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EXPERIMENTAL RESEARCH ON UNDERWATER EXPLOSION

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Abstract: *In this paper we underlined some aspects regarding underwater explosions – how shock waves are transmitted trough water. The first aspect we studied was the formation and propagation of the shock wave. The second aspect represents the formation and the gas bubble pulsation.*
Keywords: *underwater explosion, pulsing gas bubble, shock wave*

Overview

At the detonation of an explosive charge, the explosive turns into gaseous detonation products at high pressures and temperature. Explosive detonation also generates a powerful shock wave which is transmitted in the environment - in seawater.

The interaction of the underwater explosion with the environment has two aspects which, taking place on different time scales, can be addressed separately. A first aspect of underwater explosion it represents the formation and propagation of the shock wave. The top of the pressure in this stage is very high but it takes very little. The second aspect represents the formation and the gas bubble pulsation.Comparative to the shock wave, this second phase is characterized by a peak pressure of less highly but lasts much longer.

Gas bubble pulsation is the result of the interaction between the products of explosion strongly compressed and hydrostatic pressure of the external environment.To simplify the studyis considered that, after the explosion, the resulting gases are found in a spherical bubble. In figures 1 and 2 are represented the characteristics of the gas bubble resulting from the detonation of a sea mine.

One of the problems which arise in case of underwater explosions is the variation of the form depending on timeand the size of the gas bubble which contains the products of the explosion. The gas bubble expands under the action of explosion products strongly heated and compressed and it rises to the surface.

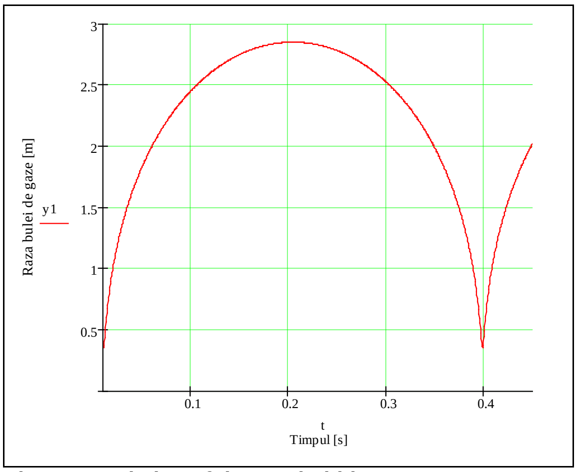

Figure 1.Variation of the gas bubble

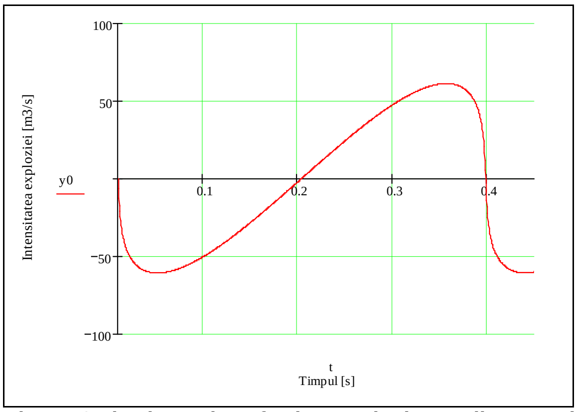

Figure 2.The intensity of mine explosion radius at mine explosion

In reality, the bubble evolution is complex, on the one hand, by the wave (which it communicates to the surrounding water a certain material speed) and, on the other hand due to the hydrostatic pressure.

The shock wave and the water speed causes to the bubble a rebound. So, it is created a relaxationlonger than the hydrostatic pressure (the equilibrium pressure) so that the interior volume of the bubble gets larger and the interior pressure is less than the hydrostatic pressure. Thus, is later a bubble compression (called contraction phase) where, by inertia, the interior volume is low and the interior pressure getshigher than hydrostatic pressure.This phase ends with the so-called gas bubble resorbtion.

In conclusion, will be another phase of relaxation or it will appear a gas bubble pulsation.This phenomenon may occur more than onceand will result the generation of the secondary shock waves, which will be of course weaker as amplitude as the main shock wave. In figure 3 are shown those phenomena of gas bubble oscillation, in which case the detonation occurs at a distance from the surface.

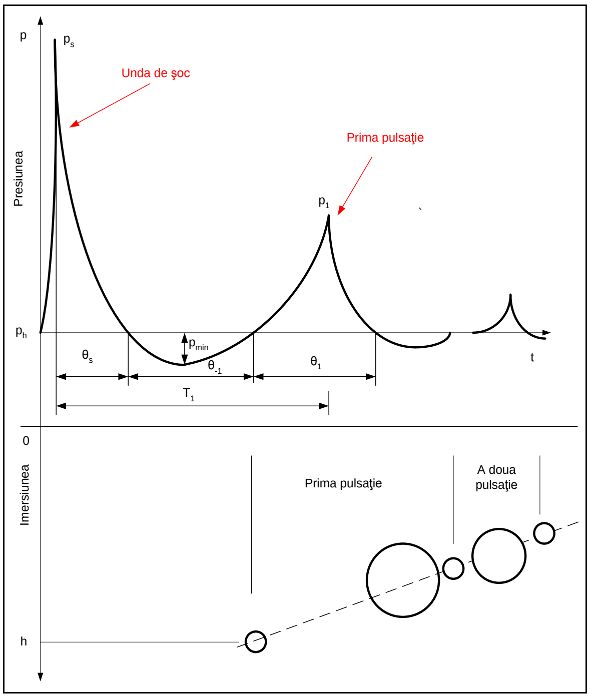

Figure 3. The pressure - time evolution for an underwater explosion

Experimental study of explosives detonation under water

The experimental study of underwater detonation of explosives was required as a necessity of validation of the physical or mathematical models used in theoretical characterization of the phenomenon.

The steps to perform tests and experimental research of underwater detonation of explosives are difficult and complex. All the same, by using the "aquarium method", promoted within the effortsto perform the tests, it has been shown that it is possible to reproduce under laboratory conditions to reproduce on a large scale phenomena occurring during the detonation of explosives in water.

The purpose of the experimental tests was:

- to obtain and to present the evolution of the phenomena to an underwater detonation of explosives (the emerging of the shockwave , the evolution of the gas bubble etc)
- to emphasize the physical units taken into consideration in the theoretical study of an underwater detonation of explosives (diameter and radius of the bubble gas , the speed of the frontier between detonation products and water , pulsation period of the gas bubble etc.)
- to determine quantitatively to consequences of an underwater detonation (the time evolution of the gas bubble , the speed and the period of pulsation etc.)
- to validate the theory of similarity used to evaluate the characteristics of the underwater explosion

1.1. The study of the gas bubble

The equipment, the means of observation and measure including the software's utilized during the tests for the experimental study of the gas bubble are part of the Explosives Laboratory belonging to the Military Technical Academy. The utilized experimental configuration is represented in short in fig. 4

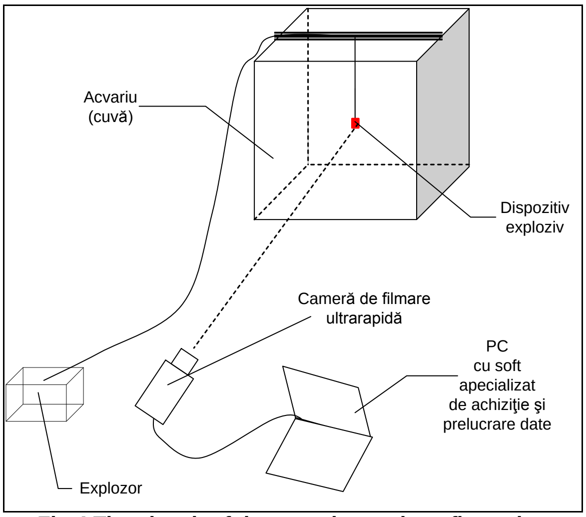

Fig.4 The sketch of the experimental configuration

The working principle is very simple to use and has the generic name of chronometry. The measured units are distances. By knowing the duration of time elapsed since each acquired image we can calculate the elapsed time during the change of distance. It is therefore possible to calculate the average speed of the gas bubble interface.

The working window processing program is shown in Figure 5.

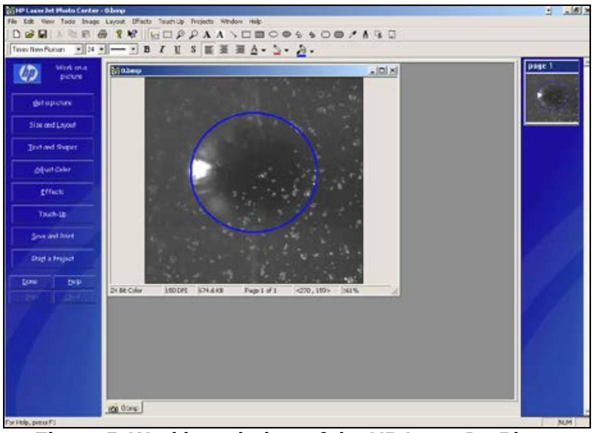

Figure 5. Working window of the HP LaserJet Photo Center

Each file is then used to describe the phenomenon recorded as a qualitative or quantitative.To characterize quantitatively the exact sizes representative for theaquatic detonation should be analyzed image by image and processed.This processing relies on marking as a graphical form of the interface (gas bubble - water) with a general program for processing graphics.

After setting and checking the scale, all representative pictures are taken and the dimensions of the frontier are measured by means of time.

The results are shown in graphical form in Figures 6 and 7.

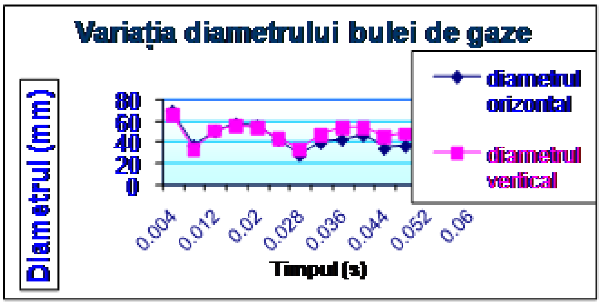

Figure 6.Diameter variation of the gas bubble generated after detonation of 100 mg of explosive

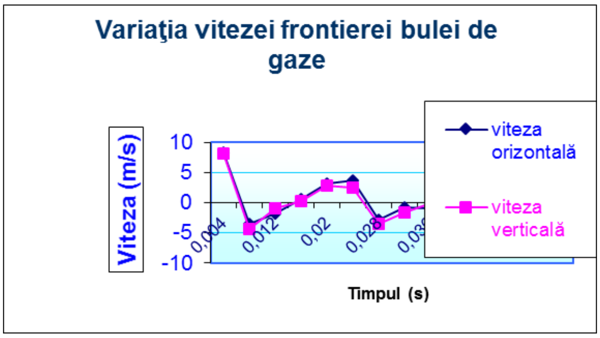

Figure 6.Speed variation of the gas bubble generated after detonation of 100 mg of explosive

1.2. Study of the shock wave generated by the underwater explosion

The experimental study of the propagation of shock waves through the water has become a necessity in order to delimit a safety zone where the explosive is used for fast cutting of metals under water.

To delimit a certain safety zone around a work site where underwater cutting of metals involving explosives is used, based on theoretical calculations to estimate the pressure in the shock wave front has become imperative to check and confirm the accuracy of the theoretical calculations by experimental tests.

The purpose of experimental tests that are the subject of this section was to obtain and present the variation during the propagation of a shock wave generated by the detonation of explosive charges of known mass, located at a precise distance from the blast.

Equipment, means of observation and measurement, as well as specialized software used throughout the tests are equipping "Mircea cel Bătrân" Naval Academy (MBNA). The components of the measuring equipment were purchased during the course of a research project and were assembled and formed as an integrated measurement within MBNA.

Schematically, the experimental configuration is shown in Figure 8.

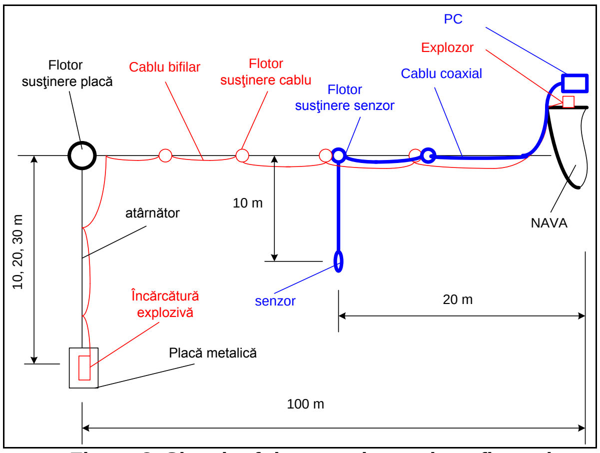

Figure 8. Sketch of the experimental configuration

The recording of the value of the over pressure in the wave front was made using "The system of measurement and recording of the pressure in a shockwave front in aquatic conditions" consisting of: sensor, current stabilizer for sensors, coaxial cable connectors, data acquisition card, driver software.

The working window of the processing program is shown in Figure 9.

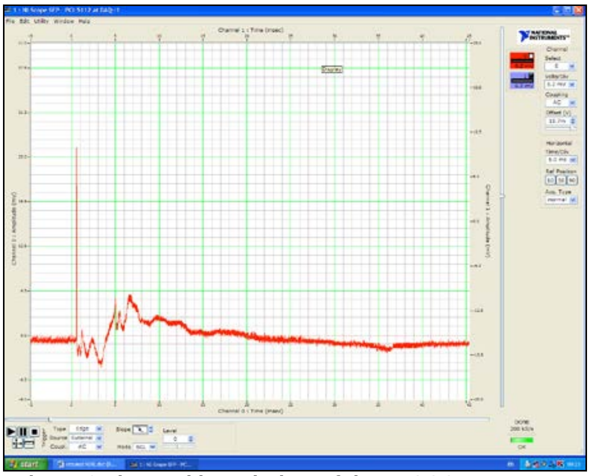

Figure 9.The working window of the NI SCOPE program

Each of the files with the recorded phenomenon is used to describe the phenomenon categorized as qualitative and / or quantitative. For example, to represent the qualitative evolution of the phenomena associated with detonation is recommended to view the image showing how the development of overpressure of the shock wavefront sensor, duration, etc.The advantage of this approach derives from the fact that large amounts of information are allowed. In order to characterize quantitatively the representative parameters for the underwater detonation the recording must be processed.

Conclusion

Tests performed in the laboratory have confirmed the fact that the gas bubble, resulted from the detonation of the load in the water has a pulsatory movement.

Bubble pulsation produced by the explosion respects in terms of quality, determined theoretical equations.

Image processing using the specialized software programs has shown that the bubble retains its sphericity, and then , the buoyancy caused the bubble to ascend towards the water surface and to deform.

The change of the gas bubble’s shape is given by the energy loss through radiation and thermal conductivityin the gas bubble interface and also because of the physical laws governing the movement of the bubble towards water’s surface.

For quantitative determinations of phenomena accompanying gas bubble pulsation is necessary that the experimental results should be harmonized with the similarity theory, a theory that has allowed us to approximate the results of the experimental tests with small loads possible in laboratory conditions. For large loads, coefficients of similarity should be correlated with more precise measurements, performed with modern devices, in order to estimate the effect of possible errors and to make them as small as possible.

The analysis of shock wave propagation through seawater considered a continuous medium and compressible, highlighted the deeply nonlinear profile of the fast, high intensity dynamic phenomena.

For a given explosive whose detonation characteristics can be calculated, the characteristics of the shock wave generated varies depending on the knock underwater explosive charge mass and the distance from the center or the blast.

The basic principle of similarity theory in underwater explosions, is that a detonation wave transmits a water shock wave whose intensity (amplitude) decreases with distance from the blast.Thus, at a given point in distance from the initial location of the source of the shock wave we can see the same shape as the original beam (identity profile), but at a lower intensity.This wave's amplitude reduction is directly proportional with the increase of the distance from the wave's source.

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