

Study on Explosively Formed Projectiles Test System

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Abstract—Explosively Formed Projectile (EFP) is a new branch of the shaped charge technology. It is developed as an anti-solid target technology in recent decades. Velocity of EFP changes quickly with the change of EFP shape. It is very important to research the velocity and morphology change of EFP in their movements to improve its performance. In this paper, theory of the exploding forming effects of EFP is analyzed, the working principle and design process of the EFP test system are introduced, and a particularly detailed description of the structures is given. The way of assembling test system and the process of data processing in the experiment are described. The experiment result shows that this system has a bright application future in the area of the EFP test, and it is worthy to further study.

Keywords-Explosively Formed Projectile, laser Parallel Screens, net target, velocity

1. Introduction

Explosively Formed Projectile(also known as Self Forging fragment or Projectile Charge)is a new branch of the shaped charge technology. It has developed very quickly and has become a new technology in recent several decades [1]. With the principle of utilizing energy collection theory, shaped charge liner material with the action of high-heat and high-pressure condition happens greatly plastic deformation by means of the detonative action of explosive. The liner is squashed and closed together with the time. Shaped charge liner comes into being a body that is along with high velocity(1500~3000m/s) and structural shape projectile. Projectile penetrates goal in the case of high velocity. The difference between shaped charge jet and EFP is the obviously large velocity gradient of shaped charge jet, and shaped charge jet is constantly stretched at motion process. But the velocity gradient of all parts of EFP is obviously small, it forms the shape like projectile penetration ultimately, and the velocity of every stable projectile is same.

Recently EFP warhead has become an important warhead type in flexible anti-armour weapon. It is applied in practical condition generally. Every Military power has been carried out the EFP numerical simulation and tested research of forming mechanism, motion principle and damage efficiency.

Therefore, the text regards explosively formed projectile technology as the research object, and the flying velocity and deformation process of EFP are studied. The test system has profound guiding significance for evaluating the kill efficiency to goal and damage effectiveness.

There are lots of disadvantages in the test method on the forming process of common EFP. The disadvantages includes such as high test costing, difficult maintenance on the scene, difficult to acquire data and so on. On the basis of analyzing and summarizing the previous test means, the velocity and the shape of EFP test system which is based on relatively low costing net target and parallel laser light system is put forward. The system can test the forming process of EFP.

2. The System Design Of EFP

Explosion projectile fragment test principle schematic diagram

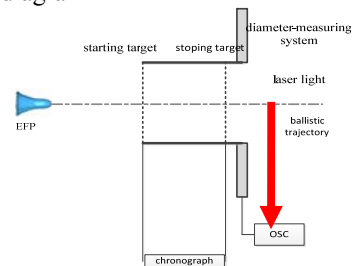


Fig 1 The principle of EFP velocity and the shape appearance test system

There are two major parts in the velocity, shape and appearance of EFP test system, including the net target velocity-measuring system and Laser light target diameter-measuring system. The velocity-measuring system is composed of starting target, stopping target and chronograph. The velocity-measuring system adopts area cutting velocity measuring method. The corresponding formula is $V \approx V_{aver} = S/T$. S stands for the distance between two net targets, and T stands for measured time by the chronoscope in the formula. Laser light target diameter-measuring system includes laser device, Fresnel lens and photoelectric detector and oscilloscope. In order to test the transformation process

of projectile at laser light location with time, the test system result is performed analog simulation by the use of Matlab software. The shape and appearance of Explosively Formed Projectile warhead can be got.

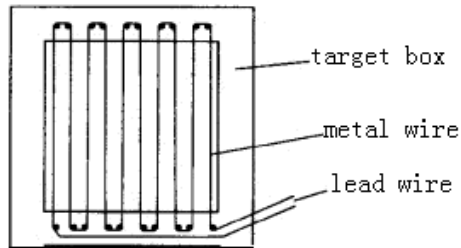


Fig 2 velocity-measuring system net target structure

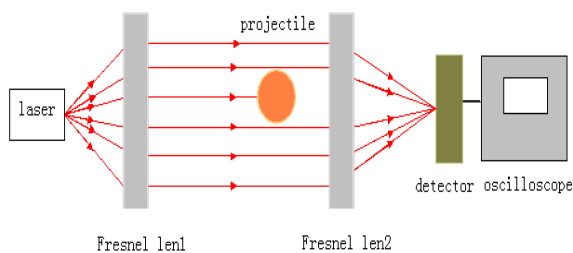


Fig 3 Laser light target diameter-measuring system principle

The pictured above is the Laser light target diameter-measuring system principle. According to Fresnel lens character, a linear red semiconductor laser is placed at the focus of Fresnel lens. Laser and lens must be kept vertical in the system, and parallel laser light comes out for a while. There is the other same Fresnel lens at the receiving terminal. Laser light is gathered in location with coincidence of lenticular focus. The function of lenticular focus is to detect the transformation of laser energy at photoelectric detector [2]. When projectile goes through parallel laser light, it impedes the part of light accordingly. The width of blocked laser light is identical with the diameter of projectile. A corresponding energy decrease has happened when the laser light is gathered in detector owing to blocking out laser light, and the output voltage transformation happens at the same time. The energy transformation which is detected by photoelectric detector and the diameter transformation of projectile which goes through laser light are deemed to be proportional in the error range. The energy transformation of laser light via photo-electricity conversion can be displayed by oscilloscope. So we can deduce the diameter of projectile in accordance with voltage transformation displayed by oscilloscope. The diameter changes are in accordance with the wave shape of EFP displayed by oscilloscope, so the text detects the diameter changes process of EFP along with time. Then the shape and appearance of going through parallel laser light EFP can be simulated. We load the wave shape data measured by oscilloscope into Matlab.

The horizontal axis represents time and the vertical axis represents voltage U. The diameter D of EFP projectile blocked laser light is translated into vertical axis voltage U. The conversion formula is:

$$D=L_{total} - (L_{total}/U_{total}) *U$$

L_{total} stands for the total parallel laser light width, and U_{total} stands for the total output voltage measured by oscilloscope in the case of unblocking laser light .

3. The Analysis Of Test And Simulation Result

3.1. The simulation result

The advantage of ANSYS/LS-DYNA simulation software is high velocity impact. The process of projectile impacting on target is simulated by the simulation software, and different velocities in the process of projectile impacting on target are analyzed.

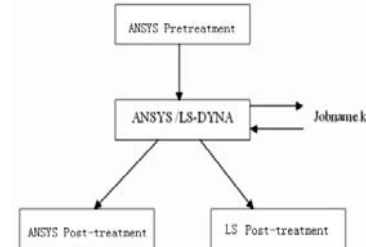


Fig 4 finite element analysis module

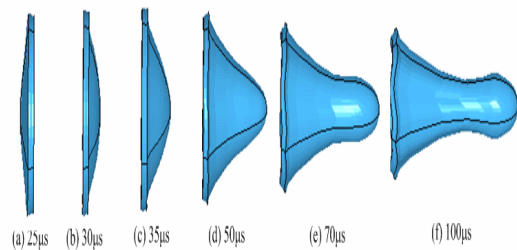
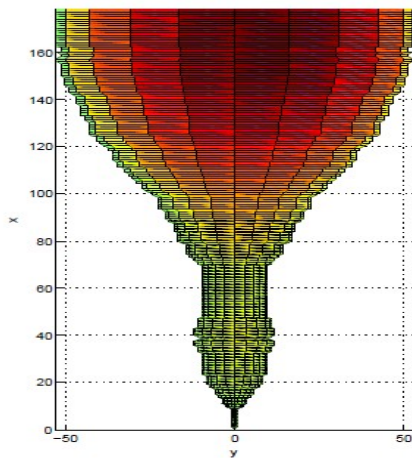


Fig 5 EFP forming process

The analog result of EFP forming process is shown in Fig 5. The instructions for the process are detailed below. The centre of liner accelerates beforehand, but the edge section of liner accelerates latterly. The latter is driven to move towards axis of symmetry at the same time. The liner turns so quickly that the head of it becomes symmetrical and the Shape of stern is trumpet-shaped. Because the center of gravity of formative hollow projectile is in front, the stability is relatively good when it is flying. The projectile forms a penetration at last.

Data measured by Laser light target diameter-measuring system is loaded into Matlab software. With the relation between voltage wave shape and the diameter of the projectile which blocks laser light, we get the simulation that projectile goes through Laser light target diameter-measuring system..



Detonation point1300mm projectile simulation model

Detonation point5500mm projectile simulation model

Fig 6 different simulation models

3.2. The Test Result

Two sets of data in the practical EFP warhead test are selected. When EFP attacks armour on the side, Laser light target diameter-measuring system is set at the location apart from detonation point 5500mm. When EFP attacks armour downward, Laser light target diameter-measuring system is set at the location apart from detonation point 1300mm. EFP velocity test system is placed at the front of laser light target diameter-measuring system. The measured velocity can be approximately deemed to the velocity of EFP which goes through Laser light target diameter-measuring system.

Two different EFP wave shapes from detonation point1300mm and 5500mm are respectively collected by Laser light target diameter-measuring system, and they are shown in Fig 7 and Fig 8.

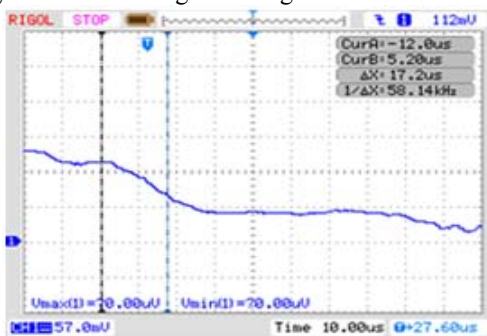


Fig 7 The collected wave shape at 1300mm

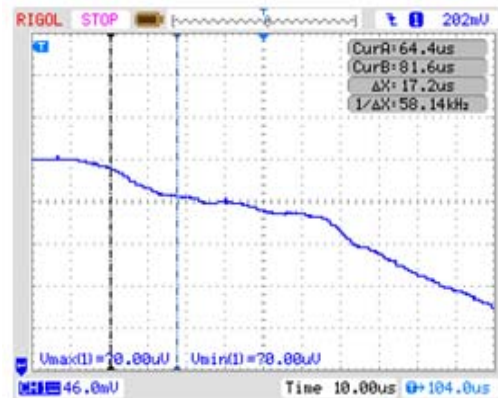


Fig 8 The collected wave shape at 5500mm
Table1. The diameters of projectile and the output voltage amplitude transformation

diameter (mm)	Amplitude transformation1 (mV)	Amplitude transformation2 (mV)	average (mV)
130	448	392	420
120	424	368	396
110	392	376	384
100	384	352	368
90	368	336	352
80	328	304	316
70	296	272	284
60	264	240	252
50	232	208	220
40	184	176	180
30	152	136	144
20	120	120	120
10	56	56	56

The output voltage transformation is averaged by solving different object diameters. We draw up the relation curve between the diameters and voltage transformation characteristics. The relation curve is shown in Fig 9.

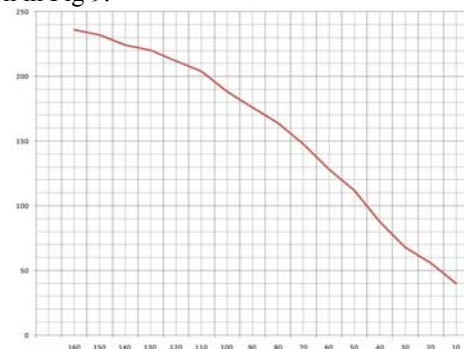


Fig 9 amplitude transformation characteristic curve

The flying time captured by the EFP velocity test system is respectively 1492μs and 1633μs when EFP attacks armour in two different ways. According to the

distance 3000mm between two targets, we can work out the velocity of EFP in both cases in accordance with formula. It is shown in Table2.

Table2.The velocity of EFP

Test characteristic	EFP target time (μs)	EFP velocity (m/s)
EFP attacks armour on the side	1492	2010.7
EFP attacks armour downward	1633	1837.1

4. Conclusion

In modern warfare, EFP warhead have become an important warhead type in flexible anti-armour weapons. It is widely applied for anti-tank and resistance to the armour goal of airplane and warship and so on. Therefore the flying velocity and forming process of EFP are of great importance for researching the penetration ability of EFP. The paper puts forward adopting laser light to forming process research and designing the test system of velocity and diameter of EFP. The system is detailedly tested and verified in the article.

The characters of The test system:

(1) Uniform laser light which has large area is easy to adjust. The monochromaticity and high anti-interference capability of it are excellent;

(2) The theory and technology of high-frequency response photo-electricity conversion system are put forward. The moving object through target with high velocity can be captured;

(3) The theory and technology of acquiring the cross profile shape of object by using of laser light scanning is adopted.

(4) Contiguous target is combined with non-contact target, and the test process has more feasibility and economy.

(5) P-warhead forming process is preliminary explored and researched.

Ultimately the test data and simulation result are mainly matched. The text can explain that the EFP forming system has ideal stability, and the Explosively Formed Projectile deserves to be studied and discussed further finally.

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