Double Shock Experiments on PBX Explosive JOB-9003

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1. INTRODUCTION

One-dimensional plate impact experiments have been performed to study the double shock to detonation transition and Hugoniot state in the HMX-based explosive JOB-9003. The flyer was a combination with sapphire and Kel-F, which could pass two different pressure waves into PBX Explosive JOB-9003 sample after the impact. The particle velocities at interface and different depths in the PBX JOB-9003 sample were measured with Al-based electromagnetic particle velocity gauge technique, thus obtaining particle velocity - time diagram. According to the diagram, the corresponding Hugoniot state can be determined based on the particle velocity and shock wave velocity in the sample. Comparing with the single shock experiments, PBX Explosive JOB-9003 shows desensitization features due to the pre-pressed shock wave, the shock to detonation transition distance is longer than those single shock experiments.

2 Experimental Facilities

Experiments are done on a single stage power gun, using EMV technique. The single stage power gun has a 57 mm bore, and is capable of projectile velocities up to 1.6 mm/μs. The one-dimensional planar impact of the projectile generates well-supported shock waves with a square wave shape. The square pressure pulse generated by the projectile and the long pulse duration simplify the time-dependent behavior of the growth of the reactive wave. The powered gun projectiles have highly repeatable velocities, permitting accurate manipulation of time and pressure parameters, and reproduction of the experiments. Double shock experiments in the PBX JOB-9003 explosive sample are done using a composite impactor consisting of a low impedance thin layer(KEL-F) on the front surface of a high impedance impactor (sapphire) mounted on the front of the projectiles. Particle velocities is measured directly using eight nested magnetic gauges, and shock wave velocity is obtained independently from time of arrival at the different gauges. The scheme of the experiments using EMV technique is shown in Fig.1, which includes: power gun loading device, flyer of sapphire combined with Kel-K(Fig.2), the measuring ring of flyer velocity with laser gun (as shown in Fig.3), a permanent magnet resulting in a 0.14T

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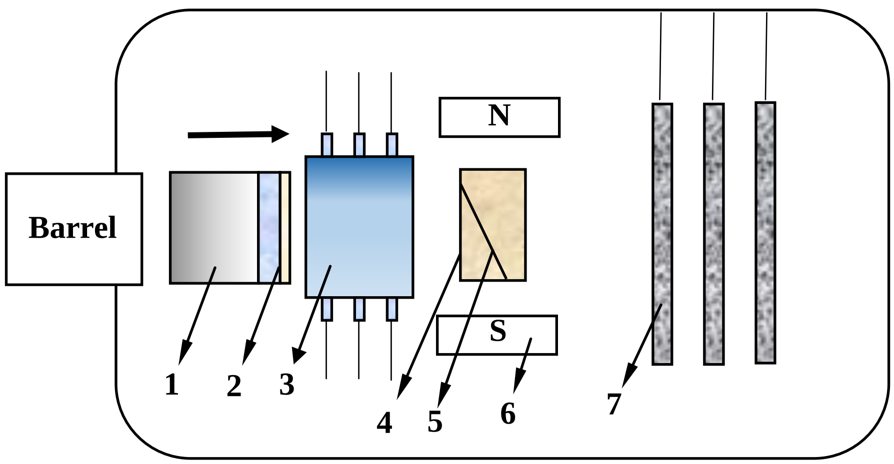
uniform magnetic field, JOB-9003 sample (1.845g / cm3), EMVs and oscilloscopes used for recording the data.

EMV technique is used to measure particle velocity in JOB-9003 explosive samples. During the experiments, the EMV gauges were glued at a 30 ° angle. The length of the active elements range from 5-12 mm, therefore the active elements are spaced 1 mm apart and cover depths of roughly 1- 8 mm with the origin at the impact surface, when mounted at 300 between the explosive wedges, as shown in Fig. 2. The principle of EMV technique is Faraday's law of electromagnetic induction: wire cutting magnetic line induced electromotive potential. In the experiments, magnetic field intensity B is known, the effective cutting length l, the recorded electromotive potential by the oscilloscopes E, so the particle velocity is:

$$v = \frac{E}{Bl} \tag{1}$$



1- Sabot 2- Flyer 3- Vel-measuring ring 4- Explosive sample
5- Electromagnetic Particle Velocity Gauge 6- Permanent Magnet 7- Target Buffer
Fig.1 Scheme of the Experiments

Laser gun is used to measure the flyer velocity before impacting on the sample, as shown in Figure 3. When the flyer flies through the measuring velocity ring, it will block three laser signals whose interval is 25 mm (as shown in Figure 3, only one pair of laser fiber is shown). The oscilloscope records the three signal falling times, whose differences can be used to calculate the flyer velocity.

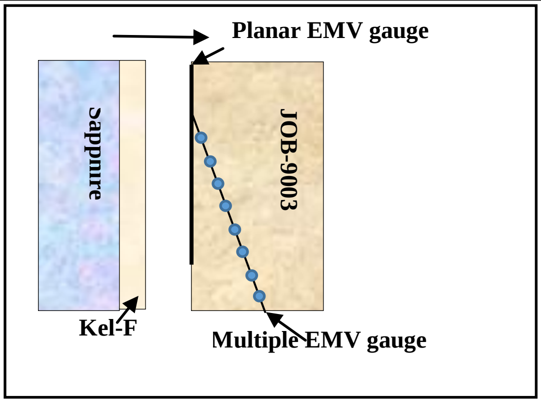


Fig.2 Flyer and Explosive sample

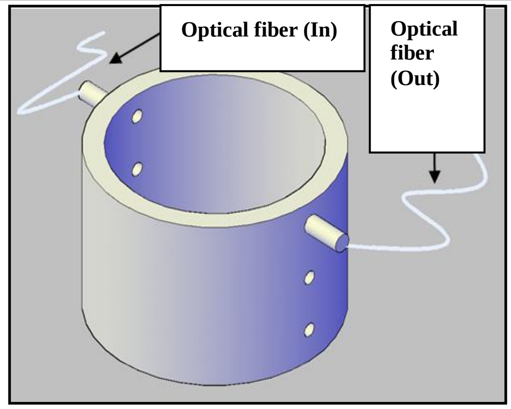
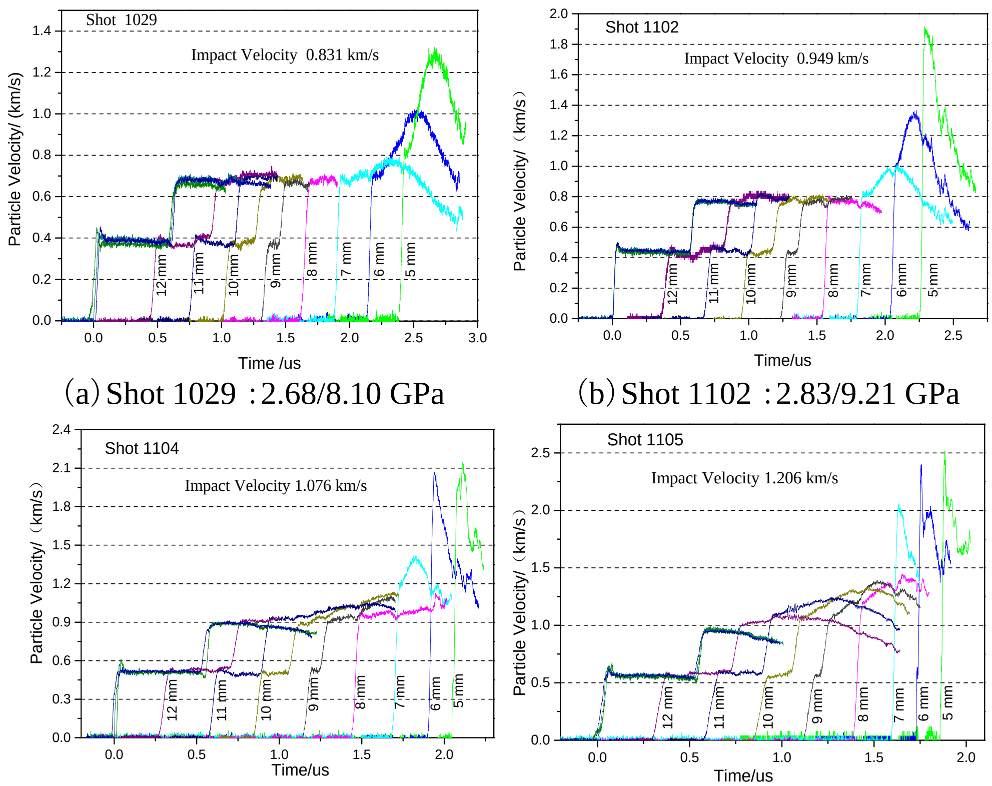


Fig.3 Flyer velocity measured Ring

3 Results

According to the experimental data and Formula (1) , the particle velocities are calculated. Fig.4 (a), (b), (c), (d) show the particle velocity -- time diagram in the four experiments.



(a) Shot 1029 :2.68/8.10 GPa (b) Shot 1102 :2.83/9.21 GPa

(c) Shot 1104 :3.34/10.81 GPa **(d) Shot 1105 :3.88/13.13 GPa**

Fig.4 Particle Velocity VS Time

Note: (1) 5mm~12mm as marked in the diagram refer to the effective length of Al wire in EMV

(2) The two pressures marked under each diagram are calculated in Section 3.2

The double shocks experiment contains a lower pressure pre-shock and a subsequent higher pressure main shock. Since the main shock (the second wave) propagates in the compressed material by pre-shock, it will propagate faster and eventually catch up with the pre-shock. At the place two waves combining, a single higher pressure wave will be produced. As we can see in Fig 4, the main shocks catch up with pre-shocks all at somewhere between 9 mm wire and 8 mm wire in the four experiments.

Additionally, the four diagrams in Fig 4 have common properties: the velocity of first wave (pre-shock) does not increase with time significantly, indicating that there are no obvious chemical reactions in this process, so the first wave is called "no reaction pre-shock"; while the velocity of second wave (main shock) increases with time, which is more obvious in Fig 4 (c) and (d) with higher impact velocity, indicating that the second wave cause reactions, and play a main role in leading to the detonation finally.

Due to that the pressure of pre-shock is weak enough, no explosive reaction occurs, indicating that detonation must occur after the confluence of two waves, which means detonations are formed behind the location of 8 mm wire: shot 1029 shows no detonation, shot 1102 detonation formed at the location of about 5 mm, shot 1104 detonation formed between 7 mm and 6 mm, shot 1105 detonation formed between 8 mm and 7 mm. Section 3.3 will explain that detonation occurs after two wave’s confluence quantitatively through a compression with sustained pulse Pop-plot.

Double shocks experiments comparing to the sustained pulse impact experiments, the biggest difference is the "double shock desensitization". Explosives after the first compression, becomes more insensitive, harder to reach detonation when the second shock comes. The particle velocity--time diagrams describe that as: while the main shock in double shocks have the same pressure as sustained pulse wave, the distance to detonation (or time to detonation) is much greater.

In addition, preshock compressed explosive do have a homogenous reaction behavior as shown in figure 4. The initial particle velocity in the material is almost a constant in the preshocked region before the arrival of the second shock, moreover, all the reactive waves start from nearly the same initial velocity.

4 Conclusions

One-dimensional plate impact experiments have been performed to study the double shock to detonation transition and Hugoniot state in the HMX-based explosive JOB-9003. By making flyer from two different impedance materials (sapphire and Kel-F), we provide double shocks into explosives. Particle velocity-time diagrams shows that pre-shocks didn’t make explosives react obviously, while main wave caused the reaction, and contributed to the formation of detonation. In this paper, we calculated the relationship between the particle velocity and pre-shock velocity, then obtained Hugoniot state of JOB-9003, and thus obtained the pressure of pre-shock. According to the conservation of momentum, we got the densities of explosives after pre-shock compressing, and further obtained the pressures of the main shocks.

In order to verify the double shock desensitization quantitatively, we compared the Pop-plots of sustained pulse and double shocks experiments. In order to get tid of the effects of pre-shock,we eliminate the time of pre-shock compressing. We found that for the same impact pressure, the time to detonation of double shocks is longer than that of sustained pulse experiments, which indicates that explosives in the double shocks are less likely to form detonation,or namely " double shock desensitization".