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Short Duration Pulse Shock Initiation Characteristics of Ultrafine LLM-105

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Abstract: The two types of flyer were designed to study short duration pulse shock initiation characteristics of ultrafine 2,6-diamino-3,5-dinitro-pyrazine-1-oxide(LLM-05). The firing testing of ultrafine LLM-105 is implemented by D-optimal method based on analysis of flyer velocity. It is found that the flyer velocity is increasing as increasing pulse current. The velocity is sensitive to current variety for large dimension flyer by contrasting small dimension flyer. The inferior velocity consistency for large flyer exists, which has the relationship with air resistance. The air resistance is increasing with improvement of flyer dimension. The 50% firing current, of ultrafine LLM-105 is 2.14 kA by small dimension flyer, which is almost equal to initiating threshold of HNS-Ⅳ. It is indicated that ultrafine LLM-105 would be used for initiation explosive at slapper detonator. The LLM-105 explosion system will satisfy the development trend of slappde detonator, namely, desensitization, low input energy, and so on.

Key words: ultrafine 2,6-diamino-3,5-dinitro-pyrazine-1-oxide(LLM-05); flyer velocity; shock initiation; initiation threshold

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1 Introduction

To meet the high energy and insentive reqirement of advanced weapon, safety and reliability of explosive were made more stringent requirements or even contradictory[1]. This problem gave rise to researchers' attention around the world. 2,6-Diamino-3,5-dintropyrazine-1-oxide (LLM-105) is a new compound, which synthesized by LLNL at 1993[2]. Its performance and insensitivity is between those of HMX and TATB. Its calculated energy content is about 85% that of HMX and 15% higher than that of TATB[3-7]. It is thermally stable, insensitive to shock, spark, and friction and has impact insensitivity approaching that of TATB in comparision to traditional explosive[5]. These properites make it very interesting for several applications such as insensitive boosters, detonators, and possibly main charges in specialty munitions. But it has few reports about slapper detonator application based on LLM-105.

Slapper detonator usually is applied to in-line fuse, which is important component of advanced weapon. Although the safety performance of TATB explosive can satisfy insensitive ammunition criterion, it has high input energy which is not agree with the miniaturization development of weapon. So, it is potential to apply for LLM-105 in the slapper detonator. In this paper, study on short duration pulse shock initiation characteristics of ultrafine LLM-105 has been conducted, which is useful for slapper detonator development.

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2 Experimental

2.1 Materials

The ultrafine LLM-105(100-600 nm) was synthesized by institute of chemical materials (ICM). The purity of ultrafine LLM-105 is higher than 98.7%. The specific surface area of ultrafine LLM-105 is higher than 7.7 $m^2 \cdot g^{-1}$. The dimensions of charge used is Φ5 mm×4 mm for shock test, whose density is 1.63 $g \cdot cm^{-3}$.

2.2 FlyerImpacting Initiator

The flyer impacting initiating device is composed of five parts, namely exploding foil, flyer, barrel, explosive charge, and seal apparatus, which is shown on Fig.1. The material is copper, steel andkapton of exploding foil, barrel and flyer, respectively.

2.3 Equipment

The velocity of flyer is measured byphotonic dopplar velocity (PDV) which is made by Nanjing university of science and technology. The principle diagram of PDV system has shown on Fig. 2. The movement velocity of sample is based on difference frequency between basic light and reflection light. The basic light is the reflection of probe by the 2-port optical circulator laser. The reflection light is the reflection of movement sample. The light probe detector collects the two different lights from the 3-port circulator[8].

The high voltage discharge circuit is fabricated by ICM. The capacitor is 0.22 μF. The duration of discharge circuit is 1.10 μs.

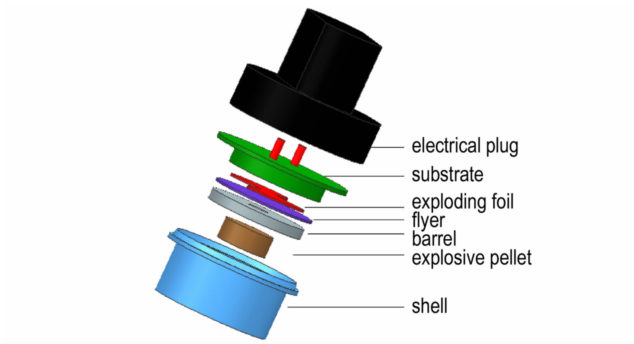

Fig.1 Schematic image of flyer impactingintiator

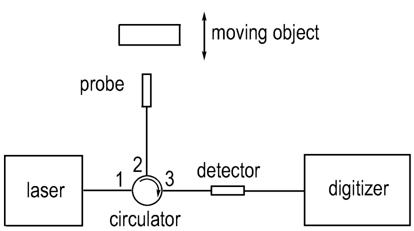

Fig.2 Principle diagram of PDV system

2.4 Experimental

The initiation threshold testing is implemented of ultrafine LLM-105 under two type flyers. The curve of flyer velocity is collected by PDV system, which is shown on Fig.3. The short duration pulse shock initiation sensitivity is achieved by calculation. The total amount of sample is twelve. The D-optimal method is applied for testing pulse initiation threshold.

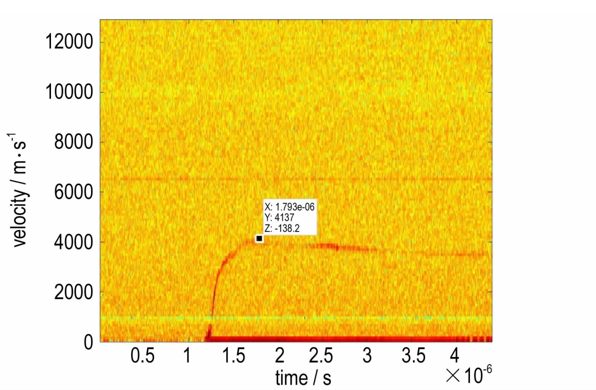

Fig.3 Curve of flyer velocity by PDV

The contrasting test has been conducted of two different flyer parameters. The material of flyer iskapton. The parameter of two type flyer is shown on Table 1. The type 1 is corresponding to large dimension flyer. The type 2 is corresponding to small dimension flyer.

Table 1 Parameter of two type flyer mm

No.	dimension of bridge foil	dimension of barrel	thickness of flyer
type 1	0.6×0.6×0.004	Φ0.8×0.4	0.05
type 2	0.4×0.4×0.004	Φ0.6×0.4	0.05

3 Results and Discussions

3.1 Results of Flyer Velocity

The velocity of two type flyer has shown on Table 2. It is indicated that the flyer velocity is increasing as increasing pulse current. But the increase amplitude of flyer velocity is high based on type 1(Fig.4) by contrasting with type 2. It is indicated that the large dimension flyer is sensitive to input electrical energy in comparision with small dimension flyer. But the velocity of flyer is higer with type 2 than type 1 under the same inputting pulse current. It can be explained by Gurney equation (1)[9].

$$V_f=\sqrt{2kJ_b^n}\left(\frac{m_f}{m_e}+\frac{1}{3}\right)^{-\frac{1}{2}} \tag{1}$$

Where k and n are the constants of experiment determined, respectively, $k=2.36\times10^{-6}$, $n=0.85$[9] for the Cu foil, m_f and m_e are the flyer and exploding foil masses per unit area, respectively, J_b is the density of exploding current A/cm^{-2}.

J_b is calculated by equation (2):

$$J_b=\frac{I}{S} \tag{2}$$

Where I is the initiation current, A; S is the cross-section area of exploding foil, cm^{-2}.

The velocity of flyer is increasing as increasing pulse current according to equation (1) and (2) under the same dimension of exploding foil. The type 2 with small dimension flyer has high velocity because of high current density, resulting high energy per area under the same input pulse current.

The velocity consistency is not good of type 1 with large dimension flyer under the same pulse current. It may be resulted by error during testing process. But the phenomenon is only existing big flyer, so it is not true. The air resistance may be the main reason caused the bad consistency of flyer velocity based on large dimension flyer. According to aerodynamics, the distance can not keep constant between the centers of air resistance and mass during the flying process based on large dimension flyer. The departure of center has caused the existence of turning torque, resulting competition of distortion and anti-distortion. So, the flyer can not keep the plane integrity, which will exacerbate centroid departure, resulting velocity dispersity of type 1.

Table 2 Results of flyer velocity

type 1				type 2			
No.	initiation current/kA	velocity of flyer/m · s^{-1}	average of velocity flyer/m · s^{-1}	No.	initiation current/kA	velocity of flyer /m · s^{-1}	average of velocity flyer/m · s^{-1}
1		4137		1		4238	
2	5.0	3229	3700	2	5.0	4541	4372
3		3734		3		4339	
4		3835		4		4314	
5	4.5	3027	3431	5	4.5	4137	4250
6		3431		6		4299	
7	4.0	3128	2977	7	4.0	3936	3986
8		2826		8		4036	
9	3.5	2876	2876	9	3.5	4011	4011

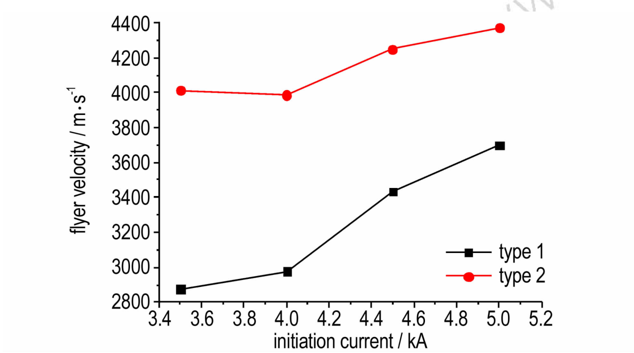

Fig. 4 Curves of flyer velocity

The short-duration pulse initiation criterion value for solid heterogeneous explosive is $P^2\tau$ = constant[10]. Force P is dependent on velocity of flyer. Pulse duration τ is dependent on thickness of flyer. It is indicated that the high flyer velocity is favorable for initiating explosive under the same thickness of flyer.

3.2 The Firing Test of Explosive

The initiation testing of ultrafine LLM-105 has been applied with two type flyer by D-optimal method. The result of initiation threshold has shown on Table 3.

Table 3 Initiation threshold of ultrafine LLM-105 and HNS-Ⅳ

No.	initiation threshold	
	LLM-105	HNS-Ⅳ
type 1	2.57	–
type 2	2.14	1.96

The initiation threshold current is 2.14 kA based on type 2 flyer, which is almost equal to HNS-Ⅳ initiation threshold, namely 1.96 kA. But the initiation threshold is high (2.57 kA) of type 1 flyer, which is consistent with above analysis. It is found that the improvement of flyer velocity is benefit for explosive initiation.

4 Conclusions

In the present work, we proposed the initiation threshold of LLM-105 under two type of flyer. The conclusions indicated that:

(1) The flyer velocity is increasing as increasing pulse current. But it is sensitive for input current of large dimension flyer incomparision with small flyer.

(2) The flyer velocity consistency is bad of big size flyer, which has relationship with air resistancel.

(3) It is found that the initiation threshold is almost equal between LLM-105 and HNS-Ⅳ by firing test, which will offer fundamental data for slapper detonator.

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超细 LLM-105 短脉冲起爆特性

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摘　要: 为了研究超细 LLM-105 炸药的短脉冲起爆特性,设计了两种参数的飞片起爆系统,在对两种飞片系统驱动飞片速度分析的基础上,采用较佳匹配系统进行了超细 LLM-105 炸药的发火阈值测试。试验结果表明:两种飞片系统中飞片速度随着输入起爆电流的增加而增加,但是大尺寸飞片对输入电流的变化更加敏感;在相同起爆条件下,大尺寸飞片获得的最大速度一致性较差,这与尺寸增加,受空气阻力影响更明显有一定关系;采用飞片速度较高的飞片系统进行超细 LLM-105 炸药起爆阈值测试,得到超细 LLM-105炸药的 50% 发火阈值电流为 2.14 kA,与 HNS-Ⅳ相差不大。由此表明,超细 LLM-105 炸药作为冲击片雷管始发药应用是可行的,即能满足冲击片雷管钝感化要求,又不会对引爆系统的能量提出过高的要求,符合目前冲击片雷管低能、钝感的发展趋势。

关键词: 超细 LLM-105; 飞片速度; 冲击起爆; 发火阈值
中图分类号: TJ45; O389　　**文献标志码:** A　　**DOI:** 10.11943/j.issn.1006-9941.2016.09.016