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Research Article

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Experimental study on a thermite reaction fragment

Wang Zhanlei, Li Yifan, Wang Huiping, Wang Wensheng and Hou Zhonghua

Department of Engineering Mechanics, Henan University of Science and Technology, Luoyang, Henan, China

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ABSTRACT

The paper investigates the energy release characteristic of Al-WO_3 in dynamic loads, which is a metastable thermite belonging to multifunctional energetic structural material. The Al-WO_3 powders of different compositions were first pressed, the formability were studied. On the basis of the fine formability, the Al-WO_3 powders of three molar ratios (6:1, 8:1, 10:1) were moulded into an approximate hemispherical liner. The reaction energy release characteristic of reactive fragments in dynamic loads was studied. The three kinds of reactive fragments penetrated the steel targets, respectively in high and low detonation velocities, and the penetrating effects were analyzed. The results showed that the Al-WO_3 energetic materials could keep fine formability and reaction energy release property at the molar ratio of 8 to 1.

Keywords: Reactive fragment; Aluminum thermite; Al-WO_3; Warhead

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INTRODUCTION

Multifunctional energetic structural materials[1-3] (also called as reactive fragment) usually refer to the agglomeration of one or more kinds of metals by certain combination technology, which could produce exothermic chemical reaction in certain conditions. The agglomeration may be a thermite, intermetallic compounds, metal-polymer, or metastable compounds, etc. When the fragment penetrates the target at high speed, producing intense burning or explosion, it would release a large quantity of heat. This would effectively improve the probability of damaging internal components and increase the lethality inside target. On account of the advantages of energetic fragment, the foreign scholars conducted more thorough research in the mechanism, energy release and controlling method. Some country, including America and Russian, have paid great attention to the study of energetic fragment technology.

America DE company has already started the research of energetic fragment tech- nology in 1990s. Their energetic fragment has passed adaptability test in the explosion environment, and the experiment showed that the kill efficiency was far better than the common fragment. According to report[4], America has applied the energetic technique to a type of "Tomahawk" missile. In the promotion of academic development and defense applications in recent years, the energy release mechanism of energetic materials has also become more active in China. The study is mainly to track foreign research[5-7], which is concentrated on typical warhead verification of the energetic materials used in experimental research.

It is significant to develop the fragmentation warhead incorporating high- strength, high-density reactive composite materials as the warhead fragments. In order to realize the application of energetic materials, the key problems must be resolved, namely the energy release characteristic and inertness. The energetic fragment must be sufficiently insensitive in the acceleration process of detonation wave and does not react. The chemical reaction release energy occurs in the process of penetrating target, increasing its damage ability. According to the reaction types, the energetic fragments could be divided into metal oxidation reaction, thermit reaction, alloying reaction. In recent years, the metastable thermite has become a research hotspot in material field [8,9]. Because of its high thermal effect, flexible composition ratio and stability, it is widely used in metallurgy, material, fireworks and military field[10]. In metastable thermits, the reaction rate of Al-WO_3 is higher, at 412 m/s, however the reaction rate of Al-Fe_2O_3 is 30 m/s.

In the paper, the energy release characteristics in high dynamic load and forma- bility of thermit Al-WO3 would be studied. According to the reaction equation of Al and WO_3 and the specific volume of two powders, the appropriate volume ratio of two powders was judged based on the formability. The mixed powders were compressed into hemispherical liners by molding technology. The penetration process of the EFP was carried out, and the inertness and reactivity of the reactive fragment were investigated. Finally, the optimum formula of energetic fragment was acquired from the experiment.

EXPERIMENTAL SECTION

The powders of Al and WO_3 used in the experiment are Mesh 200 in particle size. Al reacts with WO_3 following the equation $2Al+WO_3=Al_2O_3+W$, and the Al:WO3 molar ratio must be 2:1 for complete reaction. The powder mixture at this ratio is poorly formed due to poor formability in WO_3 and so cannot be pressed into a material with desired strength without addition of sufficient amount of powder Al. It has been determined that Al:WO3 molar ratio is to be 6:1 as minimum to obtain a well-formed bulk with sufficient strength by comparing volumes of both powders and through the press test.

Based on the volumetric ratio of both powders, the powder Al:WO_3 molar ratios used in the experiment were 6:1, 8:1 and 10:1, respectively. Mixtures of three ratios were cold-pressed with moulds into nearly hemispherical charge liners in the weight of 8 grams at the relative density of about 85%. To compare the penetration effect, the powder Cu (density: 8.92 g/cm^3), of which the density is close to WO_3 (7.16 g/cm^3), was used to mix with the powder Al into an inert fragment which has a density close to that of the energetic material and same mass. Subsequently, they were sintered in the inert conditions. The sintered energetic material is malleable to some extent, the shape of the charge liner shown in Figure 1.

Figure 1. The shaped charge liner by mould pressing

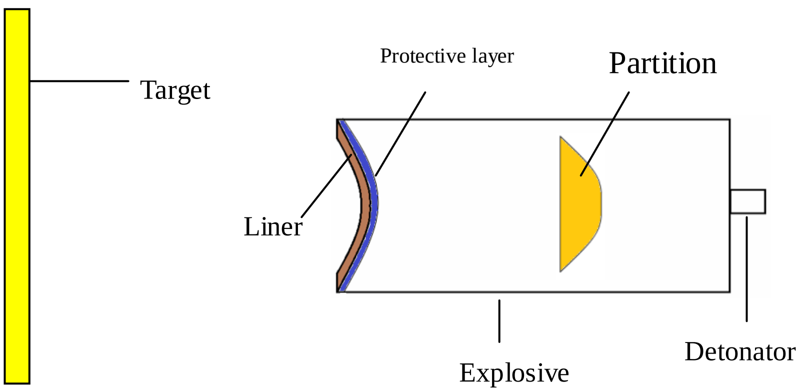

Figure 2. The experimental process of penetrating the steel target

The liner was Charged. A protective layer is provided to separate explosive from the charge liner to prevent the explosive's detonation wave from directly igniting the charge liner containing energetic material and meanwhile a partition is added into the explosive for controlling the wave shape. After charged, the penetration effect of energetic materials of different ratios striking the target when it is driven under the explosive detonation would be tested and the striking effect of fragments at different velocities will be determined when driven by the high detonation velocity explosive (HDV) and low detonation velocity explosives (LDV), respectively. The explosives used in the experiment were TNT(1.4 g/cm^3) and RDX(1.8 g/cm^3), respectively, and the experiment process is presented in Figure 2.

RESULTS AND DISCUSSION

The energetic material is in metastable state. One of keys to the energetic fragment warheads lies how to keep the energetic fragments chemically stable under a certain dynamic load, i.e. in this experiment, how to maintain the energetic fragments in stable state under the driving action of explosives. Controlling the detonation waveform in the right way so as to leave the detonation wave close to the shape of the charge liner may effectively narrow down the shearing effect of the detonation wave on the energetic fragments and thus make the generated penetrators steadier and more penetrative. Therefore, partition was placed in the explosives to control the waveform, subsequently changing the original detonation waveform.

Under the driving of explosive detonation, the material contained in the charge liner can produce formed projectile flying at a certain speed. The projectiles, however, are not penetrative to the desired degree unless they have sufficient strength. In the figure 3, under the detonation driving of HDV explosive RDX, the inert fragments and the energetic fragments at ratios of 8:1 and 10:1, respectively, penetrated the steel target while the one at the ratio of 6:1 failed. Analytically, the reason is that the energetic material at the ratio of 6:1 is poor in formability and results in weak strength as it contains less Al and more WO_3. Also, it was observed by comparing penetration effect of the inert fragments and the energetic ones, there were significant signs of metallic ablation on the holes penetrated by the energetic materials while this did not happen in inert materials. This suggested the energetic material burned when it was penetrating, indicating that the energetic materials at ratios of 8:1 and 10:1 were able to react and release energy instantaneously under the action of high-speed striking.

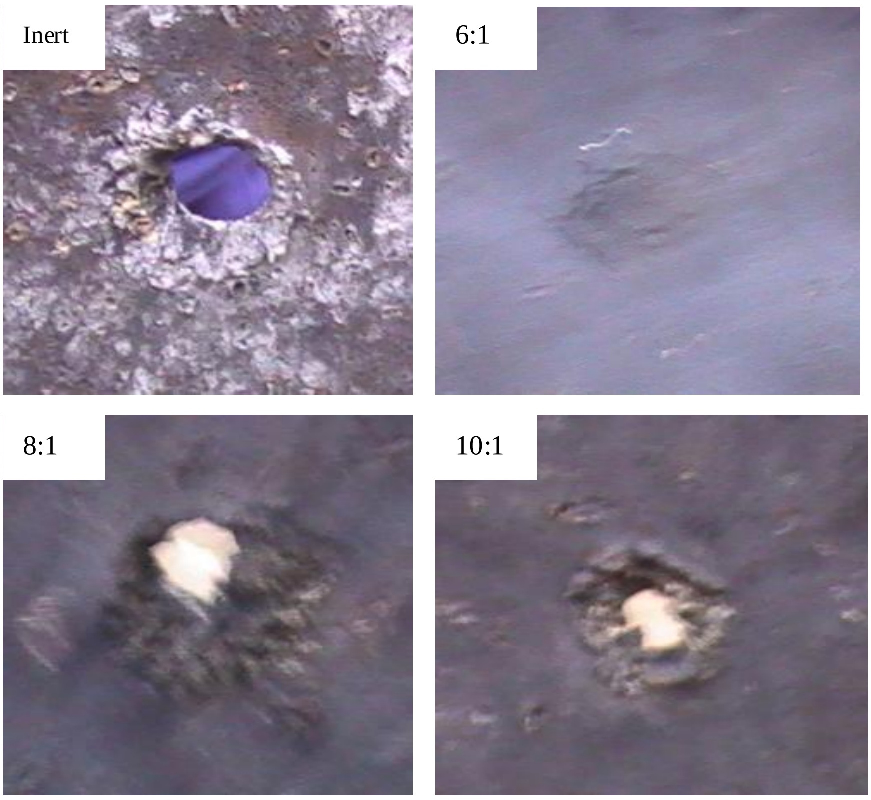

Figure 3. The penetrating results of fragments in HDV (RDX)

In the comparative experiment on another group, the energetic fragments penetrated the steel target under the detonating driving of LDV explosive TNT as shown in Figure 4. Comparing it with HDV penetration, it is known from the figure that under the LDV driving, all shaped shots had no sufficient kinetic energy to penetrate the steel target. In the case of the ratio 8:1, however, the steel target was penetrated to some depth and therefore it was inferred that the energetic material burned and released heat which melted part of the metallic target and led to craters which was measured about 3 mm deep to be formed in the target because of being penetrated by the projectile's remaining kinetic energy.

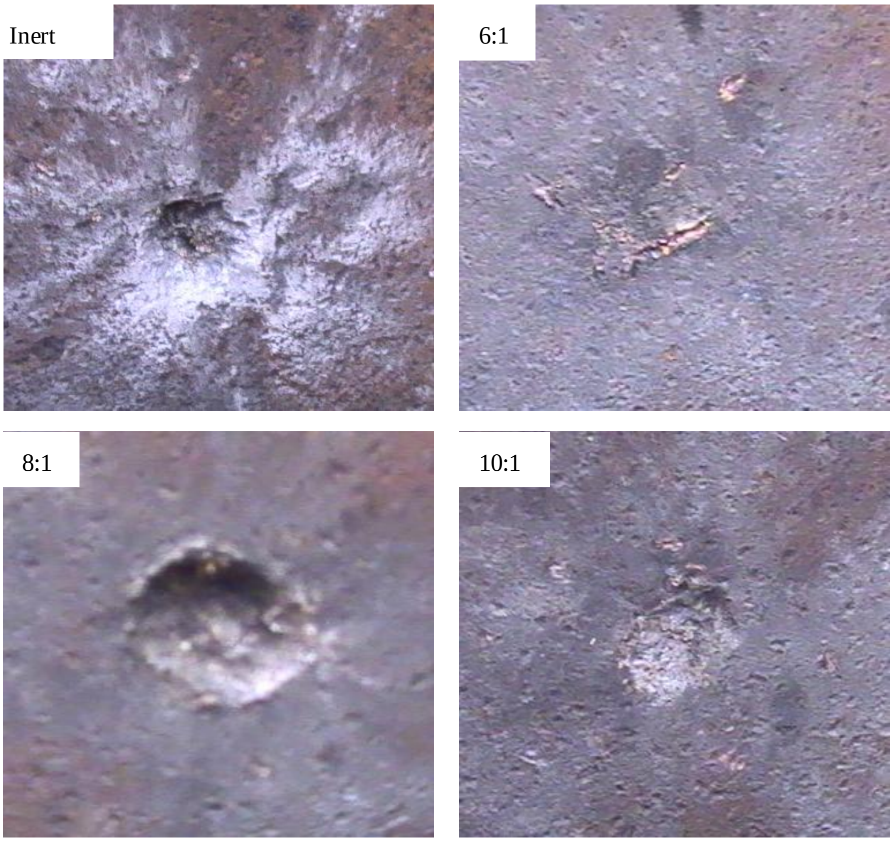

Figure 4. The penetrating results of fragments in LDV (TNT)

Because the energetic material is required to react and release energy in a very short moment, powders must be mixed at certain ratios. In the case of small percentage of powder Al, the energetic fragments are not strong enough to maintain the energetic fragments in a complete shape of formed projectile during the acceleration under the driving of the explosive detonation, thus limiting its penetrating performance at the striking of high speed. On the contrary, in the case of large percentage of power Al, it is hard for the energetic material to reach the condition triggering reaction and releasing energy under high dynamic load. Both cases have been well demonstrated in the experiment. From the above experiment, it was determined that the energetic material at the Al : WO_3 ratio of 8:1 could provide both better formability (or sufficient strength) and desired reacting and energy-releasing characteristics under dynamic load.

CONCLUSION

Successful application of the energetic material in the warhead entails the manufactured energetic fragments to be strong enough to form energetic penetrators with good ability in amour piercing. In the meantime the super-pressure from the shock wave due to striking could trigger the energy-releasing such as burning or detonation. So the ingredients contained in the energetic material must be mixed in the right percentages. It was concluded from the study on ratios of metastable thermite Al-WO_3 in the experiment that the energetic material at the Al:WO_3 molar ratio of 8:1 would have better formability and reaction energy-releasing characteristic. In addition, as the energetic fragment prepared in the study was cold-pressed into the charge liner, its density is lower and this would affect the material' strength and energy-releasing characteristic. Other formation techniques may be used to increase the density in order to get better effect.

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