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Fig. 1

Figure 1: Fig. 1

Abstract

Full Text

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ON THE DETONATION OF NITROMETHANE NEAR THE LIMIT

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In measuring the shock adiabat of nitromethane (NM $-CH_3NO_2$) (1), one of the authors observed that, when detonation arose in it, the record of the process from the lateral surface of the charge showed inhomogeneities (such as those in Figs. 2 and 4 of the present paper).

For the purpose of clarifying the nature of these inhomogeneities, it was decided to record, by high-speed photography, the process of propagation of detonation through NM simultaneously from the end face and from the lateral surface of the charge. The process was scanned with a high-speed photorecorder (SFR); the scanning speed was 2.25 mm/μsec. The slit was set along the center of the charge. All experiments were carried out according to the scheme shown in Fig. 1. A magnesium plate 5 mm thick was placed tightly against the end face of an active charge of trotyl 40 mm in diameter, with density $\rho_0 = 1.43$ g/cm^3. A cylinder of Plexiglas with a wall thickness of 2 mm, containing NM, was glued to the plate. A plane detonation wave propagated through the active charge.

Fig. 1. Experimental scheme: 1 –active charge; 2 –magnesium plate; 3 –Plexiglas cylinder with NM; 4 –mirror projecting the image of the end face of the charge onto the film; 5 –SFR

Some of the photographs obtained according to this scheme are shown in Figs. 2, 3, and 4*. It should be noted that similar photographs were obtained in casings and from other materials, as well as when NM detonation was initiated by shock waves of various intensities and directly from the active charge. A characteristic feature of these photographs is the presence of dark regions (inhomogeneities) against the light background left on the film by the detonation front during end-face scanning (Figs. 2, 3, 4). In most cases these regions arise at the periphery and propagate into the depth of the charge. As the detonation propagates through the NM charge, the inhomogeneities grow. It is clearly seen that the dark regions on the end-face scan correspond to regions with weak luminosity

Fig. 2

Figure 2: Fig. 2

Fig. 3

Figure 3: Fig. 3

on the lateral scan. As the dark regions increase, there is a smooth weakening of the luminosity on the lateral scan and then a sharp transition to a stronger luminosity.

Fig. 2. High-speed photographic scan of the process of detonation propagation in NM from the end face (a) and the lateral surface (b). Diameter of the NM charge 20 mm, height 50 mm; *p* –rarefaction waves

* Photographs analogous to our end-face scan are given in paper (6) without an explanation of this phenomenon.

less intense luminescence, which also propagates in the direction opposite to the normal propagation of detonation (reverse detonation, resembling a retonation wave; see Figs. 2 and 4). The appearance of bright luminescence on the side streak record corresponds to the occurrence of luminescence on the end-face streak record. (When examining the photographs, it should be borne in mind that the upper part of the end-face streak record corresponds to the side streak record of the detonation process.)

When the detonation wave reaches the end face of the charge, bright luminescence is observed over the entire cross section (Fig. 2). This luminescence is absent if a dark region reaches the end face of the charge (Fig. 3).

Fig. 3. Photographic streak record of the detonation process of NM from the end face of the charge. **a** –charge diameter 30 mm; **b**, **c** –diameter 20 mm

Fig. 4. Photographic streak record of the process of detonation propagation. **a** –charge diameter of NM 17 mm, height 50 mm; **b** –diameter 17 mm, height 100 mm; **p** –retonation waves

On the basis of the facts set forth, the following explanation of the phenomenon under study may be given. The absence of luminescence in the regions corresponding to the dark portions, as well as the propagation of detonation along these portions in the direction opposite to the normal propagation of detonation, indicates that these portions are undetonated NM. Apparently, in the dark portions NM loses its transparency under the action of the shock wave coming from the detonating regions of the charge. In all experiments of this work,

Fig. 4

Figure 4: Fig. 4

the detonation velocity of NM, measured from the side streak record, remains constant and equal to 6300 m/sec up to the cessation of detonation. However, when NM detonates near the limit, the front of the detonation wave does not encompass the entire cross section of the charge; zones of unreacted substance remain, which can subsequently detonate. In the case where a region of absence of reaction, or several such regions, completely cover the transverse cross section of the charge, detonation ceases (Fig. 4b).

From the results presented, nothing can be said about the width of the region of absence of reaction, since the photographs were obtained through a slit and provide information

only of the local development of the process. Thus, in Fig. 4b it can be seen that the zone of absence of reaction crosses the entire cross section, and nevertheless the detonation passes through. Apparently, in this case the detonation propagates along the edges of the charge and then causes reaction in the central region of the NM. The mechanism by which foci of absence of reaction arise and by which reaction is subsequently excited in these foci is also still unclear.

In the theoretical work of Yu. N. Shchelkin (^{2}) and the experimental work of Yu. N. Denisov and Ya. K. Troshin (^{3}) on gas detonation, it was shown that the plane front of a moving wave is unstable and that the reaction is initiated not over the entire cross section of the charge, but in separate foci. Comparing the results obtained in the present work with records of the propagation of detonation in gases near the limit, one may note a certain similarity. It consists in the fact that, although no strict periodicity in the appearance of the inhomogeneities described above has yet been observed, each inhomogeneity individually, in a side photographic record, resembles a photographic record of "pulsating" gas detonation (^{4}). In work (^{2}) the assumption is made directly that the detonation of condensed explosives should have a character analogous to gaseous detonation. It is possible that this is indeed so. In any case, the mechanism of detonation combustion in gases has been clarified to a significant extent precisely through the study of phenomena near the propagation limit of detonation. It is not excluded that the results obtained in the present work on the detonation of weak explosives near the limit will help in the further clarification of the mechanism of detonation combustion of condensed explosives.

In conclusion, it should be noted that inhomogeneities in photographic records of detonation from the side surface of the charge were noted in the work of A. Ya. Apin and V. K. Bobolev (^{5}) on the detonation of powdered explosives.

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