文章编号:1006-9941(2006)02-0118-05

强光致盲弹药技术的研究

霸书红[1,2], 焦清介[1], 杜志明[1]
(1. 北京理工大学爆炸科学与技术国家重点实验室, 北京 100081;
2. 沈阳理工大学环境与化工学院, 辽宁 沈阳 110168)

摘要: 研究了强光致盲弹药的辐射机理、配方组成、性能测试和对夜视探测器材的干扰情况。结果表明,以 $KClO_4$ 为氧化剂、以 Al 为可燃物和以环氧树脂(或酚醛树脂)为粘合剂组成的三元配方(配比 50: 50: 3)具有很强光辐射能力,感度较低。在三元配方中加入 1% 微粉石墨,可大大提高药剂的安全性。强光辐射模拟样弹装填 $KClO_4$/Al/环氧树脂三元配方的药量为 80 g 时,可见光区的发光强度可达 5.0×10^7 cd 以上,近红外波段的辐射强度达 2.1×10^5 W · sr^{-1}以上,装药量 40 g 的模拟样弹对 37 m 处夜视探测器材干扰效果明显。

关键词: 军事化学与烟火技术; 强光致盲弹药; 辐射强度; 微粉石墨; 感度; 样弹
中图分类号: TJ413$^+$.7　　**文献标识码:** A

1　引　言

强光致盲弹药本身蕴藏有很高的化学能,通过燃烧反应部分转变成光能,并以强辐射光的形式释放,达到毁伤敌人目的。这种弹药具有致人眩晕失明失去抵抗能力和使光电探测器材“致盲”不能正常工作的特点[1,2]。因其效费比高,光谱范围宽,多向辐射,便于装入多种弹体等优点,一直是世界各国研究的热点。本文介绍了强光致盲弹药辐射机理、配方设计、性能测试、样弹构造及对夜视器材的干扰。

2　强光致盲弹药的辐射机理

强光致盲弹药燃烧时高温下固体和液体的游离电子发生扰动,且随温度不同处于不同能级,能够辐射出不同波长的光,所以称为连续光谱。此连续光谱可视为灰体辐射[3]。强光致盲弹药爆燃产生的火团近似为球形,强光致盲弹药爆燃闪光辐射模型可作如下假设:

① 爆燃火团的表面辐射近似为灰体辐射,表面发射率 ε 对于某种特定产物体系来说为小于 1 的常数; ② 火药爆燃火团为均匀发光体,球体表面与内部温度一致,辐射来自于火团表面; ③ 燃烧反应产物中的气相物质均视为理想气体; ④ 发光火球表面为余弦辐射体; ⑤ 忽略火团内部辐射粒子对火团辐射的贡献及大气传输中辐射能量的衰减。根据 Plank 定律和假设,强光致盲弹药产生的连续光谱在某一波段辐射出射度为:

$$M_{\lambda-连续} = \varepsilon_0 \cdot \frac{2\pi hc^2}{\lambda^5} \cdot \frac{1}{e^{hc/(\lambda kT)}-1} = \frac{\varepsilon_0 \cdot c_1 \cdot \lambda^{-5}}{e^{\frac{c_2}{\lambda T}}-1} \tag{1}$$

式中,$M_{\lambda-连续}$为烟火药燃烧火焰连续光谱单色辐出度; ε_0 为烟火药火焰中连续光谱的发射率; h 为普朗克常数; c 为光速; λ 为波长; T 为燃烧火球表面温度; c_1 为第一辐射常数; c_2 为第二辐射常数。

对其波长从 0 到∞ 积分得:

$$M_0 = M_{连续} = \varepsilon_0 \cdot \int_0^\infty \frac{c_1\lambda^{-5}}{e^{\frac{c_2}{\lambda T}}-1}d\lambda \tag{2}$$

利用 $\lambda = c_2/xT$ 及 $d\lambda = -c_2dx/Tx^2$ 进行变量转换,得到灰体辐射的斯蒂芬-玻尔兹曼公式:

$$M_0 = \varepsilon_0 \cdot \int_0^\infty \frac{c_1}{\left(\frac{c_2}{xT}\right)^5} \cdot \frac{-\frac{c_2}{Tx^2}}{e^x-1}dx =$$

$$\varepsilon_0 \cdot \frac{c_1}{c_2^4}T^4\int_0^\infty \frac{x^3}{e^x-1}dx = \varepsilon_0 \cdot \sigma T^4 \tag{3}$$

由辐出度定义可得出火球的辐射强度:

$$\Phi_{0(\lambda_1-\lambda_2)} = 4\pi r_0^2 \cdot M_0 = \varepsilon_0 \cdot 4\pi r_0^2\sigma T^4 \tag{4}$$

根据辐射强度定义 $I = d\Phi/d\Omega$ 得闪光火球的辐射强度公式:

$$I_0 = \Phi_0/4\pi = \varepsilon_0 \cdot r_0^2 \cdot \sigma T^4 \tag{5}$$

上式表明: 闪光火球的辐射强度与火球表面温度的四次方、火球半径的平方和灰体发射率 ε_0 成正比,这也为强光致盲弹药配方设计提供了依据。

3　强光致盲弹药配方设计、筛选

强光致盲弹药配方设计有两个基本要求:一是要

收稿日期: 2005-09-14; 修回日期: 2005-12-10
作者简介: 霸书红(1970 -),男,在读博士,研究方向为军事化学与烟火技术。e-mail: bashuhong@bit.edu.cn

图 4　试验前夜视仪观察视场情况

Fig. 4　Screen of night vision equipment before igniting

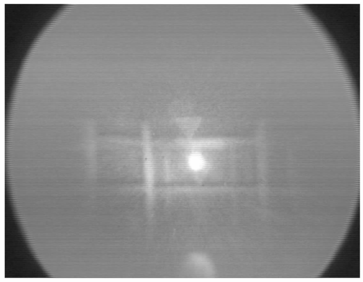

图 5　闪光剂样弹点火的一瞬间

Fig. 5　Screen of night vision equipment at igniting

图 6　样弹点火后 0.04 s

Fig. 6　Screen of night vision equipment at $t = 0.04$ s

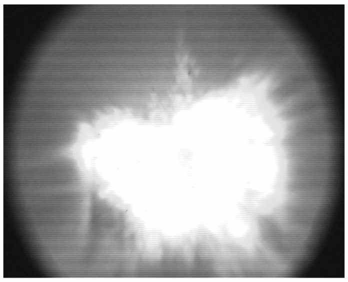

图 7　样弹点火后 0.08 s

Fig. 7　Screen of night vision equipment at $t = 0.08$ s

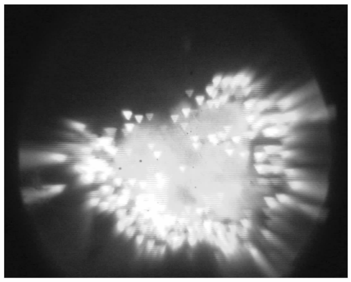

图 8　样弹点火后 1.6 s

Fig. 8　Screen of night vision equipment at $t = 1.6$ s

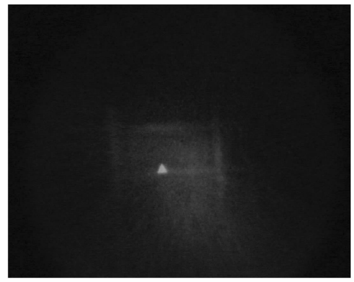

图 9　样弹点火后 3.52 ~ 24 s

Fig. 9　Screen of night vision equipment at $t = 3.52 \sim 24$ s

（2）当遇到较弱光源，夜视仪即出现弱的光晕现象，对观察目标略有影响（见图 5）；

（3）当光源辐射强度很大时，二代夜视仪的光阴极达到饱和，成像满屏泛白，遮蔽整个夜视仪的视场（见图 6）；

（4）随着闪光剂样弹最亮点的消退，夜视仪受到强光干扰的视场逐渐缩小，在一定程度仍能遮蔽目标（见图 7、8）；

（5）强光过后，夜视仪受干扰处出现的亮"▲"持续 20 s 左右时间才完全消退，说明夜视仪受强光干扰后要经历几十秒时间才能完全恢复（见图 9）。

从图 4 ~ 9 可以看出，样弹对二代微光夜视仪干扰效果明显，主要受样弹发光强度及强光持续时间影响。

6　结　论

（1）利用高温高压复杂系统化学反应计算程序计算得出，氧化剂 $KClO_4$ 和可燃物 Al 组成的二元体系具有较强辐射能力。

（2）实验得出二元体系中 $KClO_4$ 和 Al 的质量比为 50∶ 50 时光辐射能力最强；而理论计算得出 $KClO_4$ 和 Al 的质量比为 40∶ 60 时光辐射能力最强。这种差别是空气中的氧参与反应的结果。

（3）$KClO_4$/Al/粘合剂三元体系中，粘合剂选择 3% 酚醛树脂或3% 环氧树脂光辐射能力较强，感度较低。

（4）$KClO_4$/Al/3% 环氧树脂三元配方外加少量微粉石墨，可大大降低配方的冲击感度，提高药剂安全性。

（5）样弹发光强度及强光持续时间对夜视器材干扰效果明显。

参考文献：

[1] 常非. 烟火药爆燃闪光辐射研究[D]. 北京：北京理工大学，2002.
CHANG Fei. Studies on the flash radiation by pyrotechnic deflagration [D]. Beijing: Beijing Institute of Technology, 2002.

[2] 焦清介，马威，许又文. 闪光烟火剂强光辐射实验研究[J]. 北京理工大学学报，2000，20(1)：129 - 132.
JIAO Qing-jie, MA Wei, XU You-wen. Experimental study on the radiation of pyrotechnics flash[J]. *Journal of Beijing Institute of Technology*, 2000, 20(1): 129 - 132.

[3] 梅飞鸣，王兴安. 辐射换热[M]. 北京：高等教育出版社，1989.
MEI Fei-ming, WANG Xing-an. Radiation Heat Transfer[M]. Beijing: Higher Education Press, 1989.

[4] 傅献彩，沈文霞，姚天扬. 物理化学[M]. 北京：高等教育出版社，1990.
FU Xian-cai, SHEN Wen-xia, YAO Tian-yang. Physical Chemistry [M]. Beijing: Higher Education Press, 1990.

[5] 王汝霖. 润滑剂摩擦化学[M]. 北京：中国石化出版社，1994.
WANG Ru-lin. Lubricant Tribochemistry[M]. Beijing: China Petrochemical Press, 1994.

The Technology of the Strong Light Blindness Ammunition

BA Shu-hong[1,2], JIAO Qing-jie[1], DU Zhi-ming[1]
(1. *State Key Laboratory of Explosion Science and Technology*, *Beijing Institute of Technology*, *Beijing* 100081, *China*;
2. *School of Environmental and Chemical Engineering*, *Shenyang Ligong University*, *Shenyang* 110168, *China*)

Abstract: The radiation mechanism, formulation composition, properties test and the disturbance on night vision equipment with strong flash blindness ammunition are studied. The results show that the trinary formulation containing $KClO_4$, Al and epoxy resin (mass ratio is 50∶50∶3) has higher radiation and lower sensitivities. The ammunition security is greatly improved when 1% micro-powder graphite is added into the trinary formulation. When 80 g charge amount of trinary formulation (the mass ratio of $KClO_4$, Al and epoxy resin is 50∶50∶3) is loaded into the simulation bomb, the luminesced intensity at visible region is more than 5.0×10^7 cd and the radiation intensity at near-infrared band exceeds 2.1×10^5 W · sr^{-1}. Moreover, 40 g charge amount of the trinary formulation has obvious disturbance on night vision equipment at 37 m.

Key words: military chemistry and pyrotechnics; strong light blindness ammunition; radiation intensity; micro-powder graphite; sensitivity; pattern bomb

(上接107页)

Numerical Simulation of Blasting Warheads Exploding Based on ALE Method

LI Wei-ping[1], WANG Shao-long[2], WANG De-wu[2], HAN Xiu-feng[2]
(1. *The Second Artillery Engineering College*, *Xi'an* 710025, *China*;
2. *The Second Artillery Arming Institute*, *Beijing* 100085, *China*)

Abstract: Using the Arbitrary Lagrangian-Eulerian (ALE) algorithm, the numerical simulation of the blasting warheads exploding in the air is realized. During the modeling process, the explosive was plotted with ALE elements, the shell with Lagrange elements and the air with Euler elements, the ALE meshes of the initial void were created in which the explosive products could flow, the meshes of explosive and the initial void were joined with common nodes, and the fluid-structure interaction was defined between the meshes of the explosive, shell and air. The diffusion of explosive products and the pressure distribution were obtained. The overpressure values at different distance to the explosion center were presented. The results show that the relative errors between the simulation results of overpressure and the experimental results at different distance to explosion center is less than 10%.

Key words: explosion mechanics; blasting warhead; explosion effect; numerical simulation; ALE algorithm

(上接117页)

Synthesis and Characterization of 3,6-Dihydrazine-1,2,4,5-tetrazine and its Energetic Salts

PAN Jie, HE Jin-xuan, TAO Yong-jie
(*The* 42*nd Institute of the Fourth Academy of CASC*, *Xiangfan* 441003, *China*)

Abstract: 3,6-Dihydrazine-1,2,4,5-tetrazine and its energetic salts were synthesized from the easily available starting materials like triaminoguanidine and 2,4-penatanedione. The synthesis route in literature was magnified properly. Moreover, the synthesized compoundswere characterized by spectra analysis (IR, NMR, EA and MS) and the explosive properties (impact and friction sensitivity) and thermal properties (TGA/DTG) were studied.

Key words: organic chemistry; 3,6-dihydrazine-1,2,4,5-tetrazine; synthesis; tetrazine; high-nitrogen energetic material