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Analysis and calculation object detection capture rate in multi-sky-screens across measurement system

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ABSTRACT

In this paper, a new calculation method on the capture rate of multi-sky-screens across measurement system was researched and analyzed. The measurement principle of multi-sky-screens across measurement system was introduced, and the optical detection principle and detection sensitivity were discussed based on photometric theory. According to the relation of detection screen thickness, projectile length and photoelectric detector performance, and the gradient screen characteristic, the calculation expression of capture rate on multi-sky-screens across measurement system was induced and analyzed in detail. From the three kind states relation between projectile length and detection screen thickness, the function of capture rates was analyzed and calculated by experimentation under different detection distances and different environments. The result shows when the projectile length is more than and equal to the detection screen thickness under the same conditions, the capture rate is highest; when the projectile length is less than the detection screen thickness, the capture rate will reduce; and the gradient screen's capture rate is less than vertical screen, those experiments are consistent with the theories analysis.

1. Introduction

The capture rate of multi-sky-screens across measurement system is a core index in weapon checkout, the high or low of capture rate decide system measure's data whether or not reality and credibility, which affect weapon performance and finalize the design. Multi-sky-screens across measurement system are mainly composed of four or six sky-screens, time instrument and processing circuit [1,2]. In this measurement system, sky-screen is core test instrument, it work under natural light and detect projectile image information when projectile passing their detection screen, natural light affect its detection sensitivity and capture rate, in addition, the projectile's size, photoelectric detector sensitivity, the processing circuit, and detection screen thickness also are main effect capture rate factors [3–5], however, the capture rate of multi-sky-screens across measurement system are decided by sky-screen's detection sensitivity and their measure structure, so, we must be study sky-screen' capture rate to calculate capture rate of multi-sky-screens across measurement system.

The measurement principle and error analysis on multi-sky-screens across measurement system are introduced in many references, such as Refs. [6,7]. Ref. [8] mentioned that use rectangle linked photoelectric detector to design sky-screen's optics detection system. Refs. [9,10] introduce the research on the performance improvement of the sky-screen. But, the capture rate of multi-sky-screens across measurement system still have not idea method to introduce and analyze, so, it is very necessary to research capture rate of multi-sky-screens across measurement system.

The framework of this paper is organized as follows. In Section 2, we introduce the measure's principle of multi-sky-screens across measurement system; Section 3 analyzes detection sensitivity and capture rate of sky-screen, research projectile optical characteristic to capture rate effect, and give out capture rate calculation method, research the relation different projectile lengths and different detection screen thicknesses to capture rate effect; Section 4 gives out the experimentation and analysis. Finally, a brief summary is discussed in Section 5.

2. The measure's principle and characteristic of multi-sky-screens across measurement system

Multi-sky-screens across measurement system can measure flying projectile's velocity and two-dimensional fire coordinate, its measurement model can be shown by Fig. 1, which is mainly composed by four sky-screens and signal processing instrument.

In Fig. 1, M_1, M_2, M_3 and M_4 are four detection screens that is formed by four sky-screens, *xoy* is coordinates area, *o* is coordinate central, *H* is the high, when projectile passing coordinate area, we can gain the two-dimensional coordinate relative to the point $o(0, H)$ based on their spatial geometry, here, sky-screen is a detection instrument to detect the projectile image information when projectile passing its detection screen; it is mainly composed of optics

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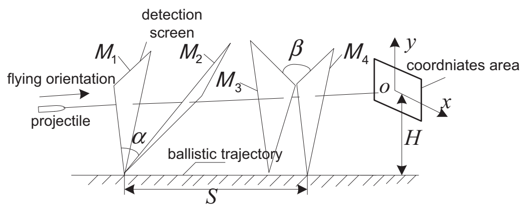

Fig. 1. The principle of four screens across.

lens, the slit diaphragm, photoelectric detector, and the processing circuit [11,12]. Because of the function of silt diaphragm that may form the detection screen, detection principle of sky-screen may be shown by Fig. 2.

When projectile passing sky-screen's detection screen, the photoelectric detector gain change luminous flux, and detection circuit output an instantaneous change simulation signal, and this signal was disposed by the processing circuit, and the terminal of detection circuit will output a digital pulse sign. We apply this digital pulse signal to time in multi-sky-screen across measurement system and combine spatial geometry relation to calculate the parameter of flying projectile.

In multi-sky-screen across measurement system, when projectile passing four detection screens of M_1, M_2, M_3 and M_4, the timer will gain three time value, the output signal in detection circuit of M_1 is timer's start signal, the output signal in detection circuit of M_2, M_2 and M_4 are timer's stop signal accordingly [13]. Suppose, t_1 denotes the time between M_1 and M_4, t_2 denotes the time between M_1 and M_2, t_1 denotes the time between M_1 and M_3, S is distance of M_1 and M_4. In design, the detection screens M_1 and M_4 are parallel and vertical to the ballistic trajectory. M_2 and M_3 are oblique detection screen, the across angle of M_1 and M_2 is α, the across angle of M_3 and M_4 is β. According to the geometry relation of multi-sky-screen across measurement system, we can calculate projectile's coordinate by formula (1) and (2).

$$x = \tan\ \beta \cdot S \cdot \frac{t_3}{t_1} \tag{1}$$

$$y = H - \tan\alpha \cdot S \cdot \frac{t_2}{t_1} \tag{2}$$

From Fig. 1, we know the lay mode of four sky-screens is different in test, M_1 and M_4 are vertical to the ballistic trajectory; M_2 is not vertical to the ballistic trajectory, there is an oblique angle α from side face observation with M_1, such as Fig. 3; M_3 is vertical to the ballistic trajectory, but, there is an across angle β with M_4 or M_1 from look down observation, such as Fig. 4; the detection sensitivity and capture rate to every sky-screen are different when the high of flying projectile is the same, so, we must research and analyze their sensitivity and calculate their capture rate according to measure spatial geometry relation of multi-sky-screen across measurement system.

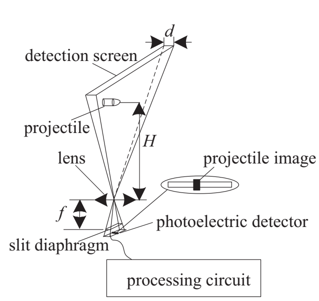

Fig. 2. The detection principle of sky-screen.

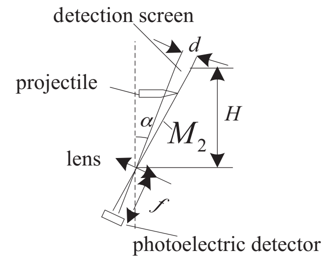

Fig. 3. The sketch of oblique detection screen M_2 from side-face observation.

3. Capture rate calculation and analysis

3.1. Detection sensitivity analysis on sky-screen

The sky-screen's sensitivity is defined as: under certain illumination condition, the sky-screen can induce minimum image information of projectile in photoelectric detector when projectile passing its detection screen, it may be shown by formula (3).

$$\delta = \frac{\Delta\Phi_{\min}}{\Phi} \times 100\% \tag{3}$$

In formula (3), Φ is the whole incidence luminous flux that photoelectric detector accept, $\Delta\Phi_{\min}$ is the smallest variation luminous flux in photoelectric detector sensitive area that can cause and bring output signal in detection system, δ is sky-screen's detection sensitivity [14].

From the sky-screen's detection sensitivity concept, when the detection circuit was ascertained, the detection sensitivity is also related to the minimum incidence luminous flux that the projectile passing through the detection screen, if the incidence luminous flux that the photoelectric detector receive are more, the δ would be very small, the detection sensitivity can be enhance. Under the same illumination condition, the incidence luminous flux is decided by the lens and the size of slit diaphragm.

According to the detection principle of sky-screen, its detection sensitivity lie on the size incidence luminous flux of projectile image area in photoelectric detector, we can calculate the background luminance in photoelectric detector by formula (4).

$$E_1 = \frac{\pi}{4} \cdot \tau \cdot B_1 \cdot \left(\frac{D}{f}\right)^2 \tag{4}$$

B_1 is sky background luminance, τ is permeance rate of lens, D is aperture of lens.

Supposed, E_2 is projectile image luminance, it can be expressed by formula (5).

$$E_2 = \frac{\pi}{4} \cdot \tau \cdot B_2 \cdot \left(\frac{D}{f}\right)^2 \cdot K \tag{5}$$

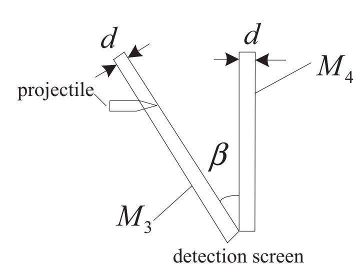

Fig. 4. The sketch of across screens M_3 and M_4 from look down observation.