OPTICAL SYSTEM FOR ANTI-AIRCRAFT ARTILLERY FIRE TRAINING OBSERVATION

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The article discusses the design and the operating principles of an optical system for the observation of anti-aircraft artillery fire training. The system is highly effective, making it suitable for use as a key element of a skills verification system aimed at sub-units and gun crews.

Keywords: metrology, optical head, anti-aircraft artillery, fire training

The optical system for fire training observation has been developed to verify the accuracy of determination by other measurement systems (in particular, acoustic systems [1—3]) of coordinates of anti-aircraft artillery projectiles in relation to their targets. The system is intended for recording images of aerial targets, determining aerial target trajectories, recording images of artillery projectile tracers' pyrotechnic flares, and determining aerial target firing miss distances.

The system is a portable device. It consists of a PC computer and two optical heads (Fig. 1), each of which consists of: a) a lens, b) a high-speed camera, c) a monitor, d) a rotation mechanism, e) an angle readout system, and f) a stand, as well as a power supply system and a wire set. The head enables the replacement of the lens, whose selection depends on the distance from the objects being observed and the optical resolution requirements. The head is equipped with a rotation mechanism with three degrees of freedom.

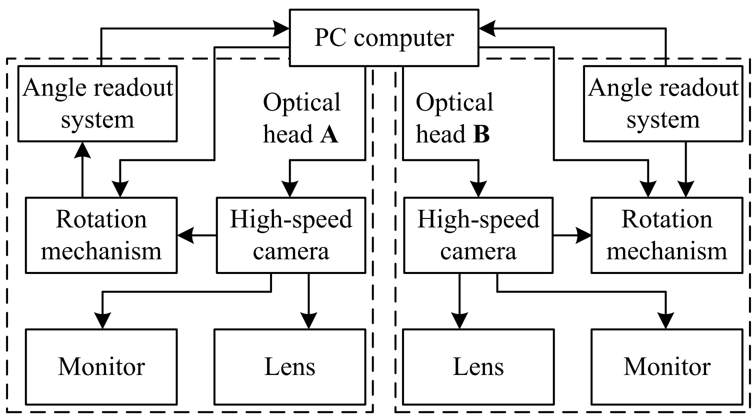

Fig. 1. Block diagram of the optical head with the PC computer

An important element of the head is the angle readout system that automatically measures the angular position of the rotation axis in the horizontal and vertical plane of the rotation mechanism. The system consists of two rotation encoders with resolutions of 5,000 impulses per revolution installed on the axes of the horizontal and vertical plane, and a decoder that calculates the momentary angles of rotation of both axes. During observation, information about the angular position of the optical camera axis is transmitted to the microcontroller that monitors the operation of the head.

The PC computer is used for program setting the operating conditions of the camera, recording images, controlling the operating modes of the heads, and monitoring the operation of the heads. It is equipped with software for post-processing the recorded measurement data in order to estimate the coordinates of both the observed targets and the fired projectiles, and to determine their trajectories. The results of the calculations constitute the values of the linear miss distances h_β and h_ε when firing at aerial targets, and are determined using the following formula:

$$h_\beta = r\tan\left[\frac{\beta_0}{fa}\left(x_p - x_t\right)\right],\quad h_\varepsilon = r\tan\left[\frac{\varepsilon_0}{fb}\left(y_p - y_t\right)\right], \tag{1}$$

where: r is the distance between the gun and the aerial target; β_0, ε_0 are the angles dependent on the focal distance of the optical head; f is the elongation factor of the focal distance of the lens; a, b are the horizontal and vertical resolutions of the matrix of the optical head; and x_p, y_p, x_t, y_t are the determined coordinates of the projectile and the target. The distance d of the flight of the projectile in relation to the aerial target equals to:

$$d = \sqrt{h_\beta^2 + h_\varepsilon^2}. \tag{2}$$

During fire training, the flight trajectories of aerial targets are recorded at a speed of at least 100 frames per second by two heads equipped with lenses, with variable focal distance in the range of 150—600 mm. The measured data is accumulated and filtered, taking into account the kinematics of the projectiles. This ensures the detection of images of flying projectiles and allows for their location in relation to the aerial targets to be determined.

For the detected locations of projectiles, the moments of ignition of the pyrotechnic flare of the tracer are determined, which subsequently makes it possible to determine: a) the distance of the projectile from the gun at the time of ignition of the tracer's pyrotechnic flare, and b) the azimuth angles of firing at the aerial target β_i, $i \in \{1,\ldots, n\}$ for each of the n recorded projectiles. The azimuth angles β_i are compared with the coordinates of the flight of the aerial target, which are stored in the memory of the autopilot, and, based on this, the distance r between the gun and the target is determined. Knowledge of the speed of the projectiles and the distance at which the tracer's pyrotechnic flares are ignited makes it possible to determine the frames of the film that correspond to the distance r. Knowledge of the relative location of the aerial target and the projectile on the selected image makes it possible, in turn, to calculate the angular components of the miss distance of the flight of the projectile in relation to the target, which, after the distance r is taken into account, then makes it possible to determine the values of the linear miss distances h_β and h_ε.

The optical system for fire training observation is highly effective. Fire training tests have demonstrated that the coordinates of the flight of projectiles in relation to the targets are determined with an accuracy of more than 95%. The system enables the detection and measurement of projectile coordinates. It also provides the statistical information about fire training results that is needed for the collective evaluation of combat objectives and their achievement. The system may constitute a key element of an evaluation mechanism to be used in the training of sub-units and gun crews during fire training exercises.

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Оптическая система наблюдения за зенитной артиллерийской огневой подготовкой

Рассмотрены правила построения, принципы работы и эксплуатации оптической системы, предназначенной для наблюдения за зенитной артиллерийской огневой подготовкой. Система характеризуется высокой эффективностью, поэтому может быть ключевым элементом контроля и оценки подготовки учебных подразделений зенитной артиллерии или отдельных орудийных расчетов.

Ключевые слова: метрология, оптическая головка, зенитная артиллерия, уровень военной подготовки.
