OPTIMIZATION OF THE USE OF AN AEROSOL SHIELD CREATED TO COUNTERACT THE LASER ILLUMINATION OF GUIDED PROJECTILE TARGETS IN SEMI-ACTIVE GUIDANCE SYSTEMS

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ABSTRACT

The article is devoted to the proposed method of optimal formation of an aerosol shield to attenuate the intensity of a laser beam aiming at a target. The problem of optimal joint use of fine-dispersed and coarse-dispersed aerosol generators is formulated and solved to increase the efficiency of the screen created to counteract the laser beam targeting the target. The optimal relationship between the optical densities of coarse-dispersed and fine-dispersed aerosols in dynamics, with their changes over time, has been determined.

Keywords: targeting, aerosol screen. fine-dispersed component, coarse-dispersed component

Introduction

One of the reliable methods of eliminating laser hazards when using semi-active missile and projectile guidance systems by the enemy is the method of creating an aerosol shield [1]. Various aerosol generators can be used for this purpose. Known aerosolgeneration tools are created based on various physical effects: The mechanisms of aerosol formation are different, such as explosion. Pyrotechnical effects ,hermal mechanisms of aerosol formation.smoke-forming etc.. The spectral range of all aerosols used for this purpose is 0.4-1.5 microns. As shown in [2], an aerosol cloud can create a masking effect for targets selected for laser illumination carried out to deliver missiles and projectiles to the target. At the same time, the effectiveness of the aerosol screen depends on the spatial, temporal, and optical characteristics of the aerosol cloud. To determine the requirements for the optical characteristics of an aerosol cloud, as an indicator of the effectiveness of target masking, we take the probability that the laser beam strength (Φ) will be reduced to the sensitivity threshold of the on-board photodetector of the object. Note that due to atmospheric turbulence, Φ may take random values. According to [2] we have

$$P = \int_0^{\Phi_n} \omega(\Phi)\, d\Phi \tag{1}$$

where ω(Φ) is the probability density function Φ; Φ_n- is the threshold sensitivity of the on-board photodetector. According to [2], the transmission of the aerosol cloud necessary to attenuate the laser beam used to control the projectile can be calculated as

$$\tau = \left(\frac{D}{D_{max}}\right)^{\frac{1}{\mu}} \tag{2}$$

Where

$$D = vt \tag{3}$$

where D_{max} is the maximum control distance; D_{max} is the distance between the laser and the projectile; v is the velocity of the projectile; *t* is the time elapsed since exposure to the aerosol. The indicator μ is defined as

$$\mu = \frac{\Phi_0}{\Phi_\Pi} \tag{4}$$

Where Φ_0 is the strength of the laser beam

From formulas (2), (3), (4) we get

$$\tau = \frac{(vt)^2 \Phi_\Pi}{D_{max}^2 \Phi_0} \qquad (5)$$

The use of an aerosol cloud to neutralize a laser beam aimed at a target is illustrated in Fig. 1.

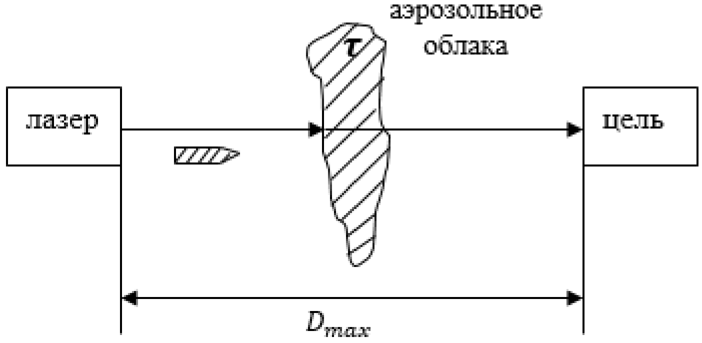

Fig. 1. Illustration of the use of an aerosol cloud to neutralize the effect of a laser beam

To estimate the optical thickness of an aerosol cloud, we use the Angstrom model, according to which [3]

$$\tau = \beta\lambda^{-\alpha} \qquad (6)$$

where τ is the optical thickness of the aerosol cloud; β is the turbidity index of the aerosol cloud; λ is the laser wavelength; α is the Angstrom index.

In general, it can be assumed that two types of aerosol generators are used to create an aerosol cloud, the first of which generates a fine aerosol. and the second one is coarse-grained. We denote the optical density of the aerosol layer created by a finely dispersed aerosol as τ_f by a coarse aerosol as τ_c . At the same time, by analogy with the model (6)

$$\tau_f = \beta\lambda^{-\alpha f} \tag{7}$$

$$\tau_c = \beta\lambda^{-\alpha c} \tag{8}$$

In this case, we assume that the total optical thickness of the created two-layer aerosol screen is determined as an additive weighted sum of τ_f and τ_c In this case, the strength of the laser beam at the outlet of a two-part aerosol cloud can be estimated as

$$I_{\text{вых}} = I_0 \exp[-(a_1\tau_c + a_2\tau_f)] \tag{9}$$

Let's assume that adjustable aerosol generators are used. In this case, τ_f can change within 0-t_ $0 - \tau_{fmax}$ with an equal step . Accordingly can change within 0- in equal increments of _ s. Further, let's assume that due to meteorological or technical circumstances, varies between 0 and in time, while the rate of change of is constant over time, i.e.

$$\frac{d\tau_f}{dt} = const \tag{10}$$

In this case, it is required to calculate the optimal function

$$\tau_c = \varphi(\tau_f) \tag{11}$$

at which the following variational optimization functional reaches a minimum, i.e. the maximum attenuation of the laser beam is carried out.

$$I_{\text{вых}\Sigma} = \int_0^{\tau_{fmax}} \exp\left[\left[-a_1\varphi\left(\tau_f\right) + a_2\tau_f\right]\right] d\tau_f \tag{12}$$

To calculate the optimal function $\varphi(\tau_f)$ we use the following restrictive condition

$$\int_0^{\tau_{fmax}} \varphi(\tau_f)\, d\tau_f = C; C = const \tag{13}$$

, Taking into account expressions (12) and (13), we formulate the objective functional F of unconditional variational optimization

$$(14)\ F = \int_0^{\tau_{fmax}} \exp\left[-\left[a_1\varphi\left(\tau_f\right) + a_2\tau_f\right]\right] d\tau_f + \lambda\left[\int_0^{\tau_{fmax}} \varphi(\tau_f)\, d\tau_f - C\right] \tag{14}$$

where λ is the Lagrange multiplier.

The solution of optimization problem (14) according to the Euler-Lagrange method satisfy following condition

$$\frac{d\{\exp[-[a_1\varphi(\tau_f)+a_2\tau_f]+\lambda\varphi(\tau_f)]\}}{d\varphi(\tau_f)} = 0 \tag{15}$$

From condition (15) we obtain:

$$\left(-a_1 - a_2\tau_f\right)\left(\exp\left[-\left[a_1\varphi\left(\tau_f\right) + a_2\tau_f\right]\right]\right) + \lambda = 0 \tag{16}$$

From expression (16) we find

$$\exp\left[-\left[a_1\varphi\left(\tau_f\right) + a_2\tau_f\right]\right] = a_1 + a_2\tau_f - \lambda \tag{17}$$

From expression (17) we find

$$a_1\varphi\left(\tau_f\right) + a_2\tau_f = \ln\frac{1}{a_1 + a_2\tau_f - \lambda} \tag{18}$$

From expression (18) we obtain

$$\tau_c = \varphi\left(\tau_f\right) = \frac{1}{a_1}\ln\frac{1}{a_1 + a_2\tau_f - \lambda} - \tau_f \tag{19}$$

To calculate λ, it is enough to insert expression (19) into equality (13) and perform integrations. We believe that it is possible to omit the implementation of this purely mathematical operation here. Note that when solving (19), the functional (14) reaches a minimum, i.e., the maximum attenuation of the laser beam pointing at the target is ensured. It is easy to check this quality using Lagrange's sign, i.e. by taking the derivative of expression (16) with respect to the desired function. The result of this operation will always be a positive expression. This solves the problem of achieving maximum attenuation of a laser beam aiming an enemy projectile or missile at a protected object.

Discussion

Thus, the problem of maximizing the attenuation of a laser beam aiming a guided missile at a protected target is formulated and solved by creating a two-component aerosol shield in the form of an additive two-layer aerosol cloud composed of layers of fine and coarse aerosol released from the corresponding aerosol generators. A model problem is considered when, due to meteorological or technological reasons, the optical thickness of a fine-dispersed aerosol is functionally related to the optical thickness of a coarse-dispersed aerosol, the optimal type of this functional relationship is calculated, taking into account the general limitation on the estimate of the optical thickness t_c, calculated through the exponent at which the maximum amount of attenuation of the laser beam is achieved.

Conclusion

The creation of an aerosol shield to neutralize the effect of an enemy laser beam pointing at a target is one of the most effective means of countering optoelectronically guided projectiles and missiles of the enemy. In this case, it is possible to use some combination of finely dispersed and coarse-dispersed aerosols to achieve maximum attenuation of the enemy's laser beam pointing at the protected target.: The model problem of using fine-dispersed and coarse-dispersed aerosol generators to increase the efficiency of the laser screen is formulated and solved. The optimal relationship between the optical densities of coarse-dispersed and fine-dispersed aerosols is determined when they change over time.

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