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The Effect of Nano-Aluminumpowder on the Characteristic of RDX based Aluminized Explosives Underwater Close-Filed Explosion

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Abstract. In order to investigate the effect of nano-aluminum powder on the characteristic of RDX based aluminized explosives underwater closed-filed explosions, the scanning photographs along the radial of the charges were gained by a high speed scanning camera. The photographs of two different aluminized explosives underwater explosion have been analyzed, the shock wave curves and expand curves of detonation products were obtained, furthermore the change rules of shock waves propagation velocity, shock front pressure and expansion of detonation products of two aluminized explosives were investigated, and also the parameters of two aluminized explosives were contrasted. The results show that the aluminized explosive which with nano-aluminum whose initial shock waves pressure propagation velocity, shock front pressure are smaller than the aluminized explosive without nano-aluminum and has lower decrease rate attenuation of energy.

1 Introduction

Aluminized explosives is a kind of high-density, high-power high-explosive heat of mixing explosives, damaging effects on the target can be increased, which has important applications in underwater weapons, air weapons and armor charge [1], especially in the underwater explosion the aluminized explosive shock wave and bubble can significantly higher than non-aluminized explosives. The aluminized explosives detonation is not ideal detonation process, for the aluminum involved in the reaction [2], the content of aluminum powder, particle size, shape and activity will effect on the detonation process and produces a large charge influence [3]-[4], therefore, such as the impact of ultrafine particles of aluminum nanopowders of aluminized explosive properties, becoming one of hot research. The effect of Nano-aluminum on aluminized explosives near field underwater explosion characteristics can provide important reference for the water weapons design and the power assessment.

Much research has been carried out on the impact of nano-aluminum aluminized explosive properties and the characteristicsof aluminized explosives for underwater explosions predecessors. Huang Hui, etc.through studied, found that thenano-aluminum composite explosiveshave stronger ability of metal acceleration, and the reaction time is more short [5]; Shen Fei, etc.have studied different aluminum-containing explosive shock wave propagation in water near field, and the results were compared with TNT, it showed the pressure decay process, the reaction of aluminum makes shock wave pressure decay rate has been reduced [6]; Zhou Lin, etc. By measuring and analyzing different types of aluminized explosives in underwater explosion energy output parameters, given the different types of aluminized explosives underwater explosion energy output characteristics [7]. However, there is little literature available on the nano-aluminum aluminized explosives underwater explosion characteristics.

In this study, a series experimental investigation were done to characterize the effects of nano-aluminum powder on the shack wave pressure decay and bubble expansion speed of aluminized explosives .

Table 1. The samples composition of aluminized explosives

Serial number	RDX	Micron Al	Nano Al	Binder	Density/(g/cm3)
ES-1	65%	30%	—	5%	1.80
ES-2	65%	20%	10%	5%	1.80

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2 Experiment

2.1 Experimental samples

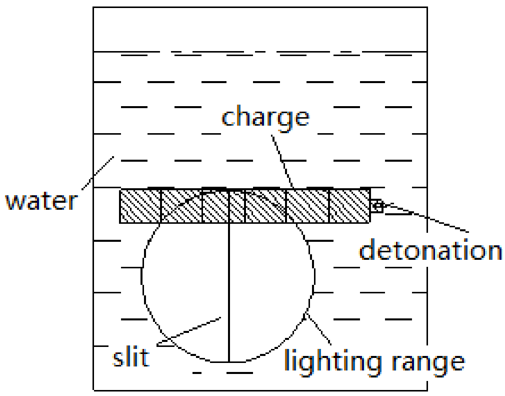
The experiment used ES-1, ES-2 two aluminized explosives formulation as shown in Table 1, wherein the nano-aluminum powder particle size: 100-200nm, chargewas collected press-fit shape, with section Φ30mm × 30mm, the main charge by the six charge bonded together, the total charge length of 180mm. TheΦ25mm × 25mm, crimping density of 1.67g / cm^3 of JH-14 used as a Booster, Booster paste in the end position of the center of the main charge.

2.2 Experimental testing principle

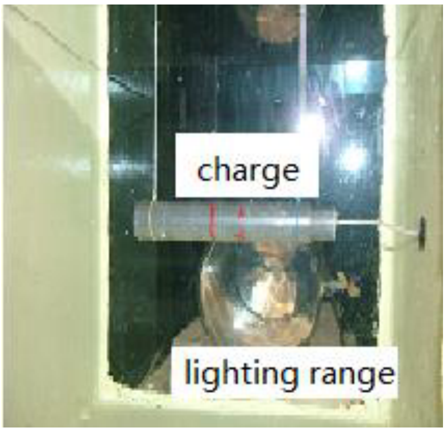
Strong shock waves generated by underwater explosives detonation, which will produce severe compression of its aqueous medium at a spread, so that the density of the water medium increases, resulting in greatly reduced transmittance. Thus, the shock wave went, it will form a dark layer in an aqueous medium. An argon bomb explosion,which Placed in the rear of the tank, as a light source, in the shock wave went dark layer blocking the light which emitted from the light source, while the track movement of the dark layer is recorded by the high-speed scanning camera[8].

2.3 Experimental device and layout

The cube tank used for the experiment with 400mm side length, between the charge andthe tank cover is connected by wire, adjusting the length of the wire, so that the charge is parallel to the bottom surface of the tank. Employed SJZ-15-type high-speed rotating mirror scanning cameras which scanning speed set to 3mm / μs, the charge axis and high-speed cameras, slits are perpendicular to the optical axis. Φ200mm × 300mm argon gas bombs used as an experimental light source, argon bomb optical axis coincides with the axis of the camera and is located behind the water tank. Experimental layout and photo shown in Fig. 1.



(a) Experimental layout sketch map



(b) Experimental site

Figure 1. Layout of the experiment

3 Experimental results and discussion

3.1 Experimental data processing

The typical scanning trajectory as shown in Fig. 2, as the figure shows, the two moving trajectory obtained, the trajectory of the shock wave spread was faster, while the detonation products bubble boundary spread slower. Combined zoom ratio and camera scanning speed image scanning negatives interpretation, described a series of two traces obtained data points (Fig. 3). As can be seen from the figure, ES-1 shock wave propagation slightly faster than the ES-2, but the expansion curve of the product bubble slower than the ES-2.

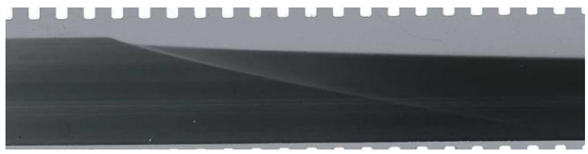


Figure2. Typical scanning trajectory (ES-1)

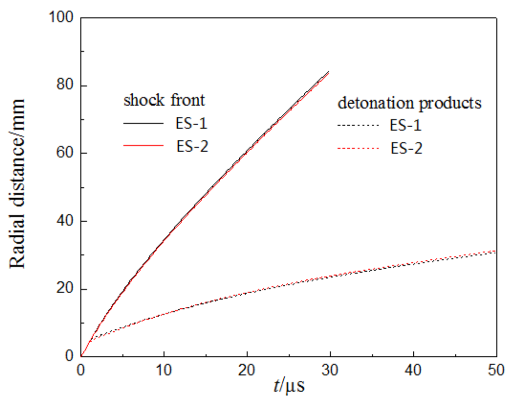


Figure 3. The shock waves and detonation products curves of radial distance-time history

3.2 Shockwave trace analysis

The nonlinear function Can be used to fit the experimental data of the shock wave propagation trace [9], the specific form of the function as follows:

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$$y_1 = A_1[1-\exp(-B_1 t)] + A_2[1-\exp(-B_2 t)] + c_0 t \qquad (1)$$

wherein, y_1 represents the propagation distance of the shock wave along the axial direction of the charge, mm; c_0=1.483mm/μs, represents the velocity of sound in the water; trepresents time, μs; A_1, A_2, B_1, B_2 on behalf of the fitting parameters. Equation (1) can better reflect the law of shock waves propagation in the water, Table 2 shows the fitting parameters.

Table 2. Fitting coefficients

explosives	A_1 /mm	B_1 /(1/μs)	A_2 /mm	B_2 /(1/μs)
ES-1	8.426	2.141×10-1	83.059	1.619×10-2
ES-2	8.269	2.089×10-1	82.689	1.596×10-2

In order to obtain the propagation velocity of the shock wave, the equation (1) derivative of time t:

$$u_s = \mathrm{d}\,y_1/\mathrm{d}t = A_1 B_1 \exp(-B_1 t) + A_2 B_2 \exp(-B_2 t) + c_0 \qquad (2)$$

The Pressure of shock wave front p_s get according to the impact of water adiabatic equation and momentum conservation relations,

$$u_s = c_0 + 25.306\lg(1+u_p/5.19) \qquad (3)$$

$$p_s = \rho_{w0} u_s u_p \qquad (4)$$

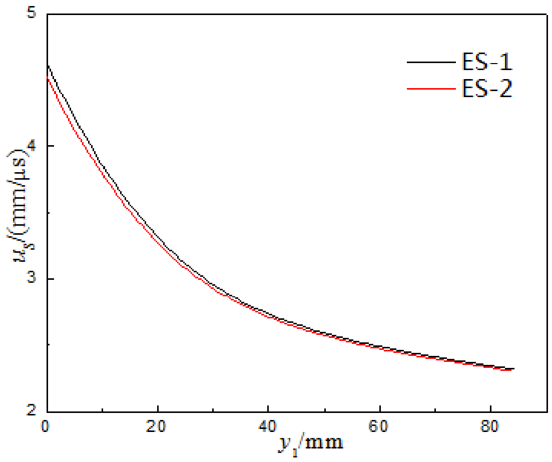

Figure 4. Velocity-distance history of the shock waves

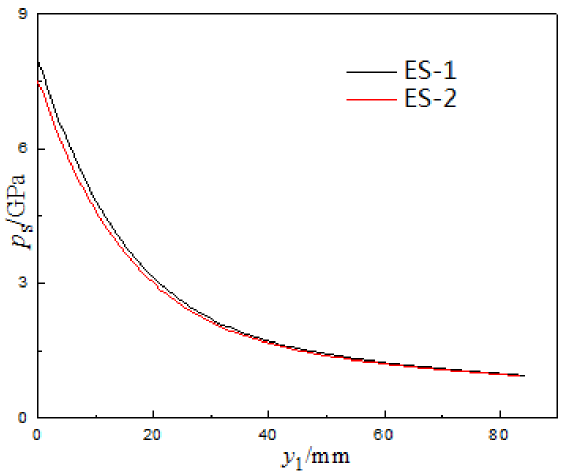

Figure 5. Pressure-distance history of the radial shock waves

wherein, u_p indicates the particle velocity, mm / μs; ρ_{w0} indicates the density of the water, which value is 1.0g / cm3. Using the formula (2) - (4) to calculate the shock wave propagation velocity u_s and pressure p_s, where along the charge radial in the near field underwater explosion, with the variation of the propagation distance, the graphs shown in Fig. 4 and Fig. 5, at the same time, the initial values of these parameters are shown in Table 3 below.

Table 3 Initial parameters of radial shock waves

explosives	u_{s0} /(mm/μs)	u_{p0} /(mm/μs)	p_{s0} /GPa
ES-1	4.63	1.72	7.97
ES-2	4.53	1.66	7.51

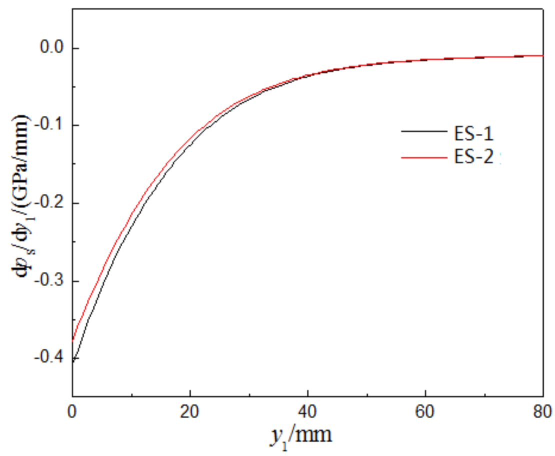

Figure 6. Pressure attenuation rate of radial shock waves

The initial shock of the pressure front is mainly affected by the explosion pressure of the explosives, propagation velocity is mainly determined by the value of the surface pressure, since the ES-2 containing nano-aluminum, its detonation velocity and pressure has declined compared ES-1 Therefore at the beginning of underwater explosion, ES-2's shock wave front propagation velocity and pressure were slightly lower than the ES-1. However, there are accompanied by a shock wave propagation wavefront energy dissipation, the main part of the kinetic energy of the shock wave irreversible converted into medium heat, pressure and shock wave front, the higher the greater the energy dissipation. As can be seen from Fig. 4 and Fig. 5, ES-1, although the curve value higher than the initial period ES-2, but the energy loss is higher than the ES-2, after a short propagation distance, it is very close to the value of the two curves .Front pressure decay rate curve shown in Fig. 6 also shows that, when the propagation distance is about 40mm, front pressure decay rate will be almost identical.

4 Conclusion

The shock wave propagation traces observed byHigh-speed scanning camera from the radial of the cylindrical charge can more accurately calculate the propagation velocity and attenuation of the shock wave pressure in the explosion near field. The ES-2 explosive, which Contained nano-aluminum powder ,whose initial propagation velocity and pressure of the shock wave are smaller compared to the ES-1explosive, but its decay rate of energy and pressure is relatively low, resulting in the propagation distance of about 40mm when two explosive fronts pressure will be more similar.

According to the experimental data, the explosive containing nano-aluminum powder, the energy and pressure decrease with increasing distance, but the attenuation rate is lower than that without aluminum explosive, so the underwater explosion operations used in explosives, explosives should be determined according to the actual needs of the aluminum content. Within 40mm, such as the need for higher pressure, it should be used without nano-aluminum powder, such as the need to slow the pressure of explosives, it is necessary to use nano-aluminum containing explosives. When the distance is greater than 40mm in the working environment, whether or not the aluminized explosives aluminized explosive, its effect is basically the same.

In military applications, especially large-scale torpedo warhead, because the explosive contains nano-aluminum can increase the loading density of explosive in warhead, and increase the heat generation after the explosive reaction, when the warhead in thin-walled shell structures such as ships, can give full play to the power of aluminized explosives.

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