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Object location fire precision test technology by using intersecting photoelectric detection target

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ABSTRACT

To improve four across screens system measurement precision on flying projectile location, the new method that adds two incline screens to four intersecting screens system to form six intersecting screens was put forward and the flying object coordinate test model was set up. This method not only gains object coordinate but also measures object's pitching and azimuth angle that can amend coordinates and improve measurement precision. The differential methods were used to analyze their measure errors, which came from the angle of intersection screen, the thick of screen, the time and distance of measuring, and give out measure errors distributing. The experimental result shows the new measure method can improve measurement precision that meets test demand.

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1. Introduction

In shooting range, the measurement of flying object velocity and coordinate are an important content in target range test, which directly provides the experimental basis for the development and production of gun or object [1]. From the test method, the velocity measurement mainly has two kinds, one is the instantaneous velocity measurement, and the other is the average velocity measurement [2]. These parameters will affect the warhead performance. The precision of those parameters is very important to the measure system, which will limit the development of new warhead. Two-dimensional coordinates of the object shooting locations are one of important parameters, especially, the inspection of the object fuze burst location in the high altitude [3,4]. The method of two-dimensional coordinates usually uses four intersecting screen system, which is composed of four photoelectric detection targets and signal disposal instrument [5], but this method has some demerits, for example, if the object cannot uprightly pass the screen, the errors of coordinates are larger, and it cannot gain the pitching and azimuth angle when object is flying. In this paper, the new method is introduced based on the high sensitivity of photoelectric detection target to improve coordinates accuracy.

2. The questions of four intersecting screens measure system

2.1. The detection principle of photoelectric detection target

The photoelectric detection target is mainly composed of optics lens, the slit diaphragm, photoelectric detector, and the processing circuit [6]. Because of the function of silt diaphragm, it may form the detection screen in photoelectric detection target; it may be expressed in Fig. 1. When object passing its screen, the screen will bring change in light energy that makes the photoelectric detector output a change in instantaneous simulation signal, and the simulation signal was disposed by the processing circuit, the terminal of detection circuit will output a digital pulse signal. We apply this digital pulse signal to time and combine measurement spatial geometry relation to calculate the parameter of flying object in multi-screen intersecting system. Here, f is focus of lens.

2.2. Four-intersecting screens system

The measurement principle of four-intersecting screens system is composed of four photoelectric detection targets, gathering and processing system. The photoelectric detection target form four detection screens, its working principle when the flying object going through the detection screen, the detection circuit of the photoelectric detection target generating a pulse signal to touch the timer. We use computer to gather three time value and calculate object's velocity and coordinates in four-intersecting screens

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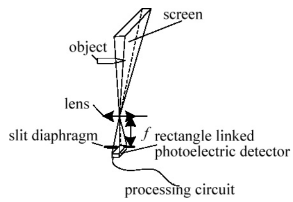

Fig. 1. The detection principle of photoelectric detection target.

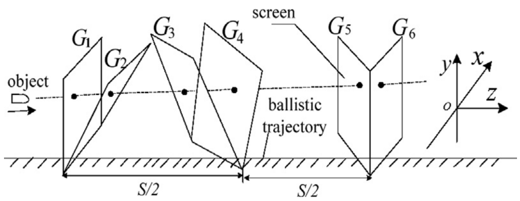

Fig. 2. Six-intersecting photoelectric detection target.

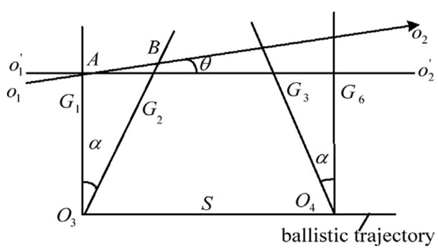

Fig. 3. The spatial geometry of *y* in improved intersecting screens system.

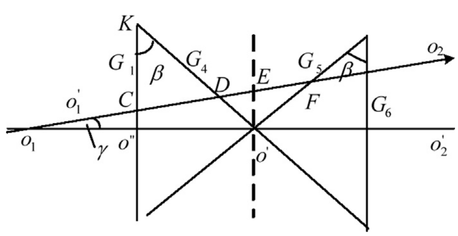

Fig. 4. The spatial geometry of *x* in improved intersecting screens system.

system. From Ref. [7], we know that the coordinates in four screens are not the real plane coordinates, the coordinates must be modified.

3. New design measure method and analysis

In order to improve the measurement accuracy, we add two photoelectric detection targets in four-intersecting screens system to form six-intersecting photoelectric detection targets, such as Fig. 2.

Their spatial geometry relations are shown in Figs. 3 and 4.

The measurement principle of six-intersecting photoelectric detection targets is that the photoelectric detection target generates a pulse signal to touch the timer, and time gather system register five time value when the flying object going through the six screens. The output of G_1 is timer's start signal, the output of $G_2 \sim G_6$ are the stop signal, their time value are t_1, t_2, t_3, t_4, t_5. Here t_1 denotes the time between G_1 and G_2, t_2 denotes the time between G_1 and G_3, t_3 denotes the time between G_1 and G_4, t_4 denotes the time between G_1 and G_5, t_5 denotes the time between G_1 and G_6, S is distance between G_1 and G_6. The intersecting angle of G_1 and G_2, G_3 and G_6 both are α. The intersecting angle of G_1 and G_4, G_5 and G_6 both are β. o_1o_2 is object idea flying track, $o_1'o_2'$ is object actual flying track, θ and γ separately are pitching and azimuth angle of o_1o_2 and $o_1'o_2'$ in the coordinates plane of xoz and yoz, the screen of G_1 and G_6 are parallel and vertical to the ballistic trajectory, o' is their central. Supposed, L is the distance between G_6 and goal model, we analyze and calculate their coordinates.

According to the geometry relation, θ can be obtain as

$$\theta = acrtg\left(\frac{t_5 - t_2 - t_1}{t_5 - t_1} \cdot ctg\alpha\right) \tag{1}$$

By geometry relation of Fig. 4 and the cosine theorem of $\Delta Eo'D$ and $\Delta Eo'F$, and then

$$\frac{DE}{\sin\beta} = \frac{Eo'}{\sin(90^\circ - \beta + \gamma)} \tag{2}$$

$$\frac{EF}{\sin\beta} = \frac{Eo'}{\sin(90^\circ - \beta - \gamma)} \tag{3}$$

Here, $DE = (t' - t_3)v\cos\gamma$, $EF = (t_4 - t')v\cos\gamma$, and $t' = t_5/2$, we can gain parameter of azimuth γ.

$$\gamma = arctg\frac{t_4 + t_3 - t_5}{(t_4 - t_3) \cdot tg\beta} \tag{4}$$

By triangle ΔAO_3B, and then

$$\frac{AB}{\sin\ \alpha} = \frac{BO_3}{\sin[90^\circ - (\alpha + \theta)]} \tag{5}$$

Here, $AB = S/t_5 \cdot \cos\theta$, we can gain the expressions of coordinates y.

$$y = \left[\frac{S \cdot \cos(\alpha + \theta)}{\sin\ \alpha \cdot \cos\theta \cdot t_5} + (S + L) \cdot tg\theta\right] - H \tag{6}$$

H is the distance between central coordinates to ballistic trajectory. In ΔCDK, we know, $\angle CDK = 90^\circ - \beta + \gamma$, $CD = S \cdot t_3/t_5 \cdot \cos\gamma$. According to the relation of triangle law of sines and spatial geometry, coordinates x can be expressed as

$$x = \frac{S}{2}ctg\beta - \frac{S \cdot t_3\cos(\beta - \gamma)}{t_5\ \sin\beta\cos\gamma} + (S + L) \cdot tg\gamma \tag{7}$$

Based on θ, γ and the direction of flying object, we can gain the velocity of flying object by expression (8).

$$v = \frac{S}{t_5 \cdot \cos\ \theta \cdot \cos\gamma} \tag{8}$$

4. Error analysis

According to the mathematical model, the parameter of s, t_1, t_2, t_3, t_4, t_5, α, β will bring to measure error in screen intersecting system. We analyze their error by calculative expressions and measure condition.

4.1. Time error

The time error always comes from the precision of time scale, the consistency of detecting sensitivity of each photoelectric detection target output signal, the thickness of screen, and the interference from surrounding [8,9]. Seen from the time benchmark, the error is lesser when the precision of time scale is more precise. The time benchmark uses 20 MHz crystalloid to design gather system, and the error unit is ±50 ns. The detection component of photoelectric detection targets is chosen rigidly to make the output signal consistent.

The test system is aimed at the measurement for parameters of big size area. The thickness of screen is thicker when the detection height is higher [10]. On the same condition, the error arouse from the output signal of detection target. If the camera lens focus

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