UDC 656.71.057(045)

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Mathematical modeling of the visibility range of the aerodromie fires of the light-signal systems from the meteorological visibility range in MatLab environment

To determine the visibility range of one from the aerodrome fires of the light-signal system, depending on the transparency of the atmosphere, for the convenient use of the toolkit in determining the visibility of the aerodrome fire based on the threshold value of illumination that corresponds to the brightness of the background, MATLAB interface is considered.

Introduction. Determining the efficiency of use of aerodrome fires for light-signal equipment in difficult weather conditions during approach is of great importance. Various methods were used to solve the problem: theoretical calculations, experiments, flight checks. The visibility of the aerodrome fires of light-signal systems which influences the formation of a light-signal picture can be determined by simulation in the MatLab environment.

Basic material presentation. At present, more attention is paid to the efficiency estimation of light-signal fires using simulation tools with a reduction of field experiment. To reduce the financial cost, it is proposed to use simulation during the evaluation of visibility of aerodrome fires of light-signal systems.

The brightness mode of aerodrome fires substantially affects safety during approach craft landing in difficult meteorological conditions. It is visual observation depends on the range of visibility and the clear perception of the aerodrome light-signal picture. To establish the light-signal picture, it is necessary to determine the optimal value of light intensity and color of the fires at any time of the day in all ranges of meteorological range of visibility.

In accordance with [1], the visibility of the fires depends on the limiting illumination on the retina of the eye, which is determined by Alar's law:

$$E = (I / R^2)\, \tau^R \qquad (1)$$

where E is the illumination created by the lighting device at a distance R; τ is specific transmittance of the atmosphere (transmittance of atmospheric layer thickness of unit length); R is the distance between the light-signaling device and the observer.

If the illumination of the retina of the eye is equal to the limiting illumination, (it is the minimum illumination which causes the visual sensation), then the studied fire can be seen and the distance R is the visual range of the visibility of this fire. The value of the minimum illumination used to determine the visual range of the visibility of light signals depends on the brightness of the background against which a light signal is observed.

According to the current normative documents, the criterion of aerodrome fire failure of the light-signal system is a reduction of light intensity by more than 50%, which for different subsystems of aerodrome fires will be 10000 to 1250 cd (for categorical light-signal landing systems) and 100 to 50 cd (for non-categorical systems). At the same time, the values of light intensity, calculated by the expression (1) for the worst, but admissible observation conditions for this category of landing system will be lower. This means that light signals will be observed at the distance exceeding the distance of the required visual contact. It is clear that the excess of light intensity of fires beyond the limit value is explained by the desire to increase the safety of flights.

Consider that the visual system gives a person up to 90% of all accepted information. Obtaining information about the outside world with the help of vision can always be considered as a sequential or simultaneous solution of the problem. Such problems may be related to search and location of the object. Under certain conditions, the eye can not separate the object. In this case, it is said that the object is below the threshold of visual perception and the probability of observation is zero. Under other conditions, the eye instantly, clearly recognizes the object - in this case, the probability of observation is 100%. It is clear that there is an area beyond which one can speak about this or that degree of probability for the correct solution of the visual problem. That is, the solution of the visual problem is possible in cases when the conditions of visibility exceed the threshold values of illumination on the eye apple of the observer, which in our case is the pilot of the aircraft.

The term "visibility" of the object has a fairly broad interpretation and is related with meteorological conditions, in particular with atmospheric optics, light engineering, physiological optics, and others.

It is known that the visual perception of point light sources, which includes aerodrome fires of the light-signal system, is determined by their shine. The location of the aerodrome fire is most often known if the aerodrome fire is located in some line of sight. To find the object related with its search, the shine of the point object should be greater than the threshold value of $E_{thr} = 2 \cdot 10^{-8}$ lx at a brightness of the background of 10^{-6} cd / m^2, and the more the probability of its finding, the less search time.

Dependence of threshold illumination from the brightness of the background is a continuous function approximated by the expression:

$$\log E_{thr} = 0{,}05\,(log\,L_{bgr.})^2 + 0{,}57\,log\,L_{bgr.} - 6{,}66 \qquad (2)$$

where E_{thr} is threshold illumination, lx; L_{bgr} is the brightness of the background, cd/m^2.

Consider that at the stage of visual piloting, for a sure visual contact of a pilot with a light-signal system, aerodrome fires should create in the plane of the eye apple the illumination which is not lower than the threshold. The distance to the fires at the beginning of visual piloting depends on many factors, but the number of these values is reduced to four depending on the category of radio-lighting equipment landing. The influence of the factors of atmosphere transparency is taken into account by the value of the specific transmittance, which varies from 0.9 to $10^{-8.5}$.

The obtained information can be considered with the help of vision as a series of problems of search and finding of the object, recognizing it by a number of features (form, color, presence of details, etc.), that is, visual problems.

It is clear that there is an area for which one can speak about this or that degree of confidence of the correct solution of the visual problem. The main factors determining the visibility of aerodrome fires in their visual search in the atmosphere are:

- contrast of the object of observation with the background;
- light power of the fire; angular field of overview;
- search time; transparency of the atmosphere;
- object speed; probability of detection;
- state of observer adaptation.

Presence of other objects in the line of sight also affects the detection of the considered object etc.

The probability of detecting point objects is determined by the expression [2]:

$$P = 1 - exp\,(-(a_b\, E^2\, t)/\,((2\beta)^2\, L^{2\,n}), \tag{3}$$

where P is probability of detection; a is coefficient characterizing the individual characteristics of the observer. According to the results of experiment for binocular vision follows that $a_b = 2.6\ 10^{14}$ deg^2 (cd / m^2)^{2}lx^{-2} s^{-1}, for monocular vision $a_m = 1.8\ 10^{14}$ deg ^{2} (cd / m^2) ^{2}lx^{-2} s^{-1}; E is illumination in the plane of the eye apple of the observer from the point source of light, lx; t is search time, s; 2β is the angular field of the search, deg; L is background brightness, cd / m^2; n is a coefficient depending on the brightness of the background and is calculated by the empirical formula:

$$n = 0{,}6 + 0{,}1\, lg\, L \tag{4}$$

within brightness change:

10^3 cd / m^2 $< L <$ 30 cd / m^2,

if $L >$ 30 cd / m^2 then $n = 0.75$;

if 10^{-6} cd / m^2 $< L < 10^{-3}$ cd / m^2 then $n = 0.3$.

We can determine the necessary illumination in the plane of the eye apple, if we specify some values of the listed quantities and then using the inverse squares law we may find the observation distance of the fire on which it fire will be detected with probability P.

Using the interface MATLAB [3, 4], a toolkit was created to determine the visibility range of the elements of the aerodrome light-signal systems, depending on the transparency of the atmosphere (Fig. 1), with the output of the graphic representation of the each dependency separately:

- probability of observation from meteorological conditions;
- estimation of visibility score;
- visibility range of the aerodrome fire from the transparency of the atmosphere;
- visibility range of the aerodrome fire from meteorological conditions.

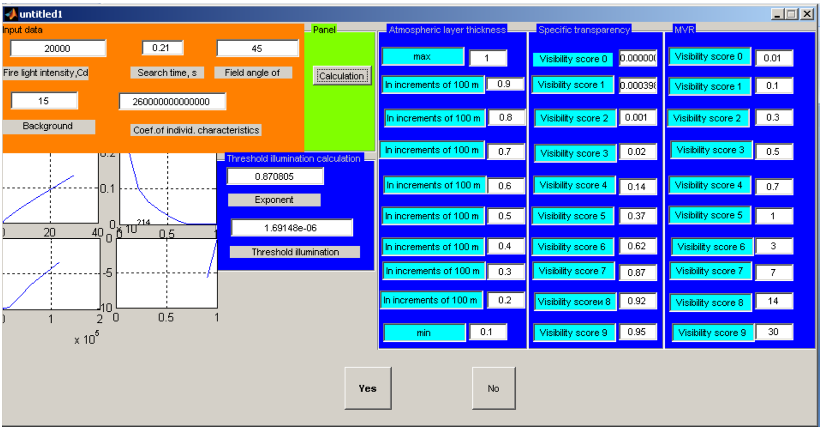

Fig.1 Graphical interface of the MATLAB environment for determining the visibility range and providing an estimation of the visibility of the element of the aerodrome light-signal system

Conclusion

Use of the created tool in the MatLab environment to determine the visibility ronge of the aerodrome fires of light-signal systems from the meteorological visibility range (MVD), allows to reduce the time for determining the illumination created at the eye apple from aerodrome fire. At the same time, it is possible to obtain an estimate of the visibility of the light signal and determine the probability of observing the light signal that will help to justify the failure criterion of the aerodrome light-signal fires.

References

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