

Experimental investigation of cylindrical detonation wave

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Abstract. One of the methods of experimental investigation of cylindrical detonation wave formed by the multipoint initiation method is presented in this work. The experimental setup was specially developed for this purpose. Two types of “Nanogate” high-speed cameras were used in the experiments. The phenomenological descriptions of initiation process, dynamic of formation of detonation wave and gas dynamic flow of detonation products are presented. This method in combination with the other modern methods will allow carrying out more profound investigations of such problems.

1. Introduction

Cylindrical detonation wave is widely used as for fundamental investigation in high-pressure physics [1,2] so for solving practical problems. Currently the method of formation of cylindrical detonation wave as well as the methods of formation of waves with different configuration (plane, conical, spherical) with the use of the multipoint initiation is widely used in experimental investigations. This method is used for creation of special charges (patent of Russian Federation No. 2498200 “Initiation devices for explosive charges”), in different constructions of explosion devices for imploding works (patent of Russian Federation No. 22451895 “Setup for formation of detonation wave”), in different types of electrodynamical devices MHD, EMG [3], in pulse generators of high pressure and other devices [4–6].

Until now it was considered that during the multipoint initiation of detonation the wave is smoothed due to formation of triple wave Mach configuration in points of conjugation of neighboring detonation waves [7] which leads to formation of smooth detonation wave [4]. In works of Zel’dovich, Guerri and others [1,8] the parameters of convergent detonation waves were discovered theoretically. The practical use of cylindrical, flat, conical, spherical waves formed by the method of multipoint initiation impose the certain restrictions. Those waves must be smooth at the exit to the target and must be formed without variations in time and local ejections of pressure.

2. Experimental technique

The experimental setup with multipoint initiation of cylindrical detonation wave (see figure 1) was created for more detailed investigation of these questions. The main target of this investigation is receiving the information:

- about formation of the detonation wave created by the multipoint initiation method;



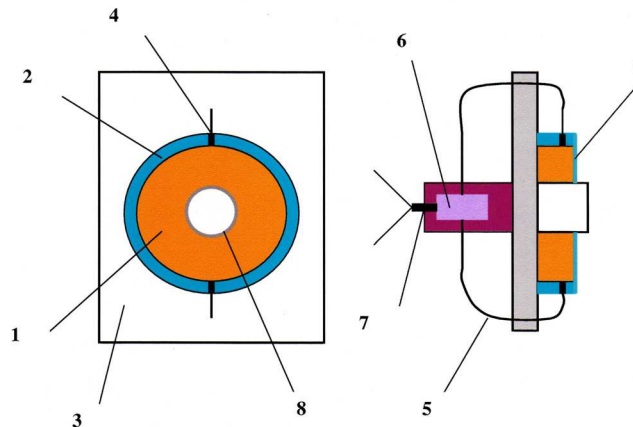


Figure 1. The scheme of experimental setup for the investigation of cylindrical detonation wave: 1—explosive charge; 2—external holder for the fixation of initiation points; 3—the base of the setup; 4—point of initiation (from 6 to 24 ps); 5—detonation cord; 6—intermediate plastic explosive; 7—electric detonator; 8—cylindrical copper target; 9—protective glass.

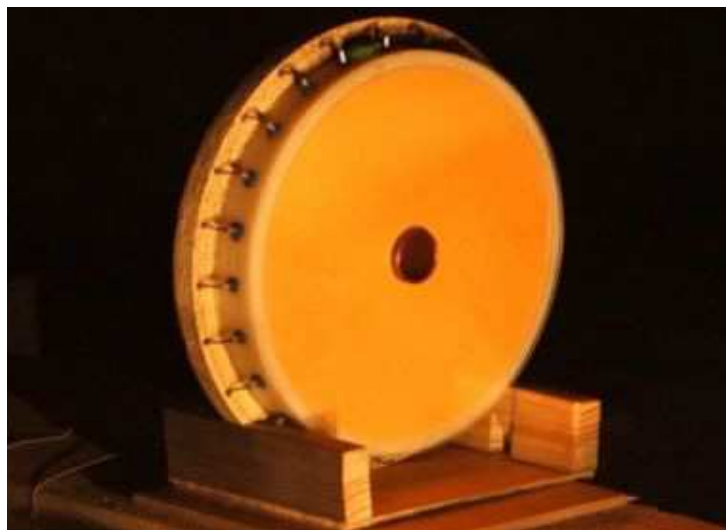


Figure 2. The photo of the setup.

- about existing of triple point Mach structure in the point of conjugation of neighboring detonation waves;
- about the velocity of convergence of detonation wave to the center;
- about gas dynamic of flow and kinetics of detonation products.

Besides, the shock-wave system, which is created in detonation products, can drastically affect the practical use of this method.

The circular charge of high explosive 1 is placed inside the external holder 2 and all this is fixed on the base of the setup 3. The points of initiation 4 in an amount from 6 to 24 ps are placed evenly along the entire length of the holder. The external diameter of the charge is about 215 mm its thickness is 20 mm. The points of initiation are connected with the intermediate

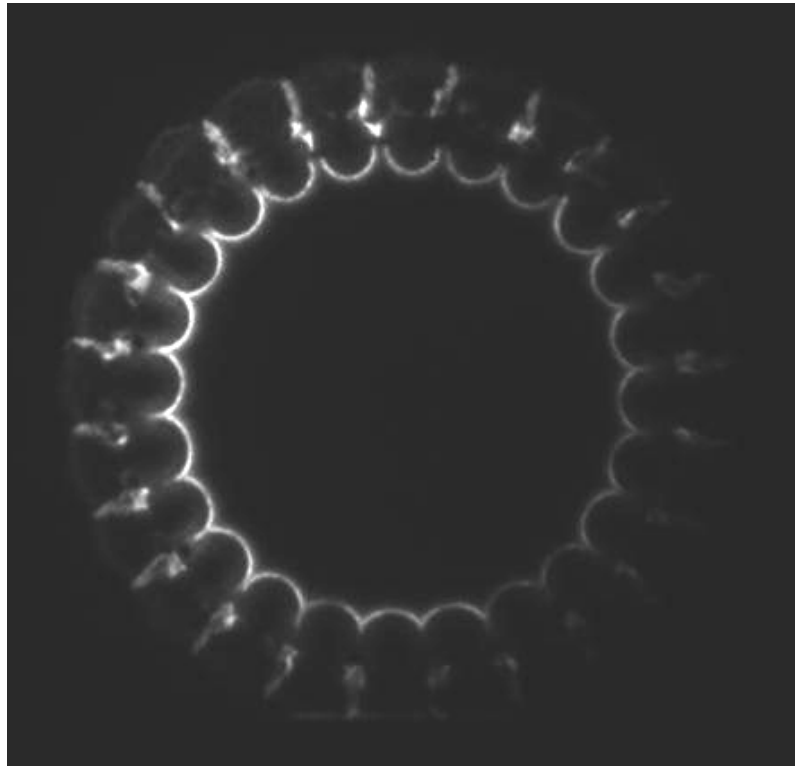


Figure 3. The initial time of detonation wave forming, 24 points of initiation.

plastic explosive *6* with the use of detonation cord of identical length *5*. The electric detonator is mounted on the intermediate explosive. The charge with the circle shape has the central hole in which the thin-walled copper target with a diameter from 70 to 90 mm is tightly installed. The transparent glass *9* covers the charge from the outside.

The photo of the setup is presented in figure 2.

For the registration of the detonation process the high-speed camera “Nanogate 4BP” was used in the majority of experiments. The camera parameters are as follows:

- (i) the optical system has one input objective and mirror lens system for dividing the image to 4 channels. Each channel is recording one frame;
- (ii) the spectral sensitivity range of 380–800 nm;
- (iii) time of exposure from 10 ns to 20 μ s;
- (iv) resolution 1380×1024 px².

3. Results

The experiment was carried out in the following way. Pulse generator creates the high voltage signal for the initiation of the electrical detonator. At the same time the generator “Stendford” starts, it forms the start pulse for the “Nanogate 4BP” camera with the rise front less than 5 ns. This start pulse has the delay, which is equal to the total time of work of the electro detonator, the intermediate explosive, the detonation cord and points of initiation. The delays and the exposure times for each frame are chosen according to which part of detonation wave path or compressing of cylindrical target is necessary to capture.

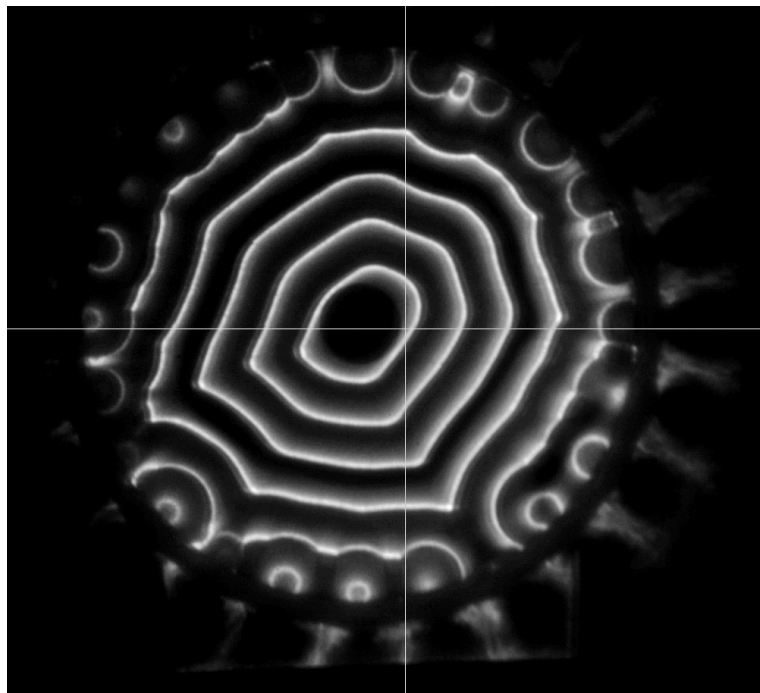


Figure 4. Formation of cylindrical detonation wave by the multi-point initiation method. The picture was taken with “Nanogate 22” high-speed camera.

The initial time of detonation wave formation is shown in figure 3. From the points of initiation the detonation wave propagates on spherical path. The moment when the waves are exiting to the front surface and interface with each other is shown on picture.

The further formation of cylindrical wave is shown in the figure. In this experiment, the difference in triggering times of initiation points and consequently formation of improper cylindrical detonation wave can be well observed. According to the results of the experiment with “Nanogate 22” high-speed camera (8 frames) it is possible to estimate the parameters of the detonation wave in process with multi point initiation (Figure 4). From this picture, we can estimate the change of detonation speed in motion to the center, the speed of flat and angular parts, dynamics of wave formation.

Gas-dynamic flow of detonation products after converging of cylindrical detonation wave shown in figure 5 is of the special interest. Bright “cords” converging to the center originate at the lines of interfacing of detonation waves propagating from the adjacent points of initiation. We assume that the “cords” temperature, pressure and density are higher than the correspondent parameters of the rest detonation products. Moreover, this will certainly influence the forming of shock wave at the target, which can be placed at the center. Therefore, the dynamics of plasma and particles flow ejection from the target surface will be changed [9, 10].

During the cylindrical detonation wave forming (created by multipoint initiation), interesting features of gas-dynamic flow of the detonation products were first detected. These features make us consider the dynamics of detonation waves forming and detonation products flow in details. They are that the complex flow of detonation products, having cell structure, is formed behind the detonation wave. The structure is not changed during the whole time of detonation wave converging, i.e. for more than $10 \mu\text{s}$. At the interfacing (contact) points of adjacent detonation waves the triple-wave Mach configuration can be formed. It is the subject of further investigations.

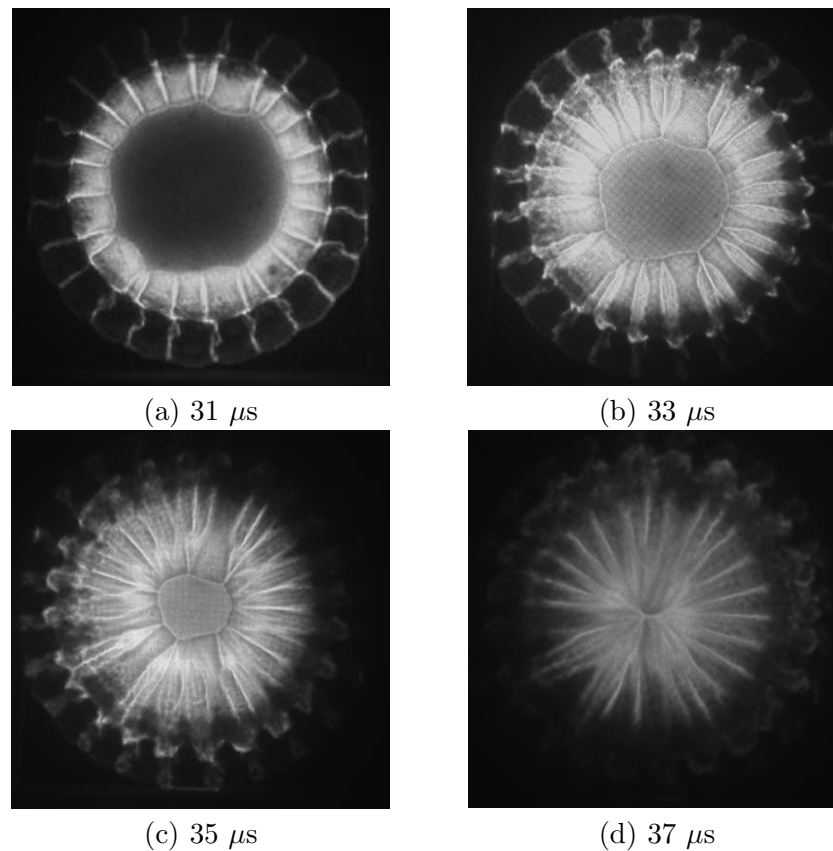


Figure 5. Gas-dynamic flow of the detonation products after converging of cylindrical wave. Assembling without internal canal.

Acknowledgments

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