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STUDY OF NANO-NITRAMINE EXPLOSIVES: PREPARATION, SENSITIVITY AND APPLICATION

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Abstract

Nano-nitramine explosives (RDX, HMX, CL-20) are produced though grinding the micron-sized particles on a bi-directional mill. Compared with the micron-sized samples, the nano-products show obvious decrease in friction and impact sensitivities. In the case of shock sensitivities, nano-products have lower values by 59.9%(RDX), 56.4%(HMX), and 58.1%(CL-20), respectively. When nano-RDX and nano-HMX are used in plastic bonded explosives(PBX) as alternative materials of micron-sized particles, their shock sensitivities are significantly decreased by 24.5%(RDX) and 22.9%(HMX), and their detonation velocities are increased by about 1.7%.

Key words: Nano-nitramine explosive, PBX, sensitivity, detonation velocity, application

1. Introduction

The brisant nitramine explosives (RDX, HMX and CL-20) have high detonation heat, detonation velocity and detonation pressure. They have been extensively used in plastic bonded explosives (PBXs) and propellants. However, the micron-sized explosives are very sensitive, which seriously threatens the safety of the ammunitions. The reduction in sensitivity has become a research focus. The studies have shown that the sensitivities of nitramine explosives are affected obviously by the sizes and size distributions of the explosive particles[1-2]. The sensitivities of explosives can be cut down effectively by reducing the particle sizes. If the nano-particles were obtained, the sensitivities would be greatly decreased[3-5].

As an inspiring fact, nano-RDX and nano-HMX, which are characterized by regular shapes and narrow size distributions, have been produced in batch using a wet ball mill, and the prepared nano-sized particles can be effectively extracted by freezing drying[6-7]. Based on these experiences, nano-CL-20 had been successfully produced and effectively extracted. The sensitivities and explorative applications of the three nitramine explosives are researched in this paper.

2 Experimental

2.1 Sample Preparation

2.1.1 Preparation of Nano nitramine explosives

Micron-sized RDX and HMX are separately suspended in a miscible liquid which is a mixture of deionized water, ethanol and isopropanol, with the volume ratio of 10:10:1. Micron-sized CL-20 is suspended in water. Their mass concentrations are 15%.

The three nitramine explosives (RDX, HMX and CL-20) of 500-1000 grams are processed at a time respectively, and their suspensions are put into a bi-directional rotation mill[8] , of which the axle and the barrel rotate reversely and simultaneously, for 6h, 5h and 4h, respectively. The

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pulverized slurries are freezingly dried and the product yields are about 97%.

2.1.2 Preparation of PBX samples

The explosives are coated by slurry technique. RDX is coated with dinitrotoluene (DNT), polyvinyl acetate (PVAc) and stearic acid (SA,). The mass percentage of RDX: DNT: PVAc: SA is 94.5: 3: 2: 0.5. HMX is coated with fluororubber Viton (F), polymethyl methacrylate (PMMA) and wax. The mass percentage of HMX: F: PMMA: wax is 95: 3: 0.8: 1.2.

2.2 Test of Sensitivities and Detonation Velocities

2.2.1 Sensitivity test of pure nitramine explosives

The friction sensitivities are measured by sliding friction test at 3.92 MPa (RDX, HMX) and 2.45 MPa (CL-20). Fifty tests are carried out to obtain the mean explosion probability ($\bar{P}$, %).

The impact sensitivities are measured by drop-hammer test and characterized by the characteristic heights (50% probability of initiation ($\overline{H}_{50}$)), which are statistically calculated by 25 effective test values obtained by using a 2.5kg drop-hammer.

The small scale gap test (SSGT) is selected to measure the shock sensitivities. The gap thicknesses (δ) are calculated by 25 effective values.

2.2.2 Shock sensitivity tests of PBX samples

The shock sensitivities of PBX samples are measured by the gap tests. The gap thicknesses (δ) are calculated by 25 effective values.

2.2.3 Detonation velocity tests

The detonation velocity is tested by ionized probe method, as shown in Fig.1, and the detonation velocities are calculated by 5 effective values.

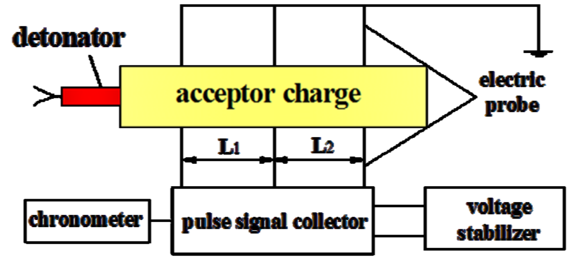

Figure 1. Schematic diagram of set-up for detonation velocity test.

2.3 Symbols and Abbreviations

M-: Micron-sized explosives; N-: Nano-sized explosives;

M-RDX: Micron-sized RDX; N-RDX: Nano-sized RDX; M-HMX: Micron-sized HMX; N-HMX: Nano-sized HMX; M-CL-20: Micron-sized CL-20; N-CL-20: Nano-sized CL-20.

P-M-: M-contained PBX samples; P-N-: N-contained PBX samples.

P-M-RDX: M-RDX-contained PBX sample; P-N-RDX: N-RDX-contained PBX sample; P-M-HMX: M-HMX-contained PBX sample; P-N-HMX: N-HMX-contained PBX sample.

3 Results and Discussion

3.1 Particle Size Distributions and SEM Images

The particle size distributions and SEM images of explosives are shown in Fig.2-4.

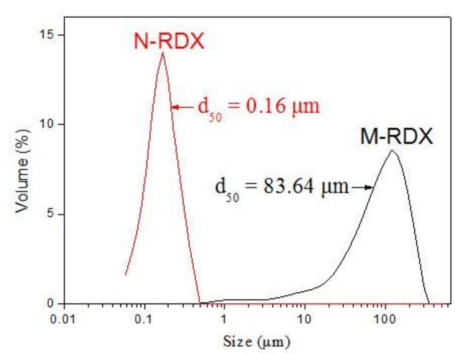

Figure 2. The size distributions of RDX particles.

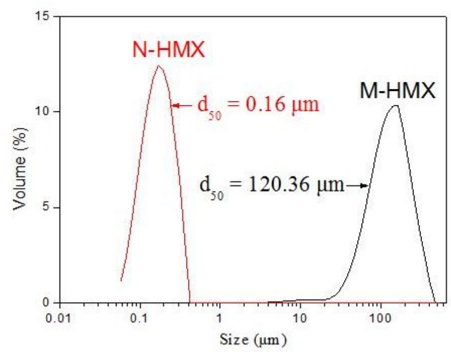

Figure 3. The size distributions of HMX particles.

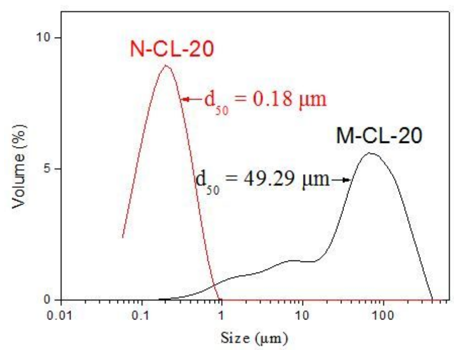

Figure 4. The size distributions of CL-20 particles.

As shown in Fig.2-4, the average particle sizes of micron-sized RDX, HMX and CL-20 are 83.64 μm, 120.36 μm and 49.29 μm with wide size distributions, and the average sizes of the nano-sized particles are 0.16 μm, 0.16 μm and 0.18 μm with narrow size distributions, respectively.

3.2 Sensitivities of Pure Nitramine Explosives

The friction, impact and shock sensitivities of pure RDX, HMX and CL-20 samples are listed in Table 1-3.

Table 1. The friction sensitivities.

Sample	$\bar{P}$ /%
M-RDX	80
N-RDX	50
M-HMX	86
N-HMX	58
M-CL-20	88
N-CL-20	66

As listed in Table 1, compared with the micron-sized samples, the fiction sensitivities, are decreased by 30%, 28% and 22%, respectively.

Table 2. The impact sensitivities.

Sample	$\overline{H}_{50}$ /cm	$S_{dev.}$
M-RDX	49.8	0.14
N-RDX	99.1	0.13
M-HMX	44.1	0.15
N-HMX	63.0	0.09
M-CL-20	13.6	0.11
N-CL-20	29.4	0.09

As listed in Table 2, compared with the micron-sized samples, the shock sensitivities of RDX, HMX and CL-20 are decreased by 99.0%, 42.8% and 116.2%, respectively.

Table 3. The shock sensitivities.

Sample	δ /mm	$S_{dev.}$
M-RDX	15.38	0.41
N-RDX	6.17	0.32
M-HMX	13.96	0.40
N-HMX	6.08	0.32
M-CL-20	43.72	0.42
N-CL-20	18.31	0.35

As listed in Table 3, compared with the micron-sized samples, the shock sensitivities of RDX, HMX and CL-20 are decreased by 59.9%, 56.4% and 58.1%, respectively.

3.3 Sensitivities of PBX Samples

The shock sensitivities of PBX samples are listed in Table 4.

Table 4. The shock sensitivities of PBX samples.

PBX sample	δ /mm	$S_{dev.}$
P-M-RDX	24.65	1.32
P-N-RDX	18.60	1.24
P-M-HMX	23.74	1.19
P-N-HMX	18.31	1.02

As listed in Table 4, compared with P-M-RDX and P-M-HMX, the shock sensitivities of P-N-RDX and P-N-HMX are 24.5% and 22.9% lower, respectively.

3.4 Detonation Velocities of PBX Samples

The detonation velocities of PBX samples are listed in Table 5.

Table 5. The detonation velocities of PBX samples.

PBX sample	*v /(m/s)*	$S_{dev.}$
P-M-RDX	7850	29.58
P-N-RDX	7980	28.27
P-M-HMX	8120	27.57
P-N-HMX	8260	25.80

As listed in Table 5, compared with P-M-RDX and P-M-HMX, the detonation velocities of P-N-RDX and P-N-HMX are enhanced 1.66% and 1.72%, respectively.

4 Conclusions

Nano-sized nitramine explosives were successfully produced. Compared with the micron-sized RDX, HMX and CL-20, the friction, impact and shock sensitivities of the nano-sized explosives are apparently decreased. When RDX and HMX are used in PBXs, the shock sensitivities of the nano-sized particle-contained samples are still obviously lower than those of the micron-sized particle-contained samples.

The detonation velocities of the nano-sized particle-contained samples are higher than those of the micron-sized particle-contained samples, which could be benefitted from the larger specific surface area of the nano-sized particles. It is promising to promote the applications of nano-nitramie explosives in PBXs and CMDBs so that some of their properties would be improved.

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