Research on Charge Formula Design and Effect of Flash Blast Bomb

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Keywords: Flash blast bomb; Uniform design; Charge recipe; Performance testing; Non-lethal effects

Abstract. In order to enhance power and security performance of flash blast bomb, this paper uses uniform design to desive experimental formula, produces the preparation of the recipe according to flash pyrotechnic production technology, and conducts the flash intensity, sound pressure level and pulse overpressure test, by fragmentation effect test, fragment speed test and shock wave test, we studies on non-lethal effects of flash blast bomb charge recipes quantitatively which provides a reference to assess the effectiveness of non-lethal flash blast bomb.

Introduction

Flash blast bomb produces flash and shock effect which acts on people's physical organs and makes people temporarily incapacitating, it has the effect of reliable, good sound and light effects, the deterrent effect is obvious etc., it is widely applied to the armed police on duty at the sudden and other service. Flash bomb detonation mechanism is to produce a strong flash and shocking sound effects when they are detonated on living target, leading vision loss occurs in a short time, restore hearing impaired physiological responses and head dizziness, etc., which achieves deterrence, dispersing the masses, and controls the situation [1]. However, projectile fragments, overpressure and impulse noise and bright flash light effects generated by explosive have potentially fatal injuries on living target. This paper studies the design and the effect on charge of flash blast bomb to optimize power of light radiation and acoustic pulses, control killing effect of projectile fragments and overpressure, and improve its tactical and technical performance and provide more safe and effective non-lethal weapons for the troops at the sudden duty.

Theoretical Study on Sound and Light Effects of Flash Blast Bomb

Radiation Mathematical Model of Pyrotechnic Flash. At different radiation bands, condensed-phase particles radiant has different emittance, drawing method [2] to calculate the degree of blackbody radiation, we can see the degree of convergence of the condensed phase particles in a band ($\lambda_1 \sim \lambda_2$) is as follows.

$$M_{s(\lambda_1,\lambda_2)} = M_{s(\lambda_2)} - M_{s(\lambda_1)} = \left[F_{(\lambda_2 \cdot T)} - F_{(\lambda_1 \cdot T)}\right] \cdot \bar{\varepsilon}_{\Delta\lambda} \cdot \sigma T^4 \tag{1}$$

The radiant flux of condensed-phase particles is as follows.

$$\Phi_s = A_s \cdot M_{s(\lambda_1,\lambda_2)} = \left[F_{(\lambda_2 \cdot T)} - F_{(\lambda_1 \cdot T)}\right] \cdot \bar{\varepsilon}_{\Delta\lambda} \cdot A_s \sigma T^4 \tag{2}$$

$F_{(\lambda \cdot T)}$ is formula of blackbody radiation function, we can look up through blackbody radiation function [3] table.

Fireball radiation comes mainly from surface radiation of condensed phase particles, so radiant flux of light burning fireball is as follows.

$$\Phi = \left[F_{(\lambda_2 \cdot T)} - F_{(\lambda_1 \cdot T)}\right] \cdot \bar{\varepsilon}_{\Delta\lambda} \cdot A \cdot \sigma \cdot T^4 \tag{3}$$

A is the surface area of the fireball, $\bar{\varepsilon}_{\Delta\lambda}$ is average emission rate of a condensed phase particles in the wavelength range, which is calculated as follows:

$$\bar{\varepsilon}_{\Delta\lambda}=\int_0^{\infty}\frac{\left[N_{D_1}\left(1-\frac{\lambda^2}{2\pi^2D_1^2}\right)+N_{D_2}\left(1-\frac{\lambda^2}{2\pi^2D_2^2}\right)+\cdots N_{D_n}\left(1-\frac{\lambda^2}{2\pi^2D_n^2}\right)\right]\cdot\varepsilon_\lambda M_\lambda d\lambda}{\sigma T^4\sum_{i=1}^{n}N_i} \tag{4}$$

N represents the number of particles with same diameter size, D_i represents i of particle diameter is D.

The radiation intensity of the fireball is as follows.

$$I=\frac{\Phi}{4\pi}=\frac{\left[F_{(\lambda_2\cdot T)}-F_{(\lambda_1\cdot T)}\right]\cdot\bar{\varepsilon}_{\Delta\lambda}\cdot A\cdot\sigma\cdot T^4}{4\pi} \tag{5}$$

Sound Effects of Pyrotechnic Flash. When the pyrotechnic burns intermittently and rapidly, it enables surrounding medium vibrating and sound; when pyrotechnic continuous burns rapidly, it can explode under certain conditions to produce sound; almost all of the pyrotechnic combustion is accompanied by the sound, but the strength and volume of the sound are different.

As we all know, the explosion can produce sound. Explosion sound is due to the disturbed of surrounding gas molecules which produces a sound effect when exploses, it will be bound to promote the process when a burst of energy is released, and produces sound. Pyrotechnic sound effects are mainly due to the explosion and intermittent combustion. Velocity of pyrotechnic detonation is faster, explosion sound is more violent and explosive sound has its inherent tone, but according to different types of pyrotechnic, some voices are "sharp" and some are "rounded." Sound effect of flash blast bomb refers to a large number of gaseous product and heat constraints by the housing when releasing generated by explosion, and occurs the rapid expansion to cause the gas molecules disturbances which produces sound effects. Sound effects of flash bomb blast is related to combustion rate of charge, the charge mass and strength of the housing [4].

Charge Design

Charge design based on the uniform method

Uniform Design. Uniform design is a novel multi-level and multi-factor method, it determines the classic single-variable problem method to multi-variable problem, ignores the "neat comparable" requirement, strengthens the test point degree of "homogeneously dispersed" to achieve a minimum number of tests to get the most information about the test. Uniform design is based on a series of experiments which have been designed to improve the design table to complete the test program. Under normal circumstances, we read related books according to the experimental factors and the number of levels to determine the required uniform design table, and design experiments combined with the corresponding tables.

Mixed Level Uniform Design. In solving practical problems, sometimes there will be a few cases of different factors with different levels, such problems generally uses mixed level uniform design. For example, an experiment set three factors, which are represented A, B, C, the level number of A and B is 3, and C is 2 is. For this test, the general uniform design table is no longer applicable. If we use orthogonal design table L18 (2 × 37) to design experiments, it has too many trials. If we select uniform design, we must adopt the proposed level of technology [5]. If you choose uniform design table $U^*_6(6^6)$, according to the instructions, you select the first three columns 1, 2, 3. If A and B are placed in front of 2, C placed in the three, we merge the former two: {1,2} → 1, {3,4} → 2, {5,6} → 3 , then the first three merged into 2 levels, that is, {1,2,3} → 1, {4,5,6} → 2, we will be able to design

table $U_6(3^2 \times 2^1)$ shown in table 1. According to the actual test, the balance sheet meets the requirements.

Table 1 Quasi-level design $U_6(3^2 \times 2^1)$

No.	A	B	C
1	(1)1	(2)1	(3)1
2	(2)1	(4)2	(6)2
3	(3)2	(6)3	(2)1
4	(4)2	(1)1	(5)2
5	(5)3	(3)2	(1)1
6	(6)3	(5)3	(4)2

Uniform Design on Charge Recipe of Flash Blast Bomb. Determining of the Factors and the Level**.** We select KClO4 / Al mass ratio, the content of phenolic resin, the CS content, content of graphite as main factors, while identifying ratio (A) in KClO4 / Al is 10 levels, (B) in the CS content is 10 levels, (C) in the phenolic resin is 5 levels, (D) in the content of the graphite is 5 levels [6] [7], it is as follows:

KClO4 / Al ratio (A): 2.33 (1), 2.13 (2), 1.94 (3), 1.78 (4), 1.63 (5), 1.50 (6), 1.38 (7), 1.27 (8), 1.17 (9) 1.08 (10).

CS content (B): 10% (1), 12% (2), 14% (3), 16% (4), 18% (5), 20% (6), 22% (7), 24% (8), 26% (9), 28% (10).

The content of phenolic resin (C): 1% (1), 2% (2), 3% (3), 4% (4), 5% (5).

The content of graphite (D): 1% (1), 2% (2), 3% (3), 4% (4), 5% (5).

Construction of Uniform Design Table. Charge formulation of flash blast bomb is mixed level uniform design with 4 factors. We use uniform design table to design the test program, and select 4 rows to do the proposed level. This paper uses center L2- deviation to calculate uniformity of the proposed uniform level table. Center L2- deviation is as follows [8]:

$$CD_2 = (\frac{13}{12})^s - \frac{2}{n}\sum_{k=1}^{n}\prod_{i=1}^{s}(1+\frac{1}{2}|x_{ki}-\frac{1}{2}|-\frac{1}{2}|x_{ki}-\frac{1}{2}|^2) + \frac{1}{n^2}\sum_{k,l=1}^{n}\prod_{i=1}^{s}(1+\frac{1}{2}|x_{ki}-\frac{1}{2}|+\frac{1}{2}|x_{li}-\frac{1}{2}|-\frac{1}{2}|x_{ki}-x_{li}|) \quad (6)$$

This article seeks the lowest level table of CD_2 through computer programming, and usese the lattice points to form a uniform design table. The lowest level table of CD_2 through matlab is as shown in Table 2, the table is the uniform design table used in this peper.

Table 2 Proposed level design table $U_{20}(10^2 \times 5^2)$

No.	A	B	C	D
1	1	5	3	5
2	1	9	1	5
3	2	4	4	5
4	2	8	1	4
5	3	3	4	4
6	3	7	2	4

Experimental Program. Determining the level of each factor is as shown in Table 3.

Table 3 Charge test formulation program of flash bomb detonation

factor / No.	KClO4 / Al ratio	CS content	phenolic resin content	graphite content
1	2.33	18%	3%	5%
2	2.33	26%	1%	5%
3	2.13	16%	4%	5%
4	2.13	24%	1%	4%
5	1.94	14%	4%	4%
6	1.94	22%	2%	4%

According to the table, the paper designs 6 set formulas as training samples of BP network, We get performance parameters by testing. Also we design 6 set formulas as the validation sample of BP neural network, the test formulation is shown in Table 4.

Table 4 Formulation verification test program

Factor / No.	KClO4 / Al ratio	CS content	phenolic resin content	graphite content
7	1.38	15%	1%	2%
8	1.27	14%	2%	2%
9	1.38	14%	1%	1%
10	1.27	12%	3%	2%
11	1.63	15%	5%	3%
12	1.50	15%	2%	2%

Test Results of Design Recipe Performance. Each recipe is packed three test bomb, we use the light intensity of transient tester at a distance of 10m with the point of the test bomb to test flash intensity I, the sound level meter at a distance of 3m with the burst point to the test pulse sound bombings pressure level Lp, and ground pressure sensor at a distance of 3m with the point of the test bomb to test bomb blast overpressure ΔP [9] [10], we get 12 groups data which is shown in Table 5.

Table 5 Flash bomb blast charge elastic energy formula test results

No.	Lp（dB）	I （Cd）	ΔP (MPa)	No.	Lp（dB）	I （Cd）	ΔP (MPa)
1	139.8	4.236	0.02328	16	138.6	4.086	0.02143
2	134.5	4.548	0.02145	17	136.4	3.547	0.01787
3	140.4	3.843	0.01927	18	140.8	4.548	0.02182
4	138.5	3.045	0.01718	19	140.6	3.016	0.01949
5	142.8	3.587	0.01852	20	133.5	2.792	0.01659
6	135.4	2.882	0.01144	21	142.9	4.157	0.02182

Conclusion

This paper studies the principle of flash bomb blast, analyzes the sound and light effects generated by the explosion and its mechanism of action to the human body, though uniform design method, we test

bombings performance of different ratio, at last we establishes non-lethal effect evaluation system of flash bomb blast: effective SPL of flash bomb blast is in the range of no more than 140dB, effective flash intensity is in the range of $3.5\sim5.0\times10^{7}cd$, overpressure value controls within 0.0198MPa. This paper establishes flash radiation model of flash bomb detonation based on flash radiation theory of pyrotechnic detonation, and analyzes the factors of sound and light effects on flash bomb blast.

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