EMULSION EXPLOSIVES DETONATION VELOCITY DETERMINATIONS USING TIME DETECTORS

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Abstract: *The present work assesses the detonation velocity of emulsion explosives using time arrival detectors such as electrically charged ionized pins and optical fibers probes. They record the arrival time of an object (it's free surface) or wave. Results obtained for emulsion explosives are presented for both types of experiments. Also, numerical simulations were created in order to have a good results comparison.*

Keywords: *emulsion explosives, detonation velocity, ionised pins, optical fibers, DYNA 2D.*

1. INTRODUCTION

Detonation velocity determination of an explosive can be achieved while using detectors that record the arrival time of the particles or waves. These detectors trigger a signal on arrival of a pulse. Ionised pins electrically charged and optical fibers are important examples, and the first models being used in such determinations. Other methods for determining thedetonation velocity of explosives involves ultra-fast cameras, X-rays or holography (hologram).

Studies on the shock wave propagation driven by Graham, Asay and Chhabildas concluded that the mechanical devices can not be used for determinations of such type due to the speed at which events occur.

Detonation velocity determinations were conducted for emulsion explosives.

2. EMULSION EXPLOSIVES

Emulsion explosives are consisted of a matrix and a sensitiser. The matrix is formed by mixing ammonium nitrate (ammonium nitrate), water and a mineral oil, the last being added in order to reach a stoichiometric ratio with an emulsifying agent which improves the mixture of the emulsion. Matrix can not detonate without adding a sensitizer. Sensitizers are usually glass microspheres filled with air, diameter of about 100 µm or cenospheres, ash microspheres, sorted by size and density.

Emulsion explosives (EMX) are widely used in mining.

Emulsion explosives have a number of significant properties: good detonation parameters, are less sensitive to heat and mechanical action, detonation velocity can vary widely depending on manufacturing technology and composition.

Theoretically, the detonation of explosive emulsion has not been studied adequately. Several mechanisms have been proposed to describe this phenomenon. A "hot spot" model was proposed by Deribas, while Sil'vestrov chose an empirical model based on three parameters chosen from the condition of similarity with data obtained experimentally.

Medvedev chose adiabatic compression mechanism as the most suitable to describe the phenomenon of detonation of emulsion explosives. This mechanism is applicable to all porous heterogeneous explosives, and is best suited for emulsion explosives sensitizers glass microspheres.

The combustion of the emulsion is shown schematically in Figure 1 (three stages). The scheme shows the burning surface indicated by gray and black, respectively glass microspheres as white circles. Three stages of combustion are shown (left to right):

• Initial phase, with a low burning surface
• Increase of sphere burning phase, with a maximum area of combustion
• Burning behind Chapman-Jouguet point (CJ) phase, burning a small area.

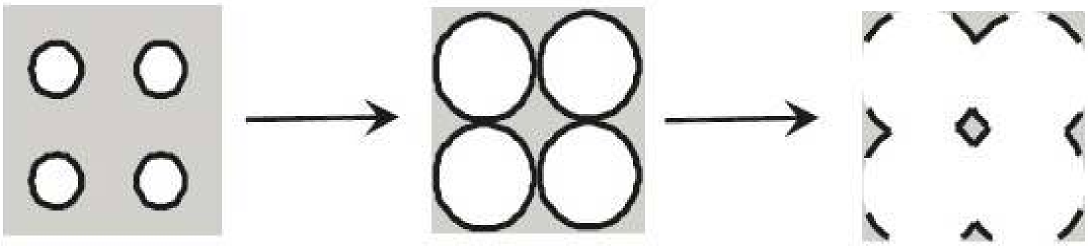


FIG. 1“Burning spheres” phenomena

The maximum of heat released is achieved when the total area of "burning spheres" reaches the maximum value. The total maximum area of "burning spheres of " is achieved when the spheres are densely packed. Even for densely packed spheres with identical diameter the minimum porosity is 0.26.

3. EXPERIMENTAL METHODS OF DETERMINING THE DETONATION VELOCITY: ELECTRICALLY CHARGED IONISED PINS METHOD

This method consisted in detonating charges with diameters of 15 mm, 19 mm, 25 mm and 32 mm; length of 220 mm. Six ionized pins with diameter of 1 mm were placed in the explosive charge at a known distance one apart from each other. The probes were connected to an electric circuit and an oscilloscope.

The shock wave when passing through the probe generates an electrical discharge materialized in the form of signal peaks (peaks) on the oscilloscope. Knowing the distance between the ionised pins and having the time periods signals were generated by the oscilloscope, the detonation velocity variation could be measured.

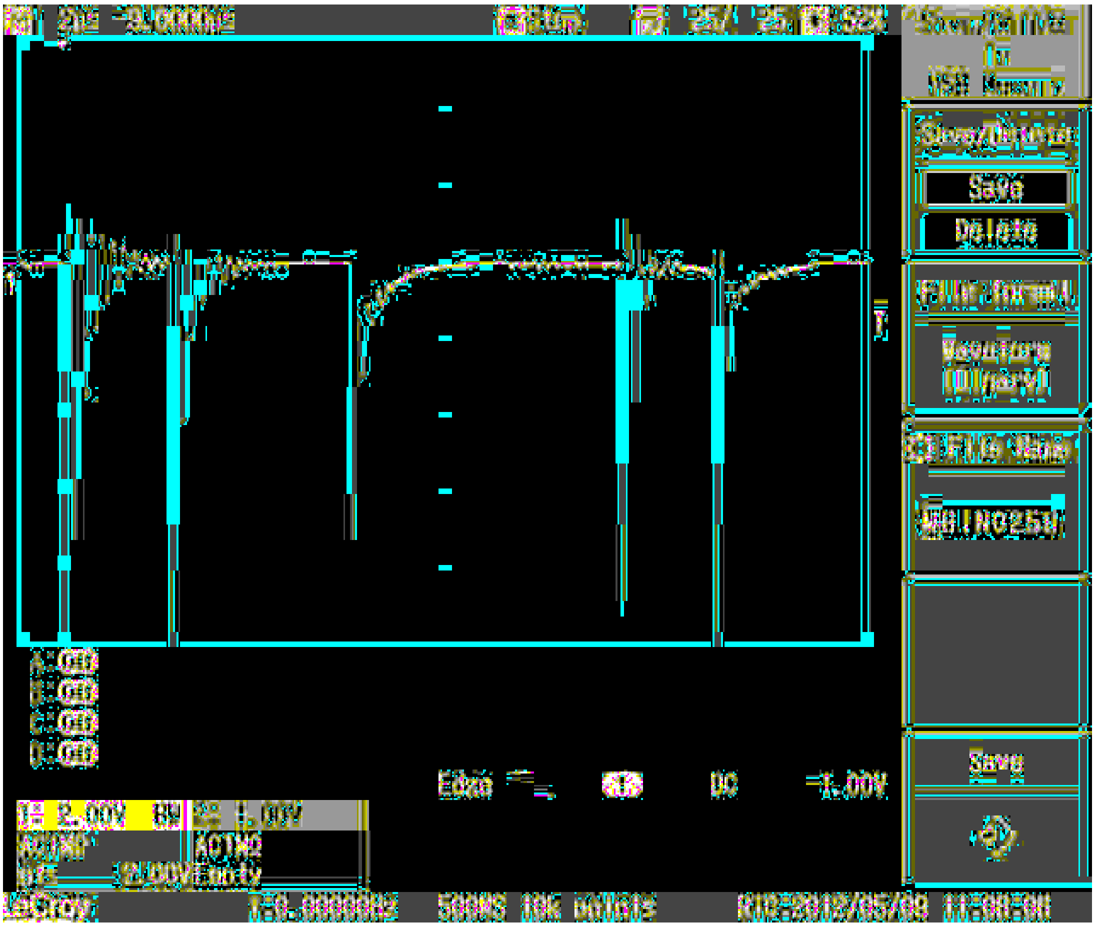
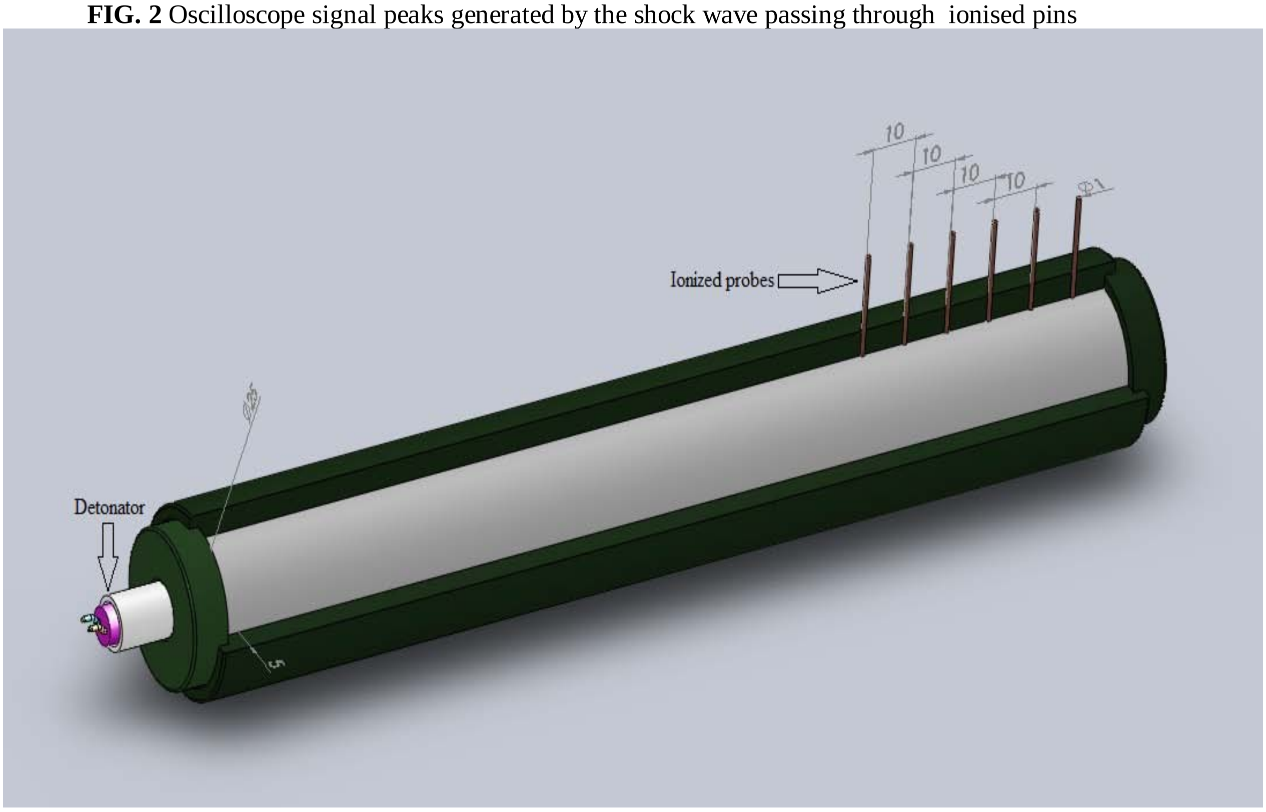
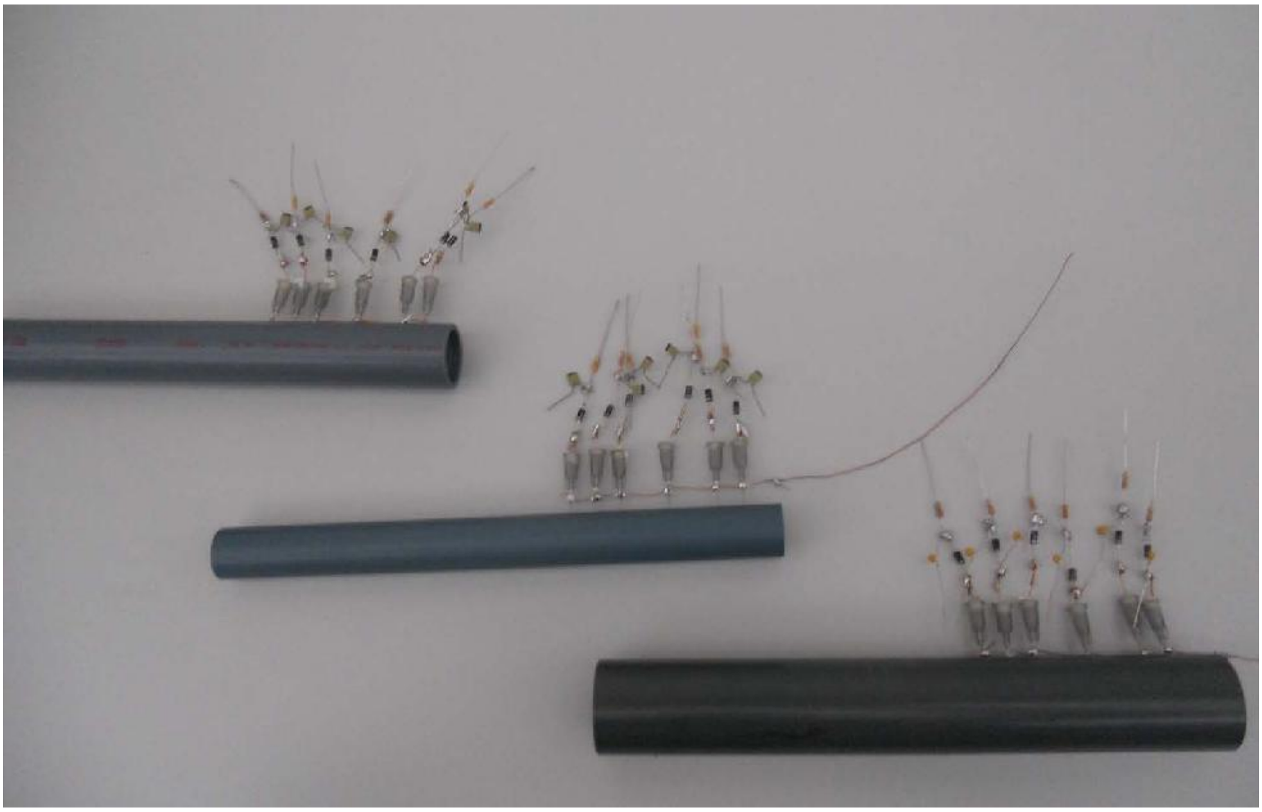


FIG. 2 Oscilloscope signal peaks generated by the shock wave passing through ionised pins



(a)



(b)

FIG. 3 Ionised pins inserted in explosive charge (Solidworks graphic and photo)

4. EXPERIMENTAL METHODS OF DETERMINING THE DETONATION VELOCITY: OPTICAL FIBERS EXPERIMENTAL APPARATUS

The detonation velocity was measured at the end of the explosive charge with a length of 220 mm and 25 mm diameter. PVC tubes with a thickness of 5 mm were used as confinement forms.Optical fiber probes with diameters of 250 microns were used for the detonation wave velocity measurements. One end of the optical fiber (MFOP) is placed inside the explosive charge (3 mm), perpendicular to the direction of propagation of the detonation wave, the other end being connected without intermediate optical equipment to the "streak" HAMAMATSU C-7700 camera.

These experiments allow evaluation of detonation with an error rate of 2-3 percent. At the end of the explosive charge a PMMA plate has been attached, with optical fibers embedded, to access speed of the shock wave induced in the PMMA plate by the detonation wave.

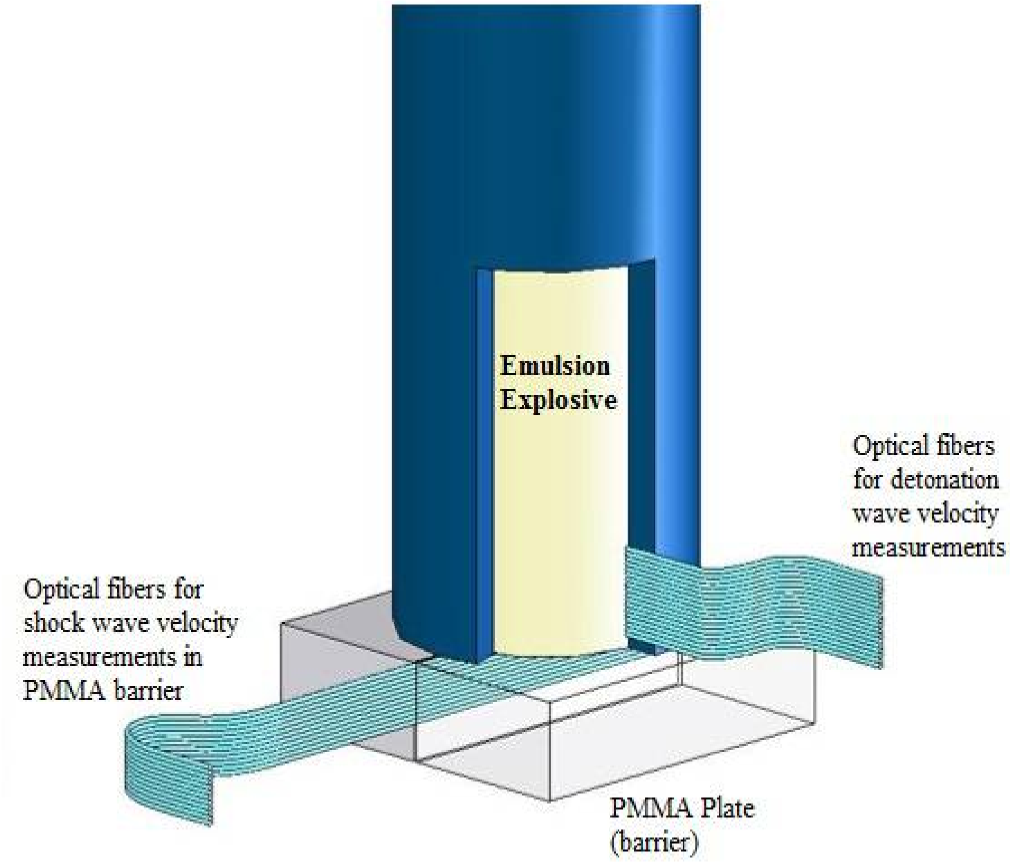
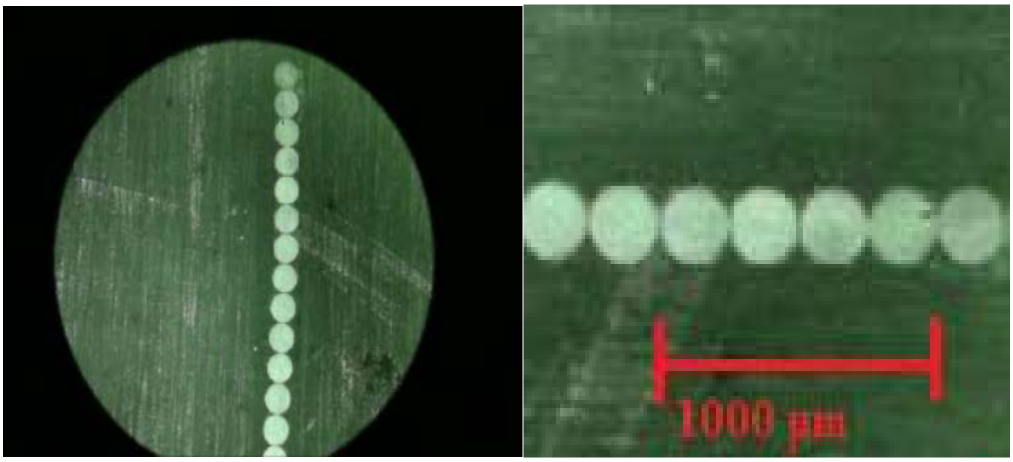


FIG. 4. Design of experimental model used for detonation velocity determinations using streak HAMAMATSU C-7700 camera



(a) (b)

FIG.5 Microscopic view of optical fibers

5. NUMERICAL SIMULATIONS

Numerical simulations were created, following the experimental model to have a wide range of results and to see the differences between them. Simulations were conducted using free-trial version of DYNA 2D software from Hydrosoft International company. This package contains the DYNA 2D, MAZE and ORION programs.

FIG. 6 Simulations Diagram

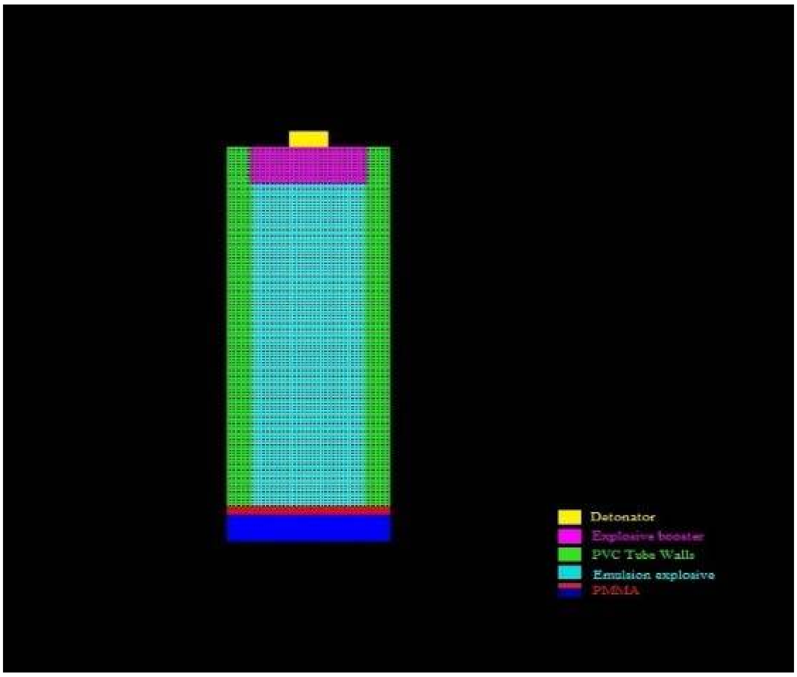


FIG. 7 Simulated Model

6. RESULTS OBTAINED

Table 1 contains the results obtained for the first time detector experimental setup, the ionised pins.

Table 1. Results obtained using ionised pins

	Charge Interior Diameter [mm]	Density [g/cm^3]	HGMB [%]	Detonation Velocity [mm/µs]
Experiment 1	25	1.041	5	**4.762**
Experiment 2	25	0.974	5	**4.560**
Experiment 3	32	1.023	5	**4.990**
Experiment 4	19	1.076	5	**4.386**
Experiment 5	15	1.073	5	**4.207**
Experiment 6	25	0.795	20	**3.514**

Next, the values for the detonation velocity obtained using the streak camera and the optical fibers are shown.

Table 2. Results obtained using ionised pins

Experiment	Density [g/cm^3]	Detonation Velocity [mm/μs]
Experiment 1	1.05	**4.892**
Experiment 2	1.12	**4.713**
Experiment 3	1.20	**4.628**
Experiment 4	1.32	**4.415**

For the numerical simulation, the results are presented in Table 3.

Table 3. Results obtained using ionised pins

Charge Interior Diameter [mm]	Length [mm]	Detonation Velocity [mm/μs]
15	100	**4.436**
19	100	**4.5996**
25	100	**4.7079**
32	100	**4.8736**
50	100	**5.1397**

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