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DETONATION OF A PHLEGMATIZED EXPLOSIVE

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It is common to use explosives containing inert organic additives as binding or phlegmatizing agents. However, not much is known about the effects of these components on the detonation characteristics. Most papers give the detonation speeds of the mixtures [1-3], while the information on the pressure of the explosion products is limited and conflicting. For example, according to some sources [4] mixing an explosive with wax increases the detonation pressure, while other sources [5, 6] quote the opposite result.

We have used manganin transducers to identify the major features in the detonation of hexogen and TEN containing 6% of macromolecular compounds of the paraffin series.

Detonation waves with planar fronts are produced in charges of these materials, and also in trotyl, in each case of diameter 64 mm. In certain experiments the charge diameter was 84 mm. The ends of the charges were formed by materials differing in dynamic rigidity: copper, aluminum, Plexiglas, and ethanol. The flat manganin transducers were insulated from the electrically conducting medium by layers of PTFE joined together with vacuum lubricant, and these were placed within the charge or at the boundary between the explosive and the end. The signals were recorded with an S1-75 oscilloscope and the pressure profile p(t) was determined from the calibration relationship of [7]. The detonation speed was measured with electrical contacts with an error of ±0.5%.

Figure 1 shows p(t) recorded with the manganin transducers for phlegmatized TEN of density $\rho = 1.655$ g/cm^3. Line 1 was recorded with the transducer inserted directly in the explosive at a distance 120 mm from the initiation surface. Line 2 characterizes the pressure change at the same distance from the boundary with an aluminum plate. Figures 2 and 3 show analogous curves respectively for phlegmatized hexogen ($\rho = 1.66$ g/cm^3) and for trotyl ($\rho = 1.56$ g/cm^3) with the same geometry. Lines 1 relate to the pressure within the charge, while lines 2 relate to the pressure at the boundary with the Plexiglas. The fluctuations in the first 0.15-0.25 μsec correspond to wave reverberations in the insulation and in the transducer itself.

Figures 1 and 2 show that the phlegmatized explosives have a horizontal part in the initial stage. Special experiments showed that the length of the plateau, behind which there is a fall in pressure, increases with the length of the charge and constitutes about 1 μsec in hexogen for L = 120 mm.

Table 1 gives the initial density ρ, detonation speed D, observed plateau pressure within the explosion products EP within the charge, and the same at the boundaries with copper, aluminum, Plexiglas (Pl), and ethanol (et). The bottom lines in the entries for the experimental pressures are the numbers of experiments used in the averaging.

We constructed the retardation and expansion branches for the EP from these experimental results in terms of a plot of pressure p against mass velocity u. The detonation pressure p* in the last column of Table 1 was determined from the point of intersection of these curves with the detonation ray $p = \rho Du$; this column also gives in parentheses the published data on the pure explosives.

Table 1 shows that 6% phlegmatizer substantially reduces the detonation pressure. On the other hand, the detonation speed is not reduced and even increases somewhat. For ex-

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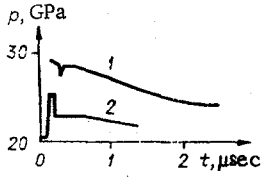

Fig. 1

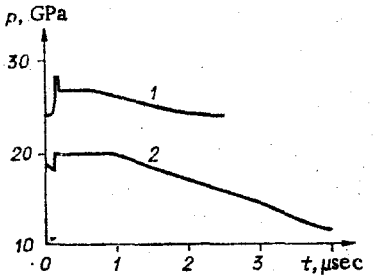

Fig. 2

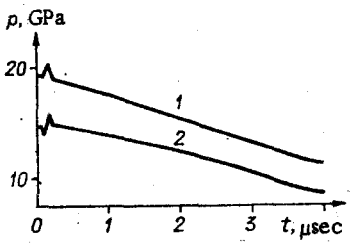

Fig. 3

ample, for hexogen D is increased by the additive from 8.23 km/sec [8] by 0.15 km/sec, while for TEN the values are 7.93 km/sec [6] and about 0.2 km/sec.

This evidence and the anomalous form of the p(t) curves, with the plateaus, shows that the detonation of a phlegmatized explosive occurs with incomplete compression [9].

This interpretation is confirmed by experiment, in which triangular pulses of initial amplitude about 30 GPa were applied to charges of phlegmatized hexogen. If the steady-state detonation in this explosive occurs with incomplete compression, then at a certain stage in the decay there should be [10] decomposition of the discontinuity into a detonation front and a shock compression wave propagating behind with a lower speed. The two-wave configuration is formed because of the supersonic flow of the EP, where the perturbation of either sign does not catch up with the front of the incompletely compressed detonation.

Figure 4 shows the pressure recorded by a manganin transducer at the boundary of a charge of density 1.62 g/cm^3, length 165 mm, and diameter 84 mm joining PTFE. The initial overcompression was produced by a cap of explosive of height 60 mm. The time scale is 1 μsec/div, and the recording shows the above features, with the plateau extending for 0.5 μsec with a pressure of 23.2 GPa (which corresponds to a detonation pressure of 26.8 GPa at a density of 1.66 g/cm^3) and a second shock wave that increases the pressure to 25.1 GPa. The leading peak of duration 0.15 μsec is due to transient effects in the measurement line and transducer insulation. Similar pressure profiles are consistently recorded when the charge length exceeds 100 mm.

The literature describes various conditions that lead to incomplete detonation compression in solid explosives. The high speed of the reaction front occurs because the initiation runs ahead in a highly porous explosive or in a mixture containing particles of heavy metals [11]. Another mechanism is possible in a system with nonmonotone energy release [10, 12]. In the latter case, the detonation speed is determined (Fig. 5) by the slope of the tangent 0-1 to the adiabatic (curve m) corresponding to the maximum heat production, while the pressure is determined by point 2, where this straight line intersects the adiabatic for the final explosion products (curve r).

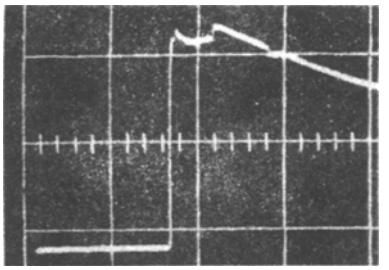

Fig. 4

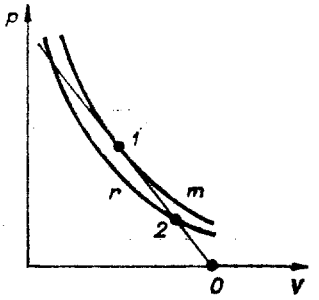

Fig. 5

TABLE 1

Composition	ρ, g/cm³	D, km/sec	Experimental pressure, GPa					p*, GPa
			p_{ep}	p_{Cu}	p_{Al}	p_{pl}	p_{et}	
Hexogen + additive, 94,3/5,7	1,66	8,38	26,0/4	4.23/3	3,15/3	19,9/8	15,45/3	26,8 (28,6[10]—30,3[8])
TEN + additive, 94,2/5,8	1,655	8,11	23,4/3	36,0/2	28,0/4	18,1/2	13,9/4	23,9 (28,4 [6])

An incompletely compressed detonation of the second type has not previously been observed by experiment in condensed explosives. In these phlegmatized explosives, the additive consisted of macromolecular compounds of the paraffin series. The adiabatics m for the maximum heat release are here the additive adiabatics of these compounds and the EP, whose parameters are close to those for the pure explosive, and the result is a slight increase in the detonation speed. The transition to the final composition and state 2 occurs as a result of endothermic processes involving the destruction of the minor-component molecules, giving simple compounds.

Estimates show that these characteristics of the detonation in phlegmatized TEN occur when the adiabatic for the final products moves downwards by a few kilobars along the pressure axis on account of the energy consumed in decomposition of 50-60 cal/g. We note that the energy required for complete decomposition of the paraffins mixed with the TEN to give simple substances (carbon and hydrogen) is 120-130 cal/g.

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EFFECTS OF ENERGY DISSIPATION AND MELTING ON SHOCK COMPRESSION OF POROUS BODIES

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Shock waves are a phenomenon not only associated with the possibility of destructive action but utilizable in a purely constructive manner: for molding of materials, welding, restoration of the thermodynamic parameters of condensed materials [1], construction of materials with a given degree of porosity, and the use of porous materials as a shock-wave damper [2].

The questions associated with the propagation of strong shock waves (pressures greater than 50 GPa) in porous bodies have been worked out in great detail [1]. The phenomenon in shock waves of strength from 0.1 GPa to tens of gigapascals has not yet been investigated in such great detail. In particular, the questions of the energy dissipation mechanism upon shock compression of porous bodies have not been investigated in this range of pressures.

Experiments with porous samples [3, 4] show that viscoplastic flow of material in the shock wave occurs most strongly in the vicinity of strong inhomogeneities. The local temperatures in these regions noticeably exceed the average temperature in the shock wave. Analogous effects are observed in connection with the explosive squeezing of cylindrical shells, where melting and evaporation of the inner surfaces of the shells occurred [5].

The distribution of the internal energy in the vicinity of an inhomogeneity is derived in this paper, and the nature of the energy accumulation and the effects of melting accompanying shock compression of porous bodies are analyzed on the basis of this distribution. The effect of thermal expansion of the material is investigated, and the behavior of the anomalous adiabats of porous media is studied in the pressure range comparable with the strength of the material. The problems of the structure of the shock front are considered, and the dependence of the melt volume on the wave amplitude is analyzed.

We will consider shock waves whose amplitude is small in comparison with the compressibility of a rigid body K ($K \sim 50$ GPa) but sufficiently large that a viscoplastic flow occurs in the vicinities of the pores. In this pressure range the width of the shock front is much larger than the sizes of the inhomogeneities [6]; one can assume the rigid body to

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