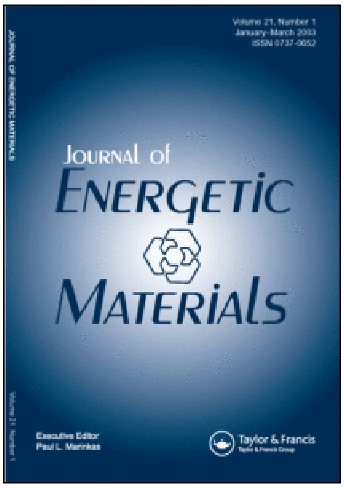

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Formation and Evolution of Decomposition Sources at Shock Wave and Impact on Explosive Charges

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Some results of test analysis using a large number of original methods for a long period of time are presented. Charges with different structural nonhomogeneities and different additions were tested. Both shock waves of 0.3 and 3.0 GPa amplitude and impacts by different strikers were considered. Analysis of the test results allows detection of the features of the explosive decomposition initiation.

Keywords: deformation, explosive grains, traces of decomposition

Introduction

This article presents some results of tests analysis received over a long period of time using numerous original methods. Charges of 2,4,6-trinitrotoluene (TNT), tetryl, RDX, HMX, pentaerythritol tetranitrate (PETN), and their mixtures with different nonenergetic and energetic additives were tested. The charges

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had different structural nonhomogeneities. Two types of shock wave action were taken into consideration. The first type are shock waves with amplitudes 0.3–0.8 GPa and with duration up to 200 ms. The second type are shock waves with amplitude 3 GPa and with duration up to 2 ms. Impacts by different types of strikers are also considered. Impacts by strikers are not accompanied by considerable shock wave effects, but non-detonation-like explosive reactions in charges are possible and are important for explosive use practice.

Overview of the Results Obtained Through Shock Loading Experiments

Figure 1 presents a range of initial conditions for test models (pressure and duration) that were used to study features of the reaction in the explosive charges. It also shows the main features of the response, determined by the corresponding research methods. In the area of conditions below line 1 there is no visible change in the explosive charge. In the area between lines 1 and 2 the charge structure is changed without visible tracers and marks of explosive decomposition (Fig. 2). Their presence is

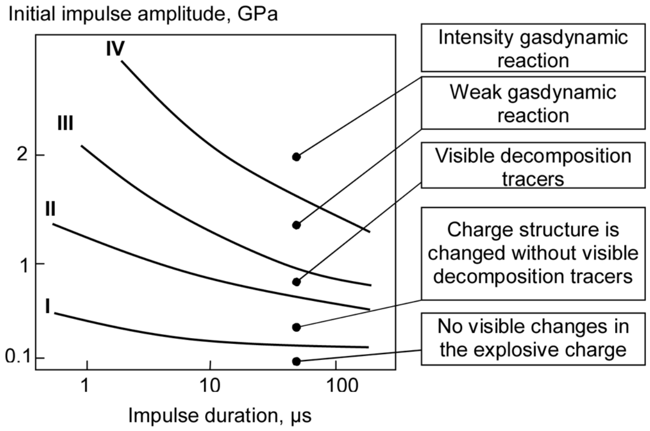

Figure 1. Regimes of response subject to variations in loading condition (approximate for RDX, pressed, and cast TNT).

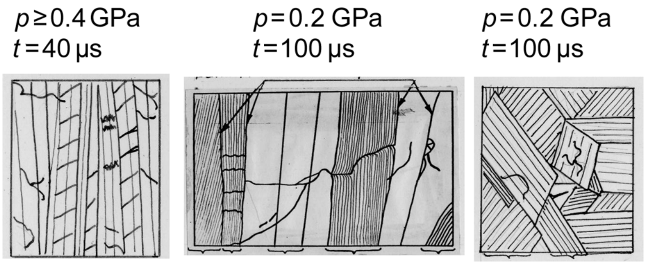

Figure 2. Typical defects of grains of cast TNT (p, $t=$ amplitude and duration of the shock wave impulse, respectively).

discovered using methods of chemical research. Two types of cast TNT granules structure damage were found in experiments. The first type was deflecting and branching cracks, which were found directly after shock loading. The second type was straight transversal cracks, which appeared several hours or even days later in the parts of crystal with no deflecting and branching cracks. The position of line 2 is determined by the presence

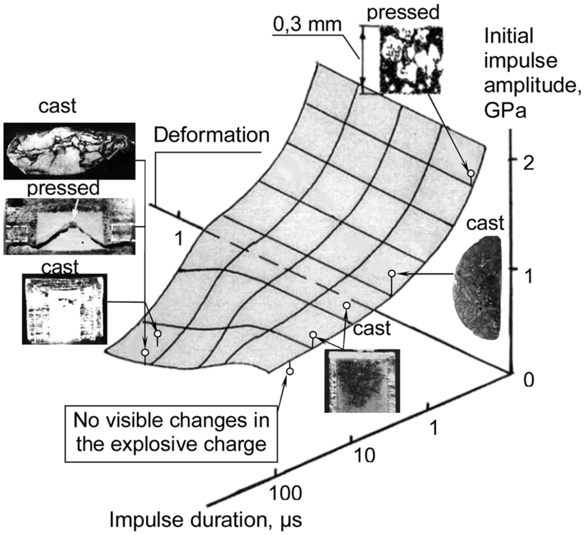

Figure 3. Conditions for appearance of traces of decomposition (black) of pressed and cast TNT.

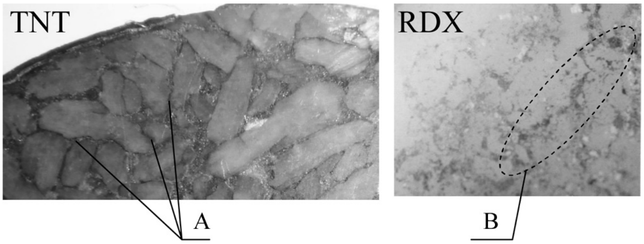

Figure 4. Partial decomposition in cast TNT and pressed RDX. (A) Intergranular borders are black because of high-molecular condensed substance (similar to coke) located on grains surface. This substance is generated by TNT decomposition. (B) Area in which the largest cavities on surfaces of explosive grains and grain agglomerates were observed. These cavities were formatted by the gaseous low-molecular reaction products of RDX.

and intensity of post–shock wave (post-SW) deformations of the explosive charge (Fig. 3).

The area between lines 2 and 3 corresponds to the explosive decomposition with very poor gasification (Fig. 4). The area of conditions between lines 3 and 4 corresponds to the gasification, where one can study the explosive reaction dynamics, observing shell deformation or using the aquarium method (Fig. 5). In the area above line 4 the intensity of the explosive decomposition is sufficiently high for use of methods applicable to measure pressure and particle velocity (manganine and magnetic–electrical sensors) and electrical conductivity. The combined results from

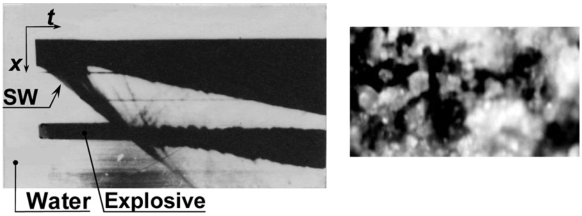

Figure 5. Photos of expansion of the RDX layer in water, initiated by a shock wave, and microphoto of RDX charge after partial decomposition.

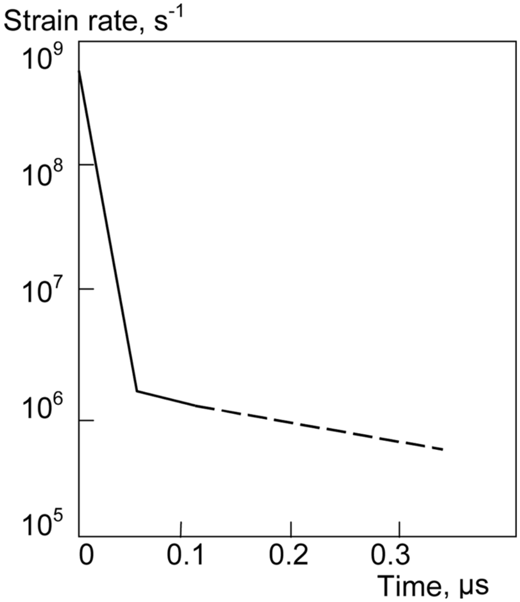

Figure 6. Strain rate deceleration of matrix matter immediately before spherical burning front in decomposition nucleus of RDX at the stepped impulse.

pressure and conductivity measurements allow obtaining data not only on the dynamic of the reaction product generation (and about the deformation speed of matrix explosive in front of combustion of the sources of decomposition; Fig. 6) but on the structure of the area of decomposition sources [1–4].

Conclusions

The attempt to explain effects discovered in the studies (conducted at different times and for different and independent purposes) using noncontradictory, unified approaches resulted in the following ideas:

1. Transformation of solid explosives into gaseous products of reaction takes place under influence of processes of shock wave stages, processes of post-SW deformations,

and processes depending on resting pressure. For cells of matrix explosive near voids the post-SW stage of deformation (and accompanying effect of thermal and catalytic decomposition intensification) takes place at collapse of voids and then at reverse flow of the matrix matter due to differences in specific volumes of the reaction products and initial matter.

2. The points of formation of the sources of decomposition are voids, intergrain boundaries, and lattice nonhomogeneities inside explosive grains in the order of decrease of probability of their discovery.
3. If a source of decomposition appears in the area of the crystal explosive, one should consider the fact that the primary destruction of explosive molecules results in the formation of intermediate products. The "mesh" effect and steric factor prevent the intermediate products from interaction with energy release. (The mesh or Frank-Rabinovich effect is characteristic for solids and liquids. It derives from the fact that the number of free radicals found in dense media is always significantly less than the number available in a low-density gas. This fact is explained by the partial recombination of radical pairs within the cavity that is formed by parent molecule disintegration. The steric factor results in a significant reduction in the explosive reaction speed. This is due to the necessity of specific orientation of radicals and parent molecules.) Reactions with finite energy release are intensified if the k-phase (condensed phase) is deformed in the area of the reaction and if there are conditions for gas release of the reacting mixture. At this case the "mixing up" of the decomposition products with the initial explosive is intensified, which minimizes the deceleration effect from the steric factor. This feature is one of the main reasons for the discovered possibility to intensify the decomposition in the conditions of post-SW deformations in the area with origins of decomposition sources and the possibility to decelerate the reaction, if the pressure is decreased outside (for example, pressure drop behind the shock wave front).

4. The decrease of a large number of defects and high reactivity of the surface layers of explosive grains, produced during "industrial" crystallization, due to solving binders or high-adhesive polymer binders (without volume decrease after hardening) considerably decreases the decomposition rate η in shock waves. However, in charges, produced by pressing, inside explosive grains remains heterogeneities, and they result in the intensification of processes of source decomposition inside grains. The generation of structural errors inside grains (possibly just cracks in grains) can increase the sensitivity of the explosive at shock wave compression if the pressing pressure is too high. One should note that the intergranular voids are not the only reason for the appearance and growth of decomposition sources inside grains.
5. Experimentally determined functions of decomposition rate η and specific energy θ on time t and decomposition degree w describing the decomposition topology as a rule differ from those that result from the model of stochastic distribution of decomposition sources.
6. The assumption on the main distribution of the decomposition sources on surfaces of explosive grains and grain agglomerates for the agreement with data on delay of electric conductivity appearance behind the initiating shock wave front should be completed by the assumptions of a "star-like" shape of decomposition sources and on the existence of a jet mechanism of the growth of sources. The jet (or turbulent) mechanism is likely connected with high values of explosive deformation rate before the combustion front of primarily compact sources of reaction (10^9 1/s by the order of magnitude).
7. The features of functions $\eta(t)$ and $\eta(w)$ at the initial stage of decomposition (initiation stage according to Craig M. Tarver's (Energetic Materials Center, Lawrence Livermore National Laboratory, CA) terminology) are connected not only with the heating of the matrix explosive at the void collapse stage and heating at explosive flow by expanding explosive products but with a high

rate of deformation of the matrix explosive, resulting in the loss of homogeneity (continuity) before the front of the primarily laminar combustion.

8. The critical conditions of the development of detonation-like reactions of explosive charges (as a response to perforation) to essentially dangerous ones are of a gas-dynamic nature. It is connected with explosive combustion fading at the pressure drop above the surface of gasification. Such explosive properties as combustion law, crack resistance of the charge at crater formation from the striker, charge compressibility, and characteristic temperature of effective reaction zone play essential roles. The characteristic temperature of the effective reaction zone defines the quasistationary burning law at standard initial temperature of the explosive ($T = 298\,\text{K}$). A significant influence of this factor is explained by the fact that the temperature of this zone is determined not only by explosive properties but by a pressure change dynamic above the burning surface in the process of testing explosives (particularly sharp and deep pressure drop).

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