Effect of Processing and Aging on Particle Size of Explosives

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Influence of such processes as molding powder production, pellets pressing and aging under different conditions on particle size of TATB (1,3,5-triamino-2,4,6-trinitrobenzene) and HMX (cyclotetramethylenetetranitramine) was experimentally studied. The results showed that particle size of these explosives was greatly changed before and after molding powder production, but for different size grade of explosive this change was not the same; pressing process had also great effect on explosive particle size, but before and after ageing process explosive particle size did not change seriously.

Keywords molding powder production, pressing, aging, particle size, explosive

Introduction

Influence of particle size of explosive on energy release, safety, detonation performance, mechanical properties and shell life of the explosive formulation is obvious. Kim[1] pointed out that explosive particle size had great effect on mechanical performance of explosive formulation in the study of methods to improve mechanical properties by neutral polymer coupling agent. The reason is that dewetting work τ_a is a function of explosive particle size.

$$\tau_a = 4\pi C_{\tau a} E/3r$$

where $C_{\tau a}$ is bond fracture energy per unit area, E Young's modulus and r average radius of the particles.

Gifford *et al*.[2] demonstrated that ultrafine pentaerythritoltetranitrate (PTEN) was more sensitive to short pulse shock wave (laser flyer) than conventional PTEN, while to long pulse (gap test), the result was converse. It was also found that explosive particle size greatly affected the properties of deflagration-to-detonation transfer.

Owing to different particle size, the density and specific area are quite different, which directly lead to the density difference of pressing pellets, accordingly affect detonation performance (detonation velocity and detonation pressure):

$$D = A\Phi^{1/2}(1 + B\rho_0), \quad P = K\rho_0^2\Phi, \quad \Phi = NM^{1/2}Q^{1/2}$$

where D is detonation velocity (km/s), P detonation pressure (kPa), ρ_0 initial density of explosive (g/cm^3), N mole number of gaseous detonation products per gram of explosive, M average molecular weight of gaseous detonation products, Q chemical energy of the detonation reaction (J/g), A, B, K constants.

Particle size also greatly affects on thermal stability[3] and sensitivity.[4] The literature indicates that coarse 1,3,5-trinitro-1,3,5-triazacyclohexane (RDX) propellant is more sensitive and burns appreciably faster than finer RDX formulations.[5] These facts can be explained by "hot spot" initiation mechanism, because for explosive particles, differences in particles lead to different porosity, surface roughness and imperfections, which lead to different reactions to heat and shock, that is to say, thermal stability and sensitivity are not the same. Therefore, particle size of explosive is one of main factors which should be considered while studying explosive formulations and production process designing.

In this paper effect of such processes as molding powder production, pellets pressing, aging on particle size of 1,3,5-triamino-2,4,6-trinitrobenzene (TATB) and cyclotetramethylenetetranitramine (HMX) was studied to learn how these processes would affect performance of formulation.

Experimental

Explosive preparation

TATB (fine TATB, called f-TATB below) was prepared by ourselves and its average particle size was about 16 μm. TATB was milled mechanically (micron TATB, called m-TATB) for 32 h and its average particle size was about 6.2 μm. Sub micro TATB was obtained by gas-flow milling and average diameter of which was about 0.5 μm (submicron TATB, sub m-TATB).

Fine HMX (named f-HMX) was commercial product and its average diameter was about 16 μm. f-HMX was milled mechanically for 32 h and its average particle size became 6.7 μm (called micron HMX, m-HMX).

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Molding powder production

Binder used was fluororesin (called F) which was commercially available. The molding powder production method was: fluororesin was dissolved in ethyl acetate, then added to mixture of explosive and water at a certain rate. The mixture was stirred and heated. When the diameter of powders was close to the needed value, filtered it and dried it.

Pellet pressing

Pellets used in the study of the particle size change of explosive before and after pressing were pressed by machine. Pressing parameters including temperature, pressure and time of keeping pressure were changed to learn the effect of pressing conditions on particle size of explosive.

Analysis of particle size

Ethyl acetate and THF were used to dissolve fluororesin in molding powder and pellet. After that, filtered the mixture and measured explosive particle size with a laser particle apparatus.

Results and discussion

Explosive particle size obtained by different methods

Explosive particle size obtained by different methods is listed in Table 1.

Table 1 Average particle size of TATB and HMX

Type	Particle size of TATB (μm)	Particle size of HMX (μm)
fine	16.45	16.32
micron	6.164	6.729
submicron	0.490	—

Effects of molding powder production on explosive particle size

(A) *Particle size change after molding powder production* Molding powder of several particle grades TATB and HMX were produced and the analysis results of particle size are listed in Table 2. From Table 2 it could be seen that particle diameter of f-TATB became smaller after production, but the growth of m-TATB and sub m-TATB was quite large after production, especially submicron TATB grew very seriously. During the molding powder production, some sub micron TATB particles got together and became larger particles, therefore great changes of particle size were observed. For f-HMX and m-HMX, their crystal size grew up twice and 1.4 times respectively after becoming molding powder, as m-TATB and sub m-TATB did.

Table 2 Particle size of TATB and HMX before and after molding powder production

Sample	Particle size (μm)	
	Before	After
f-TATB	16.45	13.20
m-TATB	6.164	7.590
sub m-TATB	0.490	0.779
f-HMX	16.32	34.94
m-HMX	6.729	10.15

(B) *Effect of production process conditions on diameter of explosive* The results of effect of production process conditions (temperature, concentration of binder) on diameter of explosive are listed in Table 3.

Table 3 Effects of different molding process conditions on diameter of explosive[a]

Condition	TATB (μm)			HMX (μm)	
	fine	micron	submicron	fine	micron
t = 70 ℃, c = 4%	13.20	7.716	0.490	34.94	9.743
t = 70 ℃, c = 5%	10.29	7.590	0.779	—	10.15
t = 80 ℃, c = 4%	12.00	8.736	0.569	47.08	10.49
t = 80 ℃, c = 5%	13.93	7.373	—	34.85	9.315

[a] t—bath temperature, c—binder concentration.

It is showed from the results that production conditions had some effect on gas-flow milled TATB, but there were almost no influences on other explosives.

Effect of pressing on particles size of explosive

Effect of different pressing conditions (pressure, rate of exerting pressure, temperature) for Φ 20 mm × 20 mm pellets on explosive particle size was studied.

(A) *Effect of pressure* Results of effect of pressure are shown in Table 4. From Table 4 it could be seen that for molding powder explosive after pressing explosive particle size became smaller with the increase of pressure, while for submicron TATB it grew after pressing and increased as increase of pressure. This agreed to the conclusion of Mang *et al*. when they characterized high-explosive system by small-angle neutron scattering.[6] The reasons were, on one hand, while pressing owing to the high pressure (up to 143 MPa even to 334 MPa), the explosive particles contacted each other (very high content), which led to defects inside crystal and explosive crystal collapsed. So did the pure explosives. Therefore, explosive particle size

decrease with pressure increasing. On the other hand, for submicron TATB, inspite of inner defects and crystal collapse, but the absorption effect and TATB plastical property appeared and were very strong, so explosive particle size increased with the pressure increasing.

Table 4 Effect of pressing on explosive particle size

Sample	Pressing force (kN)	Particle size (μm)
f-HMX	45	21.41
f-HMX	55	12.91
f-HMX/F	80	14.89
f-HMX/F	100	10.25
m-HMX/F	80	8.001
m-HMX/F	90	7.486
f-TATB	85	8.341
f-TATB	105	7.420
f-TATB/F	85	11.17
f-TATB/F	105	9.673
m-TATB	85	6.903
m-TATB	105	6.638
m-TATB/F	85	7.091
m-TATB/F	95	6.603
sub m-TATB	85	0.510
sub m-TATB	105	0.816
sub m-TATB/F	85	1.393
sub m-TATB/F	105	1.078

(B) *Effect of exerting pressure time on explosive particle size* Effect of the exerting pressure time from 0 to the needed pressure on explosive diameter was studied. Results are listed in Table 5.

Table 5 Effects of exerting pressure time on particle size

No.	Name	Conditions	Particle size (μm)
1	f-HMX/F	90 kN (30—40 s)	15.20
2	f-HMX/F	90 kN (70—80 s)	18.03
3	f-HMX/F	90 kN (90—100 s)	18.01
4	m-HMX/F	90 kN (30—40 s)	8.337
5	m-HMX/F	90 kN (70—80 s)	8.224
6	m-HMX/F	90 kN (90—100 s)	7.669
7	f-TATB	95 kN (30—40 s)	7.561
8	f-TATB	95 kN (90—100 s)	7.326
9	sub m-TATB	95 kN (30—40 s)	0.503
10	sub m-TATB	95 kN (90—100 s)	0.682
11	m-TATB	95 kN (30—40 s)	5.975
12	m-TATB	95 kN (90—100 s)	6.240

It is indicated from the results that the influence of exerting pressure time on particle size was very small, because the time was very short, and the pressure was the main affecting factor.

(C) *Effects of pressing temperature on particle size of explosive* Warm pressing was the case that while pressing the mold and explosive were heated to 70 ℃ for 1 h. Otherwise pressing at room temperature was called cool pressing. Results of pressing temperature effect are listed in Table 6.

Table 6 Effects of pressing temperature on explosive particle size

No.	Sample	Conditions	Particle size (μm)
1	f-HMX/F	90 kN	16.49
2	f-HMX/F	90 kN (warm pressing)	19.84
3	m-HMX/F	90 kN	7.486
4	m-HMX/F	90 kN (warm pressing)	10.27
5	f-TATB	95 kN	7.883
6	f-TATB	95 kN (warm pressing)	8.288
7	f-TATB/F	95 kN	9.428
8	f-TATB/F	95 kN (warm pressing)	9.492
9	m-TATB	95 kN	7.459
10	m-TATB	95 kN (warm pressing)	6.344
11	m-TATB/F	95 kN	6.603
12	m-TATB/F	95 kN (warm pressing)	7.025
13	sub m-TATB	95 kN	0.503
14	sub m- TATB	95 kN (warm pressing)	0.915
15	sub m-TATB/F	95 kN	0.490
16	sub m-TATB/F	95 kN (warm pressing)	0.593

It is showed from the results that under warm pressing particle size of f-HMX and m-HMX was obviously bigger than that of cool pressing. Pressing temperature had less influence on f-TATB and m-TATB and their molding powders, but had great influence on submicron TATB and its molding powders. The reason was that pressure made sub m-TATB and its molding powder congregated, thus particle size became larger.

Effects of aging on particles size of explosive

The effect of aging of TATB/F for 3 years on explosive particle size was also studied. The results are listed in Table 7.

Table 7 Change of particle size of TATB after and before aging for 3 years

Aging temperature (℃)	Particle size of TATB (μm)	
	Before aging	Aging for 3 years
45	7.561	9.076
55	7.561	9.376
65	7.561	8.392
75	7.561	8.712

Results show that particle size of m-TATB after aging for 3 years at different temperatures only increased a little, so the influence of aging is not obvious. This is very important for its engineering application.

Conclusions

(1) The change of particle size of explosive crystal was very obvious after and before molding powder production, but the extent of change was different for explosive with different particle grade.

(2) Effect of pressing process on particle size of explosive was very great.

(3) Aging did not seriously affect the particle size of f-TATB.

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