Detonation Transmission through High-Modulus Dispersed Media

L. A. Merzhievskii\textsuperscript{a,b}, I. A. Balaganskii\textsuperscript{a},
A. D. Matrosov\textsuperscript{b}, and I. A. Stadnichenko\textsuperscript{b}

Abstract: This paper presents the results of experimental studies of detonation transmission through high-modulus powder materials. The features of the process related to the properties of such dispersed media and the prospects for their use in protective devices are discussed.

Keywords: detonation, initiation, porous barrier.

INTRODUCTION

The phenomenon of detonation initiation in an explosive charge positioned at some distance from a detonating charge was discovered in the middle of the last century and is known as detonation by influence [1]. The active (detonation initiating) charge can be separated from the passive charge (in which detonation is initiated) by an air gap or by a barrier of a denser inert material. The mechanism of detonation initiation is qualitatively similar for different transmitting media and types of passive explosives. Detonation is initiated by shock waves propagating in the barrier.

The study of detonation transmission through air gaps or dense media has scientific and practical implications [2]. Scientifically, this phenomenon is used to study the initiation of explosives by shock waves. In this case, the main aim is to obtain the shock sensitivity characteristics of explosives (initiation criteria) which are then used for estimation and included in detonation models. In addition, the results provide an insight into the kinetics of detonation transformation. Important issues for applications are the determination of safe distances in terms of detonation transmission and the estimation of the barrier parameter that prevent premature explosion during storage and transport of explosives, in particular, the development of explosion proof containers [3–6].

There are many methods for studying the process of detonation initiation [2, 7]. For example, photorecording of glow is used to determine the distance traveled by the shock wave in a passive charge until detonation occurs [2]. In other cases, sensors are used to record pressure or mass velocity profiles. Methods of flash radiography are also applied. In the simplest, but least informative methods, the parameters of the wave entering an explosive are not measured and the sensitivity is characterized by the thickness of the shock-attenuating barrier through which steady-state detonation can still be initiated. The purpose of such experiments is to determine the critical pressure of shock-wave initiation, and detonation initiation is judged from the impact crater on a witness plate. In such experiments, the smallest thickness of the barrier is determined for which there is no detonation transmission from an active charge to a passive charge. Information obtained in this case is mainly of practical importance, while useful for testing detonation models. This paper presents a study of detonation transmission through high-modulus powders materials.

\textsuperscript{a}Novosibirsk State Technical University, Novosibirsk, 630092 Russia.
\textsuperscript{b}Lavrent’ev Institute of Hydrodynamics, Siberian Branch, Russian Academy of Sciences, Novosibirsk, 630090 Russia; merzh@hydro.nsc.ru.

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EXPERIMENTAL

In the experiments, we employed a simple but widely used method for studying critical conditions of detonation initiation, consisting of loading of a test passive explosive charge by a contact explosion of an active charge separated from a passive charge by an inert barrier or an air gap. In the foreign literature, the method was called the gap test. A diagram of the experimental setup is shown in Fig. 1.

In the first series of experiments, we investigated detonation transmission through heterogeneous dispersed medium based on silicon carbide powder (SiC) and river sand (silica, SiO$_2$) in dry and water-filled state. A photograph of the powders showing the difference in their particle size distribution is shown in Fig. 2 (sand at the top). It is clearly seen from the photograph that the silica particles are much larger. The particle size of the sand are in the range of 0.1–1.0 mm. The particle size distribution of silicon carbide is more homogeneous. The average particle size is in the range of 0.05–0.1 mm. The experimental assembly consisted of two cardboard cylinders tightly inserted into each other. The test powders were placed between the bottoms of the cylinders. The outer diameter of the assembly was 80 mm, and the bottoms of the cylinders were 0.75 mm thick. After filling the powder was compacted using a 2 kg dumbbell. It was found that complete compaction under such conditions occurs in approximately 0.5 h, and increasing the compaction time to 24 h did not change its thickness. The filling densities of the compacted dry sand and silicon carbide powder after pressing were 1.85 and 1.87 g/cm$^3$, respectively. After compaction, the assemblies were filled with water to saturation to obtain water-filled buffers. Densities of the wet powders were not determined. Data [8] show that water-saturated sand contains $\approx$20–30% water. In addition, we performed one experiment on detonation transmission through a plate of carbide silicon 12 mm thick placed, as powders, between two cardboard plates.

Detonation transmission through the media described above was studied for pairs of (active/passive) cast charges of 50/50 TNT/TNT and (40/60 TNT/RDX)/(40/60 TNT/RDX). The height and diameter of the charges was 40 mm; the 40/60 TNT/RDX weighed 83 g and had a density of 1.65 g/cm$^3$; the TNT charge weighed 79 g and had a density of 1.57 g/cm$^3$.

In the second series of experiments, we used SiC powders of different fractional composition. Fraction 1 consisted of grinding grains of black silicon carbide graded 53s No. 100 F20 with grain sizes of 1000–1250 µm; fraction 2 was a grinding powder of green silicon carbide graded 63s No. 16(M) 160–200 µm; fraction 3 consisted of a grinding powder of black silicon carbide graded 54c No. F1200 (M5) 3–5 µm; fraction 4 was a mixture of these powders in equal volume fractions, 3–1250 µm. The experimental technique was exactly the same as in the first series of experiments. Detonation transmission was studied for (40/60 TNT/RDX)/(40/60 TNT/RDX) pairs of charges. Initiation or no detonation in the passive charge was judged by the presence of a crater on the witness plate from the impact of detonation products.

EXPERIMENTAL RESULTS AND DISCUSSION

The results of the first series of experiments are presented in Table 1. Here and below, $h_1$ is the inert-layer thickness for which detonation is stably initiated in the passive charge, $h_2$ is the thickness for which detonation can still occur, $h_3$ is the thickness for which there is no detonation, $p_k$ is the calculated pressure in the damping layer at the interface with the active explosive charge. The calculation was performed by the classical scheme of discontinuity decay between detonation products and an inert barrier, and it involves no difficulties under known equations of state of the products and the Hugoniot of the inert atmosphere. For the detonation products, the polytropic approximation was used. The Hugoniots of dry and saturated sand are given in [8, 9].