Experimental Study on Impact-induced Initiation Thresholds of AL/PTFE/W composite

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I. INTRODUCTION

Al/PTFE/W is a typical kind of reactive material prepared by a specific process. It was first proposed by Hugh E. [1] in a patent in the form of a reaction fragment. Due to its high energy release characteristics, and its insensitivity under quasi-static conditions, it has received widespread attention in military applications [2]. It is mainly used in the form of reaction fragments and energetic liner in highly effective warheads. the main objectives of the work are performed to investigate the reaction process of Al/PTFE/W under high-speed impact conditions to obtain the threshold of the impact-induced initiation threshold. At the same time, it compares with Al/PTFE to get some regular practical significance.

II. EXPERIMENTAL SECTION

A. *Fabrication of Al/PTFE/W rods*

The Al/PTFE/W rods were prepared by using the cold press and hot sinter method. In addition, the same method was used to prepare Al/PTFE rods and pure PTFE rods for comparison. In this study, the Al/PTFE/W granular composites with mass ratios of 18.55/51.45/30, and the Al/PTFE granular composites with mass ratios of 26.5/73.5. The specific related parameters and the manufacturer of the materials are listed in Table 1. The material powders were first initially mixed according to the mass ratio, then mixed by a planetary ball mill at a certain speed for one hour. The uniformly mixed powders were drying in thermostatic oven, then put into a hardened steel mold and pressed at a pressure about 70MPa. The formed specimens were placed in a vacuum furnace for sintering, and the sintering temperature control curve was referred to document [4]. The temperature history of the sintering cycle is shown in Figure 1.

Table 1. Related parameters of the materials

Material name	Density (g/cm^3)	Material size
Aluminum(Al)	2.712	100-200 mesh
Polytetrafluoroethylene (PTFE)	2.152	150 μm
Tungsten(W)	19.235	200 mesh

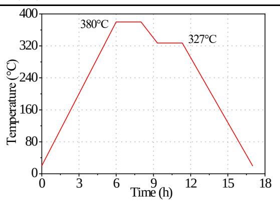
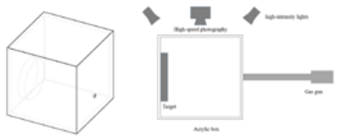


Figure 1. The temperature history of the sintering cycle

B. *Experimental Process*

A gas gun with an inner diameter of 14.5 mm was used to launch the rod-shaped specimens in this experiment, and a booster with an outer diameter of 14.5 mm was designed to keep the rods in a good attitude. The sintered specimens had diameter of 10 mm and length of about 25 mm. The three kinds of prepared rods and the processed booster are shown in Figure 2. Six 10mm thick acrylic plates were used to make a transparent box with a side length of 30cm, which had good light transmission performance, long service life and excellent rigidity and strength. A circular hole with a diameter of 20 mm was drilled at a suitable position on the front side of the box to allow the rod to be injected. A uniform armor plate as target with a diameter of 160 mm and a thickness of 30 mm is placed on the back of the box. The history of the events was recorded by high-speed photography, and the field of view was illuminated by two high-intensity lights. The transparent acrylic box and experimental layout are shown in Figure 3.

Figure 2. The rods and the boosters



(a) (b)

Figure 3. (a) The acrylic box; (b)the experimental layout

III. ANALYSIS AND DISCUSSION

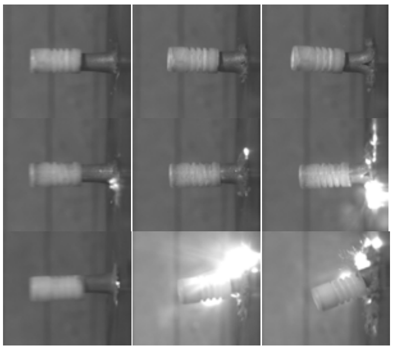


Figure 4. Three representative phenomena of the impact:(a) impact at 121.6 m/s; (b) impact at 127.4m/s; (c) impact at 187.5m/s.

The Al/PTFE/W rod impact speeds in Figure (a), Figure (b), and Figure (c) are 121.6m/s, 127.4m/s, and 187.5 m/s, respectively. When the impact speed of the rod was 121.6m/s, no fire was observed during the impact. The rod only appeared upsetting at the beginning of the impact, and then cracked and broke. When the impact speed of the rod was 127.4 m/s, the reaction flare could be observed. The moment at which the reaction flare was observed occurred earlier when the impact velocity of the rod was 187.5 m/s. There was a critical value for the impact reaction of Al/PTFE/W. When the impact condition was below the critical value, the Al/PTFE/W rod would be upsetting and even fragmented. When the impact condition was above the critical value, the Al/PTFE/W rod would react and the reaction flare would appear. The situation of Al/PTFE was similar, but the critical impact velocity was different. For PTFE, no reaction flare was observed and there were no signs of reaction from the recovered material. It indicated that PTFE cannot react under impact conditions.

The relationships between impact velocities and impact pressures during the impacting of Al/PTFE/W rods and Al/PTFE rods are showed in Figure 6. It can be found that under the same impact velocity conditions, the impact pressure of Al/PTFE/W is higher because of the higher density of Al/PTFE/W. The gray area is the part where no reaction occurs. Therefore, the initiation impact velocity threshold of Al/PTFE/W is between 124~127 m/s. For Al/PTFE, the critical value is between 145~160 m/s. But the initiation impact pressure threshold of the two materials are about 600MPa. It seems that the addition of tungsten does not show an advantage in the initiation impact pressure threshold of Al/PTFE composites, but many studies have proved that the addition of such metals significantly improves the mechanical properties of Al/PTFE composites. Some scholars believe that impact velocity or impact pressure is insufficient to predict the initiation of Al/PTFE, impact pressure and strain rate jointly affect the initiation threshold of Al/PTFE composites. The impacting strain rates can be calculated from the ratio of impact velocity and the specimen length. Figure 7 shows the relationship between impact pressure and strain rate of the rods. Two straight lines separate the reaction from the unreacted portion, and the part of the reaction appears at the top right of the intersection of straight lines. It can be observed that the initiation threshold of Al/PTFE and Al/PTFE/W composites are enough to be described on the same level, when the impact pressure is greater than 600MPa and the strain rate is greater than $5100s^{-1}$, the reaction will occur.

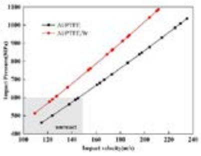


Figure 6. The relationships between impact velocities and impact pressures

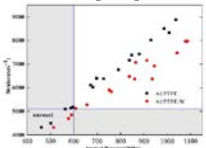


Figure 7. The relationship between impact pressure and strain rate

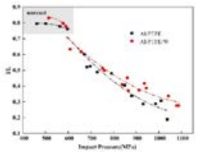


Figure 8. The relationship between the impact pressure and the ratio of the remaining length to the original length of the rod.

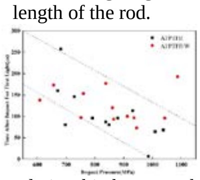


Figure 9. the relationship between the time and impact pressure

As the impact pressure rises to 1100 MPa, the ratio decreases from 1 to around 0.2. From the perspective of impact pressure, the crushing of Al/PTFE/W occurs under the condition that the impact pressure is greater than 590 MPa, and the crushing of Al/PTFE occurs under the condition that the impact pressure is greater than 560 MPa. The relationship between time and impact pressure is shown in Figure 9. There is a downward trend for the time with the increase of impact pressure although, the dispersion of data is relatively high, and the functional relationship between the two cannot be found. Different from the experiment of Willis Mock, the highest impact pressure of this experiment only reached 1086.9 MPa, and the value reached 6330 MPa for Willis Mock's experiment. Therefore, the range of the impact pressure of the data in this experiment is narrow and the same conclusion cannot be obtained.

IV. CONCLUSION

(1) With the increase of impact velocity, Al/PTFE/W rods went through the process of upsetting, fracture and fragmentation, initiation and reaction.

(2) Only when the impact pressures and the strain rates exceed critical values simultaneously can the Al/PTFE/W materials be initiated. The impact pressure and strain rate threshold for Al/PTFE/W is 600MPa and 5100s-1 in this study.

(3) Al/PTFE/W rods begin to break when the impact pressure exceed 590MPa, yet Al/PTFE rods begin to break when the impact pressure exceed 560MPa. The yield strength and impact resistance of Al/PTFE/W are greater than Al/PTFE.

(4) There is a downward trend for the time after impact for first light with the increase of impact pressure.