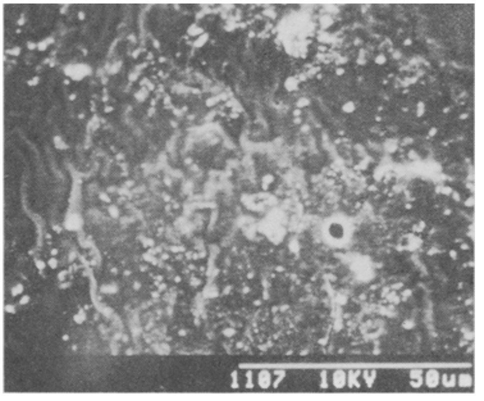

Fig. 4 DA120 Surface of interruption burning

that the apparent burning rate is increased too. Processing of the burning rate curve demonstrates that the slope is increased and the pressure exponent of the burning rate is greater than 1. On pressure increase, the convectively eroding burning reaches a dynamic equilibrium, and the pressure exponent of the burning rate again becomes smaller than 1. This is shown in Fig. 5.

In the azidonitramine propellant, which consists of RDX and DIANP, the DIANP is used as an energetic plasticizer. As RDX and DIANP are mutually soluble before their decomposition and DIANP can dissolve nitrocellulose, it is possible for the azidonitramine propellant to form a homogeneous condensed phase on the burning surface during the propellant burning. As the decomposition is synchronous on the burning surface of the homogeneous liquid phase, convectively eroding burning does not take place and the burning surface remains smooth. The results of interruption of the burning test and observation by scanning microscopy are shown in Fig. 4.

The azidonitramine propellant DA120, containing DIANP as plasticizer and with an RDX content of 25% is similar to the nitramine propellant GR5 in RDX content. However, in Fig. 4, the burned surface of the azidonitramine propellant DA120 is smooth, obvious traces of liquidized condensation can be observed and there are no exposed RDX crystals and no "volcanic craters", as shown in Fig. 3. Thus, the azidonitramine propellant will burn, displaying characteristics of a homogeneous propellant. There is no obvious turn in the curve of burning rate *vs.* pressure (shown in Fig. 5), and the pressure exponent of the burning rate is smaller than or equal to 1.

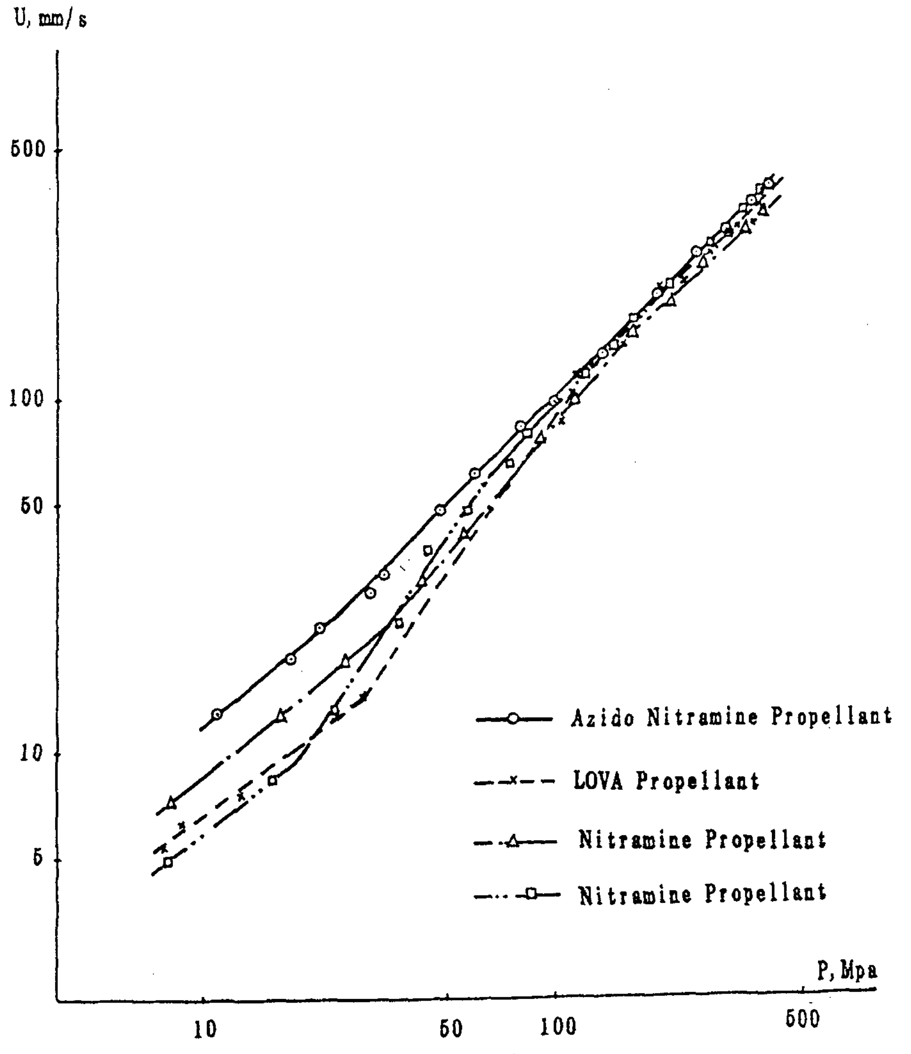

Fig. 5 U-P curves for several natramine propellants

Conclusions

RDX/NG and RDX/DIANP mixtures have thermal characteristics which affect the burning performance of general nitramine and azidonitramine propellants. Studies of the thermal characteristics of these mixtures is of great assistance towards an understanding of the combustion mechanism for propellants containing RDX.

We are extremely grateful to Prof. Hu Rongzu, Liu Ziru, Assistant Prof. Kong Yanghui, Yin Cuimei and Wu Shanxiang, who provided great help and gave much advice in connection with this study.

Zusammenfassung — Es wurden die thermischen Merkmale von Gemischen aus Cyclonit (RDX) und Nitroglyzerin (NG) sowie aus RDX und Diazidonitrazapentan (DIANP) untersucht. Die thermischen Zersetzungsprozesse von NG und RDX verlaufen nicht wie die von RDX/NG-Gemischen. Die DSC-Kurven weisen zwei eindeutige exotherme Peaks auf, einer davon bei 203°C für NG und der andere bei 240°C für RDX. Dagegen tritt in DSC-Kurven von RDX/DIANP-Gemischen innerhalb gewisser Verhältnisgrenzen wegen des Zusammenfallens der exothermen Zersetzungspeaks von RDX und DIANP und deren gegenseitige Auflösung nur ein einzelner exothermer Peak auf.

Der Einfluß der verschiedenen thermischen Merkmale verschiedener Explosivstoffe auf die Verbrennung wird ebenfalls diskutiert.