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Monitoring of performance of aerodrome lights in operating conditions

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Abstract. The technique of determining the average light intensity in the main beam of aerodrome lights by the brightness of the light aperture during operation with the help of tools using the MATLAB interface is considered. The determination of the average light intensity of aerodrome lights by the brightness of the light aperture is used in field conditions and is an integral part of the work in the system of technical operation of the light-signaling equipment. The technique was applied to detect the inoperative condition of aerodrome light-signaling lights during operation. The purpose of measuring the average light output is to decide on the further operation of the lights.

Keywords: brightness; luminance meter; luminous intensity of light; toolkit, aerodrome light; working condition; failure.

1 Introduction

Operation of light-signaling equipment generates a large number of different types of aerodrome lights states, the information of which can be measured.

The advantage of the light aperture brightness method is that the study of the aperture in real observation conditions is to be made on the background of the surface with brightness less (much less) than the brightness of the light aperture. That is, the brightness ratio does not exceed $10^2 \ldots 10^4$, and this fact allows the method to be used at dusk and even in the daytime. The technique provides the algorithm for determining the relative light power in the direction of the lights of the subsystems of the aerodrome light signal systems using the developed tools in MatLab.

2 Review of research and publications

The main objective of research and development in the field of safe landing of aircraft is to develop a system to automate the evaluation of the light signal pattern.

The International Civil Aviation Organization (ICAO) Standards and Recommendations [1, 2, 3] require periodic monitoring and diagnosis of aerodrome lights of light-signal systems during operation, but do not propose appropriate techniques.

In the works [4, 5] the method of the serviceability determination of the aerodrome lights of light-signaling systems in laboratory conditions is presented.

In work [6] it is proposed to make light-signaling lights monitoring with the help of camera, installed in the cockpit, but the evaluation of lighting equipment inoperability is implemented with respect to the ICAO recommendations.

3 Problem statement

Within the parameters which characterize the object condition the luminous intensity curve of the photometric body was selected. This parameter can be measured.

Determination of the mean light intensity of aerodrome lights by the brightness of the light aperture is an integral part of the work in the system of technical operation of the light-signaling equipment.

The purpose of measuring the average luminous intensity of lights in general, and side lights of the runway in particular, is to determine the distance to the runway visibility (RVR) for the certain airfield and to make concrete decision regarding the possibility of its further operation in certain circumstances of meteorological minimum.

As a rule, overhead lights tend to adjust during operation, whereas recessed lights require very fine adjustment even when initially installed, since further adjustments are difficult to accomplish. Deviations from the norm are thought to depend, among other things, on the quality of the design, manufacture and maintenance, but are unlikely to exceed 1 degree. Therefore, when specifying the initial characteristics of the light-signal lights required for each type of fire, the values of the scattering angles [1] should be increased from each direction by 1 degree.

Moreover, the manufacturing must strictly observe the tolerances for the light-signal lights in order to meet the standards. Unless the lights are manufactured and adjusted according to the specified normalized values of the lighting parameters, the layout scheme will not provide a consistent picture of the visible areas of the lighting system.

The average light intensity of the runway centerline lights is determined in accordance with the recommendations set out in ICAO materials [2]. The average light intensity of the lights is determined by the results of goniophotometric measurements at the installation in GOST 17677-82 [3]. The luminous intensity of light in each measured direction is determined by the expression:

$$I(\alpha,\beta) = c \cdot l^2 \cdot n, \tag{1}$$

where $I(\alpha,\beta)$ –intensity in a given direction, kd;

c –calibration constant cd / division;

l –photometry distance, m;

n – counting on a scale recording device, scale marks.

Photometry distance R is assumed to be $L = (3\ldots10)\, l_f$

l_f - the distance of the light beam formation of the light device.

The measurement results are reported in the VH photometric coordinate system. The average light intensity is determined by the results of the measured values of the light intensities as the arithmetic mean by the number of measurement points n covered in the VH diagram by an ellipse with half axes numerically equal to the selected (according to the requirements of regulatory documents) value of the scattering angles:

$$I_{average} = \frac{1}{n}\sum_1^n I(\alpha,\beta), \tag{2}$$

where n - number of measurement points;

$I(\alpha,\beta)$ - intensity towards the point in space with angular coordinates in the horizontal and vertical planes, cd.

The main beam is the area of space in the direction of propagation of the light radiation, limited by a solid angle with a vertex in the center of the aperture of the light signal. The intersection of the lateral surface of the solid angle with a plane perpendicular to the direction of propagation of the radiation is an ellipse whose large half-axis is parallel to the surface of the earth [2]. Secondary rays are similarly defined.

The average luminous intensity of the main beam is calculated using the values of the luminous intensity measured at all points of the coordinate grid that are within and around the perimeter of the ellipse that outlines the main beam. The mean value is the arithmetic mean of the light intensities measured at all given points in the grid. With the correct orientation of the lights fixture deviations from the characteristics of the main beam are not allowed.

The angles in the horizontal plane are measured relative to the vertical plane drawn through the runway axis. The angles in the vertical plane are measured relative to the horizontal plane.

It is difficult to overestimate the importance of proper maintenance. Unde·r no circumstances should the average luminous intensity fall to less than 50% of the standard value and the Flight Support Service should maintain the light intensity of the light-signaling equipment close to the specified minimum of average luminous intensity.

The light should be set so that the main beam is exposed in the space with an error not exceeding 0,5 °.

During operation, virtually all the main characteristics of light equipment change: lighting (light curve shape, coefficients and indicators of reflection and transmission of materials, their color), technical and economic (efficiency), constructive (eg, degree of environmental protection, environmental impact, serviceability), electrical (insulation resistance, contact transients) and several others. There are no sufficiently complete data regarding changes in the characteristics of light-signal lights when operating under different environmental conditions and under different methods of maintenance. Studies in this area are gradually addressing some of the most pressing issues of operation. This is especially important at solving the problems of determining the optimum service modes and the coefficients of the light signal.

In accordance with the Manzhen’s law the airfield light intensity is determined by the equation:

$$I = k\cdot \rho\cdot L_d \cdot S, \tag{3}$$

where I - the axial light intensity of an aberration reflector;

k - output coefficient, which takes into account all losses of the optical system (reflection, shielding, absorption in the protective glass, etc.);

L_d – the average brightness of the light aperture;

S - the area of the light aperture;

L_d - the brightness of the light source;

ρ - the reflectance of the reflector coating.

In the case of uneven brightness of the aperture over the area, the light intensity is determined by the expression:

$$I = \sum_{i=1}^{n} I_i = \sum_{i=1}^{n} L_i \cdot S_i, \tag{4}$$

where I - the light intensity from the device with a light aperture of uneven brightness;
S_i - the area of that portion of the aperture for which the corresponding value of L_i brightness can be considered practically unchanged.

The analysis of equation (3) shows that for this type of lighting fixture the values of k and S are constant. The value of L_d - increases slightly, with a considerable time over the light source, which is manifested in a significant darkening of the bulb. But for light sources with a relatively short running time, this value can be considered constant. The values of the coefficient ρ depend on the degree of degradation of the light reflecting coatings and it is the change of this value that will determine the change in the light intensity with time. Degradation processes cover the entire reflecting surface almost evenly. This means that the average value of the light intensity in the main beam of a new light is different from the value for an operating light in as many times as the reflectance ρ has changed, or as much as the brightness of its aperture has changed.

To determine the brightness of the runway light aperture, let us use the following considerations: the essence of the action of light-signaling devices is that some part of the light flux of the light source covered by the optical system of the device at a relatively large solid angle, after reflection or refraction, is directed along optical axis in relatively small solid scattering angle. The concentration of the luminous flux in the light beam of the instrument is determined by the brightness and the size of the image of the light source in the aperture of the optical system. The maximum possible concentration of light flux is achieved in those optical systems in which the image of the light source visible in the aperture of the system completely fills the latter.

The concentration of light flux in different directions within the light beam of the optical system does not remain the same. It is fully characterized by curves of light intensities that determine the magnitude of the light intensity for different directions inside the light beam of the device.

The aperture of the optical system produces an enlarged image of the light source, and the size of this image at this light source determines the light intensity of the system. For the same optical system, the specified image is generally different for different directions from the optical axis of the device, that is, when observing a light aperture from different directions. The image of the light source in the light aperture consists of separate points of the optical system observed light from this direction. Each point of the optical system can be seen light from a given direction in the case where the latter lies in the middle of the elementary reflection coming from this point (Fig. 1).

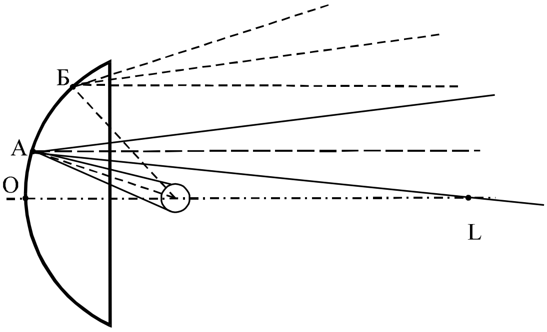

Fig. 1. The appearance of dark and light dots in the aperture of the optical system

For the observer at point L, point A on the reflector will be light and point B is dark. In addition, real devices have aberrant optical systems with an arbitrary distribution of aberration errors on the surface of the system and, as a consequence, images of the aperture of real devices have complex brightness distributions over the area.

Consequently, at different distances along the optical axis of the device, the outer rays of various elemental reflections are detected by the edge rays of the entire beam, resulting in different light curves at different distances from the device. In order to take this into account, it is necessary to photometer the aerodrome light signaling devices at distances several times greater than the total luminosity distance, in order to obtain a light curve that does not change with a further increase in distance from the device. Obviously, aerodrome light signal lights need to be photometered at working distances, that is, at operating distances. But for relative measurements of the light intensity of lights of the same type, such photometry is possible from smaller but equal distances.

There is a certain correlation between the brightness of the object and the illumination of its image constructed by the optical system, there is an opportunity to study the distribution of brightness in the images of light openings, and thus the light power of the lights themselves using photographic recording optical devices. The reason for this is that the brightness of any point of the aperture and the brightness of the corresponding point of the light source are in known dependencies.

Expression (3) should also be valid for non-axial light force, only in this case it is necessary to consider that part of the area of projection of the light aperture on the picture plane observed by the light in this direction. The last consideration allows us to determine the relationship between the light intensity in this direction and the brightness of the image constructed by the optical system.

The definition is based on the expression:

$$E'(\alpha,\beta) = \frac{\tau_1 \cdot \pi \cdot L(\alpha,\beta)}{4} \left(\frac{D}{f'}\right)^2 \cdot \frac{\beta_p^2}{\left(\beta_p - \frac{\ell'_C}{\ell_C}\right)^2}, \tag{5}$$

where τ_1 –transmittance of the optical system;

$L(\alpha,\beta)$ – the average brightness of the aperture in the direction of observation, which for a given light source and these power parameters is more convenient to represent as L ($\alpha = 0$, $\beta = 0$) • M (α, β);

M (α, β) is a two-dimensional array of coefficients that determine the relative average changes in the brightness of the aperture. The values of the coefficients vary from 0 to 1 and are determined by the angle of observation of the fire horizontally - α and the vertical - β, with a predetermined step of not less than 1 angular degree;

D –the diameter of the inlet of the optical system;

f' –posterior focal length of the optical system;

β_p - linear magnification in the inlet and outlet openings of the optical system

$\frac{\ell'_C}{\ell_C} = \beta$- linear magnification of the optical system in conjugate planes

l'_c - linear dimensions of the light hole image

l_c -linear dimensions of the aperture linear dimensions of the aperture.

With the photometer at a constant distance according to expression (5), the illumination of the image will be determined only by the brightness of the aperture in the direction of observation. In turn, this brightness will depend only on the area and the strength of light emitted by the elements of the aperture visible light in this direction of observation. Therefore, to determine the angular distribution of the light intensity it is possible to use measuring not only the aperture itself, but also its image. That is, for a given measurement distance, you can write:

$$I = k \cdot \tau \cdot \Sigma L_i N_i \tag{6}$$

where k - proportionality factor

τ – loss factor, which takes into account the reflectance and transmission losses of the optical system, etc.

L_i –the brightness of the image element

N_i – number of elements having L_i brightness.

There is a gradual change of I in operation. Of course, considering the clearing of the light signal and the replacement of the failed light source, the dependence of the $I = f(t)$ change is sawtooth (Fig. 2).

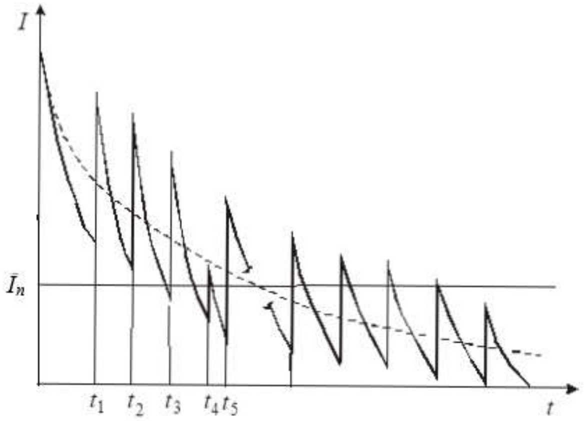

Fig. 2. Schedule of change of light power of a light-signal light during operation (t1, t2, t3, t5 - time of cleaning of a light-signal light; t4 is time of replacement of a failed light source). The dashed curve describes the average changes in the lighting parameter over time

The failure of a signal light comes at a time when $I_t = I_i$. During this period, the normalized level of the average light intensity of the light signal is provided.

4 Proposed algorithm

The monitoring of aerodrome light performance during operation can be formulated through the following main steps:

1) determination of the mean light intensity of the new light by means of a goniophotometric device or by the surface brightness of the light determined by the luminance meter;
2) measuring the brightness of the runway lights;
3) monitoring of the aerodrome light technical condition by the algorithm developed in the MatLab interface toolkit;
4) estimation of the aerodrome light technical condition by the obtained result.

An algorithm for determining the relative light intensity in the direction of the lights observation of the aerodrome light-signaling subsystems using the developed tools in MatLab is provided for monitoring.

1. It is recommended to use a TKA-YAR luminance meter with a photometric angle of 1.5^0 and laser guidance to determine the light intensity. In this case photometric distance should be at least 7 meters. The luminance meter requires a user-level adjustment of 5 m above the coverage surface and a distance that depends on the runway width but not less than 7 m at angles 4^0 to the vertical and 3.5^0 at a runway width of 45 m or 4, 5^0 at a width of 60 m runway to the direction of the runway side lights. When using the mobile platform, it is possible to install 3 devices in such a way that one is directed to the side lights to the left of the runway axis, the second is to the side lights to the right of the runway axis, and the third is for measuring the brightness of the axial lights, i.e. in the direction of the runway axis. The speed of the mobile platform movement should be no slower than 14 m / s.
2. To get more accurate estimation of the average light intensity of aerodrome lights, it is necessary to preliminary ajust luminance regulators (LR) to the nominal current.
3. During the platform movement the luminance meter readings are registered after lazer guidance to the center of lighting device.
4. Obtained data should be entered to the correspondent cells on the tool (Fig. 3).
5. Click on the RAN button (Fig. 3) and obtain: light intensities of the new lights and relative light intensities of lights, which are considered during their functioning, in view of diagrams. These results allow to analyze the instantly and determine those that are on the operability boundary.

Aerodromic lights with a light-forming optical system may have curves of light intensity with a sharp maximum close to the optical axis. Light measurements in this direction (for the maximum of the measured value) allows to implement them with a higher level of repetition (with random error much less than the instrumental one). This may help to compare aerodrome lights with each other and with those that are out of exploitation, that is, to determine relative rate of maximum (axial) light intensity.

Let us assume that the maximum (axial) light intensity rate is proportional to the average light intensity rate. In this case, the values of these rates can be used as the input parameters for the average light intensity determination of the runway side lights.

Fig. 3 Toolkit for detecting the performance of runway aerodrome lights

Photometry of aerodrome lights should be implemented on the distances several times more than the full illumination distance in order to get such light intensity curve, which is practically not dependent on rise of distance from the device. Aerodromes need to be photometered on a working distances, that is, on the distances of their operation. But for relative measurements of the light intensity for lights of the same type such photometry is possible to make from smaller but equal distances.

The determination of average light intensity of the runway side lights during their operation is implemented by analysis and processing of luminance measurement results of light-signal system lights and by matching them with requirements in according regulatory documents.

By the results of material processing it is possible to determine relative brightness change of signaling light aperture in relation to the brightness of the new light aperture.

The average light intensity of the runway side light is defined as

$$I_{average} = I_{0average} \frac{L_{tested}}{L_0} \cdot 100\%, \quad (7)$$

where – $I_{average}$ – average light intensity of the runway side light

$I_{0\text{average}}$ –the average intensity of a new light

L_{tested}– the brightness of the measured light aperture

L_0– the brightness of the new light aperture of the same construction.

The average light intensity of the runway side lights is defined as the arithmetic mean of the measured average light intensities of all subsystem lights.

The toolkit that uses the MATLAB interface contains the following data:

- parameters, m (length and width of the bright surface that emits light) of the new light, side light of the runway, axial runway fire;
- the value of the brightness of the new side and axial runway lights;
- the value of the brightness of the side lights and the axial runway lights obtained during the measurement of the lights in service

After clicking the RAN button, the screen is displayed

- Light intensity of new axial and side lights

Diagrams of the measured relative values of the light intensities of the side runway lights with color coding:

- - Red - less than 50% of the required intensity
- - Blue - between 50 - 60% of the required intensity
- - Green - more than 60% of the required intensity

Conclusion

1. The monitoring of technical condition of the aerodrome lights signaling system was developed and carried out, which allows to determine the operational state of aerodrome lights during operation.

2. The method of investigation of the operational state of the aerodrome light for the lifetime is offered, which will improve the safety of flights of aircraft at the stage of visual piloting during approaching.

3. Aerodrome Lights Monitoring provides objective information on the technical status of aerodrome lights of all aerodrome light-signaling subsystems.

4. According to the methodology, the subsystems of the aerodrome light-signaling system were analyzed during operation, which allows to immediately analyze and determine the lights that are on the operation boundary.

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