IOP Conf. Series: Earth and Environmental Science **128** (2018) 012137 doi:10.1088/1755-1315/128/1/012137

Experimental study on the influence of chemical sensitizer on pressure resistance in deep water of emulsion explosives

Lei Liu[1], Zhihua zhang[1], Ya Wang[1], hao Qin[1]

[1]Kunming University of Science and Technology, Kunming 650093, China

E-mail: 1094099704@qq.com

Abstract. The study on the pressure resistance performance of emulsion explosives in deep water can provide theoretical basis for underwater blasting, deep-hole blasting and emulsion explosives development. The sensitizer is an important component of emulsion explosives. By using reusable experimental devices to simulate the charge environment in deep water, the influence of the content of chemical sensitizer on the deep-water pressure resistance performance of emulsion explosives was studied. The experimental results show that with the increasing of the content of chemical sensitizer, the deep-water pressure resistance performance of emulsion explosives gradually improves, and when the pressure is fairly large, the effect is particularly pronounced; in a certain range, with the increase of the content of chemical sensitizer, that emulsion explosives' explosion performance also gradually improve, but when the content reaches a certain value, the explosion properties declined instead; under the same emulsion matrix condition, when the content of NANO2 is 0.2%, that the emulsion explosives has good resistance to water pressure and good explosion properties. The correctness of the results above was testified in model blasting.

1. Introduction

The study on the deep-water pressure resistance performance of emulsion explosives can provide theoretical basis for underwater blasting, deep-hole blasting and emulsion explosives development. Domestic and foreign scholars have done a large research on emulsion explosives resistance capability to deep water pressure. Xueqiang Liu studied emulsion explosives' detonation and resilience under static pressure. The detonation velocity under pressure on the detonating time reduced with the increase of the pressure, until the detonation was suspended or misfired, and with the extension of storage period, the pressure resistance decreased dramatically [1]. Yang Mingang through the experimental study on the static pressure effect on the properties of emulsion explosive, and the results showed that pressure increases, density increases, the gap distance is on the decline [2]. Lei Liu did the preliminary study on the deep-water pressure resistance property of emulsion explosives in a disposable explosion experiment device, a reusable experimental apparatus and blasting experimental models[3~5]. The studies on emulsion explosives by domestic and foreign scholars under the static pressure are mainly confined in the qualitative phase, and the research of deep-water pressure performance of emulsion explosives is especially rare. The sensitizer is the important component of emulsion explosives [6], so the study on the influence of the chemical sensitizer on the deep-water pressure resistance property of emulsion explosives is of great significance.

2. Experiments

2.1. Experimental principles

The total pressure received by underwater charge is the sum of the atmospheric pressure on the still water surface and the hydrostatic pressure. Charge environment under deep water in this experiment is simulated through changing the atmospheric pressure on the still water surface. Since the size of the experiment device is very small, water depth can be neglected. When adding 2 atmospheres on the still water surface, underwater charge would receive a 20 m high water column pressure.

2.2. Experimental device

The experimental device is shown in Figure 1. At the blasting moment, the rubber gaskets between ends sockets and the barrel are broken, decompressing to protect the experiment system from being destroyed by high pressure and high temperature. Using this experimental device would make less damage to the surrounding environment. Disadvantages: this experiment device requires relatively large labor intensity, and it needs a relatively longer time in one experiment. The experimental device test system has been successfully applied for a national utility model patent [7].

Figure 1. Experimental device.

2.3. Experimental scheme

After a series of experiments, and with underwater blasting practices, the test scheme of the resistance performance of emulsion explosives under deep water pressure is ultimately determined, choosing the following pressure points, 0.0MPa, 0.1MPa, 0.3MPa, 0.5MPa, and testing the brisance 3 times at each pressure point. The content of sensitizer in emulsion explosives is based on the industry production reality and relevant scientific literature, and the contents of NANO2 are chosen at 0.1%、0.2%、0.3%.

3. Experiment result and treatment

3.1. Characterization method of explosives' pressure resistance performance under pressure

Emulsion explosive’s pressure resistance performance is characterized by showing its drop degree with and without the pressure. If the drop degree is small under a certain pressure, it would mean its pressure resistance performance is good. If the drop degree is big, it would mean its performance is bad.

When using brisance to calculate emulsion explosives' pressure resistance performance, the following formula is applied:

$$\theta=\left(H_0-H\right)/H_0 \tag{1}$$

in which, H_0 is the explosive’s brisance without pressure (in mm); H is the explosive's brisance under pressure (in mm).

$$\theta_0=\left(H_0-H_0\right)/H_0=0,\ \theta_1=\left(H_0-H_{misfire}\right)/H_0=\left(H_0-0\right)/H_0=1$$

3.2. Experimental data processing and analysis

The test results of the pressure resistance performance of emulsion explosives with NANO2 as the sensitizer under deep water and the data processing results are shown in Table 1, and the curves based on the processing results are shown in Figure 2 and Figure 3.

Table 1. Influence of the content of NANO2 on emulsion explosives' pressure resistance performance under deep water.

Explosive No.	Sensitizer	Amount	Pressure /MPa	H_1	H_2	H_3	H	θ（%）
1#	$NANO_2$	0.10%	0.0	18.28	18.74	19.17	18.73	0.00
			0.1	14.68	13.79	14.36	14.28	23.76
			0.3	11.39	11.47	11.84	11.57	38.23
			0.5	10.86	10.35	9.32	10.18	45.65
2#	$NANO_2$	0.20%	0.0	18.54	18.87	20.23	19.21	0.00
			0.1	14.19	14.56	15.84	14.86	22.64
			0.3	11.67	12.24	12.47	12.13	36.86
			0.5	10.85	10.23	10.96	10.68	44.40
3#	$NANO_2$	0.30%	0.0	17.92	18.34	19.22	18.49	0.00
			0.1	14.42	13.46	14.82	14.23	23.04
			0.3	11.86	11.53	12.08	11.82	36.07
			0.5	10.77	10.62	10.81	10.73	41.97

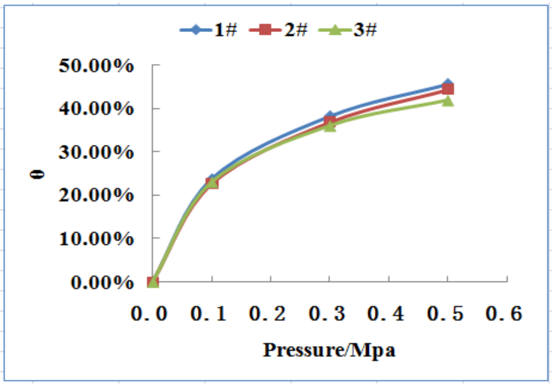

Figure 2. θ and pressure curve of Explosive 1#～3#

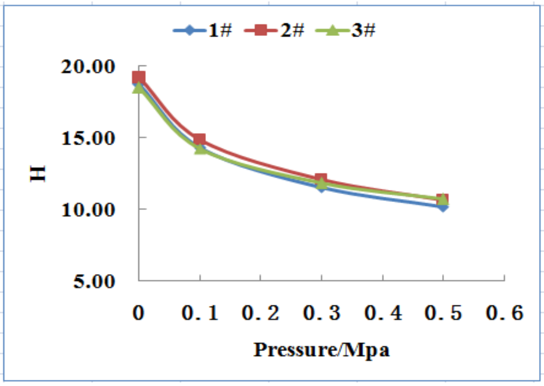

Figure 3. H and pressure curve of Explosive 1#～3#

According to Figure 2, the pressure resistance performances of the 3 explosives are similar at the beginning part. When the pressure increases to a certain degree, the resistance performance order is 3# is better than 2#, and 2# is better than 1#, but their curves are quite close, which means with the increase of $NANO_2$, the pressure resistance grows but not obvious. According to Figure 3, the detonation property of 2# is the best, the curves of 1# and 3# are almost coincident. Overall, the three curves are quite close, which means when the content of NANO2 increases to a certain amount, the increase of $NANO_2$ would have little influence on explosives' detonation property.

4. Model blasting test experiment

4.1. Experimental principle
Put the micro explosion device in the hole of mortar test blocks, add the rated pressure and then detonate, as shown in Figure 4. Apply the distribution function model G-G-S of blasted rock mass to analyze the received data [8].

4.2. Experimental scheme
In the model blasting test experiment, Explosive 2# is used since its best pressure resistance performance. For the sack of comparison, pressure spots are chosen as the experiment above. Because of the large workload in the experiment, each pressure spot is tested twice. Based on huge documents and on-site experiments, the charge amount of the tested explosive is 20g. The size of the mortar block is 500×400×300mm. The diameter of the reserved hole in the test model center is 33mm, and the depth is 17mm.

4.3. Characterization methods of the explosive's pressure resistance performance in the model blasting
In the model experiment of blasting, Evenness Indexes n, Fractal Dimension D, Broken Probability f, Average Broken Degrees K50, Large Lumpiness Rate K80 could all be used as instructions to quantitatively research the declination of explosion property under compression. With overall consideration, Fractal Dimension D is chosen to calculate the drop value of the explosive's explosion property, and the drop value is expressed in the following function:

$$\omega=\left(D_0-D\right)/D_0 \tag{2}$$

in which, D_0 is the fractal dimension of the block when the explosive is not under pressure, and D_0 is the fractal dimension of the block when it is under pressure.

$$\omega=\left(D_0-D_0\right)/D_0=0,\ \omega_1=\left(D_0-D_{misfire}\right)/D_0=\left(D_0-0\right)/D_0=1.$$

4.4. Experimental data processing and analysis
The test results and data processing results are shown in Table 2, and the curves based on the results are in Figure 5. When ω or θ is used to calculate the drop degree of explosives' pression resistance performance, their variation trends to the same kind of explosives are similar. The two test methods could commendably verify each other. That Curve θ is above Curve ω means the drop degree of explosives' explosion property characterized by θ is larger than that by ω. The reason may be that during the experiment, the pressurization is only conducted to the explosive, not to the concrete test model.

Table 2. G-G-S distribution regression calculation results of blasting models with explosives exploding under different pressure

Pressure/MPa	Test No.	n	D	f(r=1/2)	K50	k80
	A	1.4535	1.5465	0.3651	21.3	29.4
0.0	B	1.4089	1.5911	0.3766	20.5	28.7
	Average value	1.4312	1.5688	0.3709	20.9	29.1
	A	1.7010	1.2990	0.3076	22.4	29.6
0.1	B	1.6969	1.3031	0.3084	22.5	29.7
	Average value	1.6990	1.3011	0.3080	22.5	29.7
	A	1.8422	1.1578	0.2789	23.2	30.0
0.3	B	1.7863	1.2137	0.2899	22.9	29.8
	Average value	1.8143	1.1858	0.2844	23.1	29.9
	A	1.9058	1.0942	0.2669	23.4	30.0
0.5	B	1.9893	1.0107	0.2519	23.0	29.1
	Average value	1.9476	1.0525	0.2594	23.2	29.6

IOP Conf. Series: Earth and Environmental Science **128** (2018) 012137 doi:10.1088/1755-1315/128/1/012137

Figure 4. Experimental device

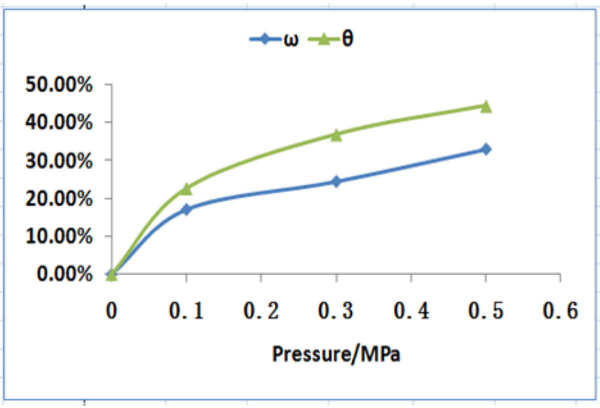

Figure 5. Comparison of Curve θ and Curve ω of Explosive 2#

5. Theoretical analysis of pressure resistance performance

To Emulsion Explosives with the chemical sensitizer, bubbles as sensitizing points play an important role in explosion. Under the static pressure, the contraction of bubbles is a significant reason for the degradation of emulsion explosives' pressure resistance performance. The static pressure presses bubbles through the emulsion matrix. The experiment finds that the emulsion matrix is a non-Newtonian fluid. It has certain shearing resistance ability, so it could not transmit pressure as well as the Newtonian fluid. When the bubble diameter is very small, the pressure resistance ability of the emulsion matrix around the bubble is enhanced, so the pressure transmission would become difficult. Therefore, the emulsion matrix around small bubbles under the static pressure bears most of the pressure, protecting the bubbles to some extent. In this way, big bubbles bear more pressure than small ones and big bubbles are adiabatically compressed larger than small ones. It would be very difficult for tiny bubbles to form "hot spots". Under the static pressure, the original effective sensitizing bubbles lose their sensitization effect with the loss of volume, so "Hot spots" reduce greatly. The temperature increase value of unexploded explosives caused by shock waves' pressure effect reduces, slowing down the reaction rate and the reaction efficiency of the reaction zone, directly leading to the reduction of explosives detonation property. Obviously explosives' press ion resistance performance would decline accordingly.

With the increase of the content of NANO2 from 0.1 % to 0.2%, the explosion property and the pression resistance performance of explosives have improved, but not improved obviously. The main reason is that when the content of NANO2 is too large, there would produce many invalid big bubbles, which leads to the increase of bubble escaping, so that the increase of "hot spots" would be not obvious. When the content of NANO2 is up to 0.3%, on the one side, the continuous increase of "hot spots" is benefit for explosives pression resistance performance and chemical reaction rate, but on the other side, with the reduction of emulsion matrix per unit volume to a certain degree the chemical reaction rate would decline according. The contribution of the increase of "hot spots" to the chemical reaction rate cannot compensate for the loss by the decrease of emulsion matrix content per unit volume, leading to the declination of explosives' explosion property.

6. Conclusions

In a comprehensive view, with the increase of the content of the chemical sensitizer, the pressure resistance performance of emulsion explosives improves gradually, and the improvement is particularly stark when the pressure is large enough. In a certain range, with the increase of the content of the chemical sensitizer, the detonation property of emulsion explosives is also improved, but when the sensitizer's content increases to a certain value, the detonation property declines instead. Therefore,

IOP Conf. Series: Earth and Environmental Science **128** (2018) 012137 doi:10.1088/1755-1315/128/1/012137

as long as the content of the chemical sensitizer is proper, both good detonation property and good pressure resistance performance can be guaranteed.

References

[1] Xueqiang Liu 1993 Emulsion explosives under static detonation and resilience research[C]. *National Engineering Blasting Fifth Annual Academic Conference* China University of Geosciences press 319-321
[2] Yang Min-gang 1994 Static pressure on the performance of emulsion explosives Test Study on the influence of blasting equipment [J] 1-5
[3] Lei Liu, Xu-guang Wang, Yi Yang 2010 Experimental Study on Compression Resistance of Deep Water of Emulsion Explosives [J] *BLASTING* **27(2)** 10-13
[4] Lei Liu, Hanglong Wang, Xvguang WANG 2012 Experimental Equipment Study on Compression Resistance Performance of Explosives [J] *Advanced Materials Research* Vols. **524** 562-568
[5] Lei Liu, Xu-guang Wang, Yi Yang 2012 Experimental Method Study on Emulsion Explosives under Hydrostatic pressure in Models Blasting [J] *Advanced Materials Research* Vols. **524** 569-574
[6] Xu-guang Wang 2008 *Emulsion explosives* [M] (Beijing: Metallurgical Industry Press) pp 127-168
[7] Yi Yang, Liu Lei, Xu-guang Wang A reusable explosive device which can test underwater brisance The utility model patent, notice of authorization number: CN2015558440
[8] Zhang Ji-chun 2001 *The Rock Mass Blasting Block Theory andApplies* [M](Chengdu: Southwest Jiaotong University Press) pp 40-52