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Abstract

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MEASUREMENT OF SHOCK ADIABATS OF CAST TNT, CRYSTALLINE RDX, AND NITROMETHANE

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In recent years dynamic methods for investigating the compressibility of various inert materials have found wide application ([1–3]). The absence of analogous studies for condensed explosives (HE) is explained by their high sensitivity to impact. The relatively low impact sensitivity of cast TNT, crystalline RDX, and nitromethane made it possible to determine their Hugoniot curves under conditions in which detonation was absent.

In the present work the reflection method ([2]) was used. The experimental scheme is shown in Fig. 1.

Fig. 1. Scheme for measuring the shock-wave velocity in the substance under investigation.
1 –intermediate charge with a detonator cap; *2* –explosive lens forming a plane detonation front; *3* –active explosive for producing the shock wave; *4* –metal plate; *5* –explosive under investigation; *6* –electrical contact gauges.
To the oscillograph

Using the laws of conservation of mass and momentum when a substance passes through a shock wave, and the condition of continuity at the interface metal–investigated substance, this method makes it possible to determine the pressure and volume of shock compression from the measured value of the shock-wave velocity in the investigated material, the particle velocity in the metal, and its shock adiabat.

In our experiments, copper plates 5 mm thick were used as the intermediate material between the active charge and the investigated substance. The shock adiabat of copper was taken from ([4]).

Table 1

TNT	TNT	RDX	RDX	Nitromethane	Nitromethane
P, 10^3 bar	l, mm	P, 10^3 bar	l, mm	P, 10^3 bar	l, mm

TNT	TNT	RDX	RDX	Nitromethane	Nitromethane
139	8	155	5	86	Does not deton.
115	13	130	9	73	Does not deton.
87	Does not deton.	98	23	54	Does not deton.
70	Does not deton.	78	Does not deton.	43	Does not deton.

Measurement of the velocity of motion of the free surface of the metal makes it possible to determine the particle velocity behind the shock-wave front, since the velocity of the free surface, as shown in ([1–3]), is equal to twice the particle velocity. The shock-wave velocity in the investigated substance and the velocity of motion of the free surface of the metal were determined by electrical contact gauges (see Fig. 1), the signals from which were recorded by cathod-

oscillograph OK-15M (developed at the Institute of Chemical Physics of the Academy of Sciences of the USSR). This instrument makes it possible to record time intervals with an accuracy of $\pm 5 \cdot 10^{-9}$ sec. When measuring the velocity of motion of the free surface of the metal, electric-contact sensors were placed at various distances from its free surface.

Experimental results

In the work, crystalline RDX with an initial density of 1.80 g/cm^3, fine-crystalline cast TNT of density 1.62 g/cm^3, and nitromethane were used.

At first, by photographing the specimens under investigation from the side surface with the aid of an SFR (high-speed photographic recorder, developed at the Institute of Chemical Physics of the Academy of Sciences of the USSR), it was established that detonation does not occur in them up to pressures of $\sim 80 \cdot 10^3 \div 100 \cdot 10^3$ atm. In these experiments

Table 2

Parameters of the shock wave*

D, km/sec	u, km/sec	P, 10^3 bar	V/V_0	D, km/sec	u, km/sec	P, 10^3 bar	V/V_0
Copper	**Copper**	**Copper**	**Copper**	**TNT**	**TNT**	**TNT**	**TNT**
5.60	1.00	500	0.82	5.22	1.64	139	0.686
5.34	0.87	415	0.841	4.93	1.44	115	0.710
5.03	0.71	320	0.862	4.60	1.17	87	0.747
4.82	0.60	259	0.877	4.35	1.00	70	0.769

D, km/sec	u, km/sec	P, 10^3 bar	V/V_0	D, km/sec	u, km/sec	P, 10^3 bar	V/V_0
4.64	0.51	211	0.893	4.20	0.84	57	0.800
4.32	0.35	135	0.917				
RDX	**RDX**	**RDX**	**RDX**	**Nitromethane**	**Nitromethane**	**Nitromethane**	**Nitromethane**
5.40	1.60	155	0.705	4.40	1.76	86	0.602
5.22	1.40	131	0.731	4.15	1.55	73	0.628
4.71	1.16	98	0.752	3.78	1.27	54	0.667
4.42	0.98	78	0.782	3.50	1.08	43	0.690
4.30	0.83	64	0.807	3.37	0.90	35	0.730
				2.83	0.62	20	0.782

* D—velocity of the shock wave; u, P—mass velocity and pressure behind the shock-wave front; V_0 and V—specific volume of the substance before and after shock compression, respectively.

the length of the specimens was 50 mm, and the diameter 20 mm. With increasing pressure P in the shock wave entering the specimen under investigation, detonation arose at different distances l from the interface between the metal and the explosive under investigation (see Table 1). This fact of detonation delay was used to increase the measured pressure interval.

Table 3

Substance investigated	Pressure at chemical peak P, 10^3 bar	Pressure in the Jouguet plane P, 10^3 bar	Relative pressure at chemical peak to pressure in the Jouguet plane
RDX	592	390	1.52
TNT	326	210	1.55
Nitromethane	209	129	1.62

To determine the velocity of the shock wave, a measurement base of 2-3 mm was chosen in all experiments. The experimental data are given in Table 2.

On the basis of the results obtained, empirical dependences of the shock-wave velocity on the mass velocity were selected for all the explosives investigated. These dependences are presented in Fig. 2.

The analytical expressions for these dependences are as follows:

$$\text{for hexogen} \quad D = (2.87 + 1.61u) \text{ km/sec} \tag{1}$$

(valid in the pressure interval from $67 \cdot 10^9$ to $155 \cdot 10^9$ bar);

Fig. 2 and Fig. 3

Figure 1: Fig. 2 and Fig. 3

$$\text{for TNT} \quad D = (2.93 + 1.41\,u) \text{ km/sec} \tag{2}$$

(valid in the pressure interval from $60 \cdot 10^9$ to $139 \cdot 10^9$ bar);

$$\text{for nitromethane} \quad D = (2.00 + 1.38\,u) \text{ km/sec} \tag{3}$$

(valid in the pressure interval from $20 \cdot 10^9$ to $86 \cdot 10^9$ bar).

Figure 3 presents the dependences of the pressure P behind the shock-wave front on the relative specific volume V/V_0. Extrapolation of the obtained Hugoniot curves, on the basis of dependences (1), (2), and (3), to their intersection with the Michelson straight line

$$D^2 = V_0^2 \frac{P}{V_0 - V} \tag{5}$$

makes it possible to estimate the pressure in the chemical peak of the detonation wave (see Fig. 3), as well as the ratio of the pressure in the chemical peak to the pressure in the Jouguet plane*. These ratios, given in Table 3, turned out for all three explosive substances investigated to be close to 1.5.

Fig. 2. Dependences of the shock-wave velocity on the mass velocity. 1—for hexogen, 2—for TNT, 3—for nitromethane. Points are experimental values.

Fig. 3. Dependence of P on V/V_0: 1—for hexogen, 2—for TNT, 3—for nitromethane. Points are experimental values. The dashed line shows extrapolation of the obtained Hugoniot curves. Segments of curves 1a and 1b are the data of M. Ya. Vasil' ev, D. B. Balashov, and L. N. Mokrousov.

Of great interest is a comparison of the curves of dynamic compressibility of the substances obtained in the present work with curves obtained as a result of static compression. The data of M. Ya. Vasil' ev, D. B. Balashov, and L. N. Mokrousov on isothermal static compression of TNT and hexogen are shown in Fig. 3. As is evident from the graph, the data on

* The parameters of ideal detonation in the Jouguet plane for all the substances investigated were taken from work (6).

the isothermal and dynamic compressibilities of hexogen are close, whereas for TNT the discrepancy between these curves exceeds the experimental error. This means that, under dynamic compression, the heating of hexogen is less than the heating of TNT.

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Note: Figure translations are in progress. See original paper for figures.