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The Apply on Photoelectric Detection Target and its Development in Exterior Ballistic Test System

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Abstract

Photoelectric detection target is an instrument which was used to measure the parameter of flying projectile in exterior ballistics. This paper introduces the effect of photoelectric detection target in weapon testing target range, and its working principle; describe its application and development. Combined with the requirement status of exterior ballistic flight parameter, the improvement proposals are put forward to eliminate the shortcoming of photoelectric detection target, and analyze the improved method and measure. Through experiment, the results show the combinatorial photoelectric detection targets can gain the velocity and coordinate of all kinds of flying projectiles, and the measure accuracy is very high.

Keywords: Photoelectric detection target, projectile, ballistics, coordinates.

1. Introduction

In weapon testing domain, assessing the index about all the kind of weapon, such as the offset on artillery shooting target, the fire compression on multi-barrel artillery, the velocity and coordinate of flying projectile, these parameters index are restricting the production of new weapons and cannonball. At present, the measuring methods of each parameter have sky screen measuring instrument which are composed of four light screens across or six light screens across in space, acoustic target measuring instrument and radar measuring instrument, etc[1]. Radar measurement instrument cost is very high and can not common use in various targets shooting range, when acoustic target measuring apparatus was used in high-altitude targets, which have many questions, such as, installation inconvenience, structure complexity, and so on.

Light screen target are mainly applied in interior measurement, also can be used in outdoor, but due to its structure characteristics, the measure surface of light screen target is very small relatively, it can not be applied in high-altitude measurement, its advantage is not subject to interference from external sources[2]. Sky screen target is mainly applied in outer trajectory to measure the parameters of flying projectiles.
photoelectric detection target at present; it can realize the speed of all kind of projectiles, the fire coordinate high-altitude proximity fuze, the speed of various a running fire and intensity parameters. The photoelectric detection target is both active and passive source detector; it has been used in the field of weapons testing, with multiple screens principle and processing system, can achieve the flight speed of the bullets, vertical target coordinates, angle and other parameters measure[3-4]. With the constantly updating and development, photoelectric detection target play an important role in weapons test area. The technology of photoelectric detection target is a part of the test weapons, and weapons testing technology is the basis for the development of weapons technology, weapons research and production is an indispensable part, history has repeatedly proved that every major breakthrough of weapons technology, often accompanied by the relevant significant progress in testing technology. Photoelectric detection target with its unique advantages, so, its improved research will play a significant role in the field of weapons.

2. Principle and characteristics of photoelectric detection target

Photoelectric detection target is a measurement instrument that is used to detect the information when flying projectile going through the measurement screen. It is made by application optical principles. Because of the slit diaphragm in photoelectric detection target, it make the detection screen turn to a certain thickness by imaging lens, usually, it was called detection light screens[5]. Once the projectile fly into the detection light screens, the projectile will shut out part light in detection screen, which will make the photocurrent of the photoelectric converter bring a change signal, the changing signal will output a pulse signal by the amplification circuit and shaping circuit, we can use the output pulse signal to time and calculate correlative parameter in across screen measurement system, and then, the correlative parameter will gain by the combined photoelectric detection target.

From the use of angle of light, photoelectric detection target can divide into sky screen target and light screen target, their work principle is same, they both are non-contact type measuring instrument and can be used repeatedly, their difference is the use of different light source when work. Sky screen target make use of natural light source as testing background, its advantages are detection area is large, sensitivity is very high, measure accuracy is high, and when it working, its stability and reliability is very good. At present, sky screen target has become an important device of target range outer ballistic testing, not only domestic widely adopted, but also exported to abroad. Due to the sky screen target make use of natural light as testing source, which is bound to be the impact of background light, and it can not work at night[6].

However, light screen target are mainly make use of active light source as testing background, it can work at night or indoor, environment light has less impact its work performance. The screen surface of light screen target is composed of many ray, its screen surface is very intuitionist, which is very advantaged to improve the measure accuracy and overcome the error of target distance, but, it exist many disadvantages when the measurement target surface is very width, such as, the layout will bring to difficulty, its detection senility is very low, it can measure the projectile burst location, and so on[7]. At the same time, due to its relatively poor seismic performance, when the environment bring big vibration, it would cause illuminant librations, and it make the measure system cause mistaken trigger. So, in the field, the sky screen target that use natural light as testing source is often used to measure projectile parameters, we name it as photoelectric detection target. Using combination photoelectric detection target and rational design its structure, combined with appropriate electronic circuit and data processing equipment, the across measure system can measure the coordinates when projectile shoot objection and velocity of flying projectile.

3. Application and improvement on photoelectric detection target

3.1 Application of optic-electric detecting fire

With the development of science and technology, the method that measure projectile parameters are constantly updated and upgraded. In the late 1970s, our country made successfully first-generation sky screen target, its name is GD-79-type level of sky screen target, it marks the photo electricity technology has successful applied to field of exterior ballistic testing in China[8]. Erenow, the projectile parameters
test is limited to the velocity measurement in the domestic range, the majority measure instrument is coil target, which use the principle of electromagnetic induction made to cross-sectional area device[9]. When projectile with magnetic characteristic go through coil area, it will bring cutting magnetic lines and output voltages signal. However, the coil target can not test the non-conducting magnetic projectile and detection area is very small, it cannot adapt to variety projectile velocity measure, such as, shelling bullets, shrapnel, and so on.

Photoelectric detection target is a non-contact measuring instrument, which is not subject to the impact of the projectiles material, when it work, once photoelectric detection target was layout, it will no need to adjust under course of the experiment, and it can measure all kind of projectile parameters. It is indispensable measurement equipment in weapons test range exterior ballistic.

Early, due to technical limitations at that time, especially, the initial developing stage, photoelectric detection target cannot meet the demand of big target surface and its detection sensitivity is very low. The first generation sky screen target of GD-79 type was made in 1985, it was compared with five kind sky screen target, two kind light screen target and laser target, the result show that GD-79 type sky has many merits, such as, the precision high, operation simpleness, reliability, and so on. It opens a new chapter to its improvement and application at future.

In recent years, with the development of photoelectric technology, the optic-electric detector with high responsibility and low noise was applied to design photoelectric detection target, it can work in multi-channel spectrum scope, and it can improve the questions that detection circuit output signal saturation by using fiber assemble measure and detection view small. At the same time, this kind detector makes the detection structure simply. Now, the photoelectric detection target use the photo-electricity tube with linked rectangle to design the detection system, its detection view reach 60°, the measure precision about is 0.005, and it can content the need of various types of guns. Velocity and fire target density are major parameters in weapon system, which are major measured indexes in product guns and drugs in currently, so, how to gain these parameter is very important. Follow, we analyze all kinds measure instrument.

Based on the measure projectile velocity system by using photoelectric detection target, we increase two tilted light screen to make the measure system turn to double type across screens, which can gain velocity and coordinate parameters of flying projectile. The system measure principle can be shown by figure 1. Photoelectric detection target is core unit in system, when flying projectile go through across screen, photoelectric detection target will output a pulse signal, combined measure geometric model and time system, and we can work out the two dimensions coordination parameters.

In four across screens measure system, the surface of ABCO, GFCO, AFDO and GFDE respectively are four light screen of $M_1$, $M_2$, $M_3$ and $M_4$, these four screen are across in space. The $\alpha_1$ is an angle between light screen $M_1$ and $M_3$, and $\alpha_2$ is other angle between light screen $M_2$ and $M_4$, when the screen were laid, the light screen $M_1$ and $M_4$ must be design to parallel and plumb ballistics. The $Q_1$, $Q_2$, $Q_3$, and $Q_4$ are their across point in four light screen, $M_1$ is start up light screen in timer system, $M_2$, $M_3$ and $M_4$ are stop light screen. Their value of time respectively are $t_1$, $t_2$ and...
We can obtain the time of \( t_1 \), \( t_2 \) and \( t_3 \) by using timer, and according to geometric relationship of across screens, the coordinate of \( x \) and \( y \) can be calculated, their relation can be expressed by formula (1) and (2).

\[
x = \cot \alpha_1 \cdot \frac{s}{t_3} \tag{1}
\]

\[
y = \cot \alpha_2 \cdot \frac{s}{t_3} \cdot t_1 \tag{2}
\]

Across screens measure system of double \( N \) type can meet measure requirement of big or small target surface base on selecting components. To small target detection meet, the demands on detection sensitivity in photoelectric detection target are not high, usually, many measure systems can meet. If the distance exceeds kilometres between cannon and object, the measure target surface is very width; the detection sensitivity of photoelectric detection target must be very sensitive and can measure all kinds of projectiles.

Optical fiber coding fire also is a kind of photoelectric detection target, the different place is their calculation principle. The space geometry calculation principle of optical fiber coding fire can be show by figure 2. \( O_1 \) and \( O_2 \) are center of lens of optical fiber coding fire, and they are lay in both sides of ballistic trajectory. \( O_1A \) and \( O_2B \) are their optical axis in calculation model, when Optical fiber coding fire work the angle of \( O_1A \) and \( O_2B \) is 90°, \( xoy \) is the coordinate system, \( \alpha_0 \) is a angle between \( O_1A \) and horizontal plane, \( \beta_0 \) is a angle between \( O_2B \) and horizontal plane, generally, \( \alpha_0 = \beta_0 = 45^0 \).

\( P(x, y) \) is a coordinate point which is passed through by projectile, \( \alpha \) is a angle between \( O_2P \) and \( O_2Q = s_2 \), \( QR = s_1 \), \( O_2R = l_2 \), \( QO_1 = l_1 \), the geometric relations can be gain by formula (3) to (6).

\[
l_1 = \frac{s_1 + s_2}{1 + \tan(\alpha_0 + \alpha)/\tan(\beta_0 - \beta)} \tag{3}
\]

\[
l_2 = s_1 + s_2 - l_1 \tag{4}
\]

\[
x = l_1 - l_1 \tag{5}
\]

\[
y = l_1 \tan(\alpha_0 + \alpha) - h_0 \tag{6}
\]

Here, \( h_0 \) is the height points \( O \) to \( O_1O_2 \). However, whether the photoelectric detection target of \( N \) type or Optical fiber coding fire, they can solve the problem that flying projectile shoot object relatively coordinates. But, because of the particularity of experimental environment, the improvement study of photoelectric detection target and Optical fiber coding fire still face many challenges.

### 3.2 Improvement and study on photoelectric detection target

With the appearing of more advanced and newer weapons, the new demands for measurements of flight projectile parameters have been put forward, such as, the initial velocity measurements on large diameter gun, the fire, high shoot frequency weapon, and so on. When these demands higher and stricter, the photoelectric detection target must be improve to meet measure need.

To measure initial gun muzzle velocity, photoelectric detection target will affected by the strong firelight, which make photoelectric detection target bring mistake trigger. So, to decrease the effect, we must place photoelectric detection target away from gun muzzle, if the distance is more away, the effect
will more small. To improve this effect, we also can use net target to measure projectile’s initial velocity, the principle of net targets are usually use the make-and-break of the iron wire. Its shortcoming is that iron wire need reconnect after every shot. If target surface is very width, the structure of net targets are large, which will be affected by environment, such as, wind, wire material, and so on. However, the effect of photoelectric detection target by environment is very feebleness, this merit the photoelectric detection target apply widely. So, it is significant to improve of photoelectric detection target. Base on the demand of gun muzzle testing, the array optoelectronic detector was put forward to design the detection system of photoelectric detection target.

We know photoelectric detection target has many merits, for example, it can resist wind, the structure design is very simple, and the detection view is relative width. Because of those merits, photoelectric detection target can be applied in many shooting range testing. In the design of shooting range, we can choose the same size of lens aperture or the larger to design its optical system. To eliminate the effect of muzzle fire, base on the characteristic that fire light affect the whole detector simultaneously, we will optoelectronic detector can divide to main detection area and the compensated area. The main detection area receives the projectile information. The compensated area can weaken the light come from the main detection area, usually, the signal of main detection area more than the compensated area, the two area signals was subtracted in detection circuit, we can distil the signal of projectile, this measurement make the performance of photoelectric detection target has improved, which can improve the initial muzzle velocity measurements in testing.

To make the photoelectric detection target have extensive application, in addition to above improvement, we should consider lighter combined screen, set up their geometry model and calculate method. If the measure model is reasonable, the application and development of the photoelectric detection target can satisfy the requirements of current external ballistic trajectory.

4. Conclusions

Photoelectric detection target is equipment to measure parameters of flying projectile in exterior ballistics, whose development and improvement is closely related with improving measurement accuracy of the parameters of the flying projectile. The discussion of more desirable method and the design of the best Detection circuit is an important part of the improvement of the photoelectric detection target. Sky screen among the photoelectric detection target has not achieved all-weather measurement. So if its work scope can more expands, photoelectric detection target will step into a new level in the weapons.

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