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METHODS FOR ESTIMATING THE INTERNAL NOISES IN AUTO COLLIMATING DEVICES

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Abstract: Methods for estimating the internal noises in auto collimating devices are proposed. These devices are designed for measuring of angular shifting of an object with mirror surface, able to make shifts in certain range. Auto collimating method for measuring of angles is one of the high accurate methods for solving of unique technological problems. The accuracy in angular measuring through auto columniation in laboratory conditions reaches ten parts of the second. Classification of the existing photoelectric devices, their optical schemes, main metrological characteristics and working principle are exemplified in [1, 4, 6] and others.

The objective of this research is the analysis of the internal light noises in AC for measuring angular shifts of the mirror surface object, which could move freely in restricted. Generally, auto collimators (AC) consists of auto collimating lens, scale, and source of light, condenser and analyzer of visible area. The scale, together with the source of light and the photo electric analyzer are placed in the focal plane of the lens and could be separated with semitransparent mirror. Having in mind the requirements of the overall dimensions and the tendency of making them smaller, the constructor has a choice of selecting a scale, analyzer and AC lens.

Key words: collimating devices

Experimental researches with different types of AC show that in the visible field of the analyzer, apart from the useful light current, that forms the auto-collimating image of the scale, in the analyzer also penetrates irregular background current, causing light noises in AC. These noises lower the accuracy and reliability of the measurements, and in the equation of intensity with the useful current, they cause unreliable measurements. The diameter of the lens should be big enough to assure the observation of the object in every position, i.e. with a relatively big diameter [2]. Every field of the lens should be observed as a spherical mirror. Sometimes a diffraction of the current may happen because of its fall on the inner surface of the construction of the lens.

The total light current $F_{\sum}$ falling on the plane of the AC analyzer, could be presented as follows:

(1) $$F_{\Sigma} = F_1 + F_2 + F_3 + F_n,$$

where: F_1 - light current, forming the auto-collimating image of the scale;

F_2 - background current, formed as a result of Frenel's reflection of the optical planes of the lenses;

F_3 - background current, formed by the diffusive dispersion of the optical planes of the lenses;

F_4 - background current, formed by the dispersion of the internal side surfaces of the lens construction.

For analysis and comparison of the components, an object of investigation is each one of them.

The light current, which forms the auto- collimating image in the scale, is calculated as follows:

(2) $$F_1 = B_1 S_1 \varpi \rho_1 \tau_1^2 k,$$

where: B_1 - brightness of the source of light on the plane of the scale;

S_1 - surface of the scale;

ϖ - angular aperture of AC lens;

ρ_1 - coefficient of reflection of the mirror plane of the controlled object;

τ_1 - coefficient of light omission of the AC lens;

k - coefficient, estimating the decrease in the light current, as a result of non equality of the reflecting area of the observed object S_2 and the area of the section of the outgoing light current S_3.

(3) $$k = \frac{S_2}{S_3}.$$

The background current F_2 is a sum of the reflected currents coming from each optical plane of the lens in the direction of the analyzer.

$$(4)\ F_2 = \sum_{i=i}^{i=n} B_1 S_{1i} \varpi_i \rho_i \tau_i \ ,$$

where: S_{1i} - area of the image of the scale, created of the optic system in the lens, when certain noises in i^th plane appear, and then $S_{i1} = S_1 \beta_i^2$ (β - linear augmentation of the system when certain noises in the i^th plane appear);

ϖ_1 - angular aperture of the optical system of AC lens;

ρ_1 - coefficient of Frenel's reflection in i^th plane (usually varies from 0,04 to 0,08);

τ_1 - coefficient of light permeability of the optical system, involved in noise creation, originating from the reflection of the light from the i^th plane of the lens.

The background current F_3 formed as a result of the dispersion of the optical planes of the lenses is calculated by the formula:

$$(5)\ F_3 = B_1 S_1 \varpi S n r \tau_1^2 ,$$

where: S - average area of the section of light ray. passing through the lens of AC;

n - the number of the optical planes of the AC lens;

r - total coefficient of luminosity of the optical planes, depending on the quality of polishing, lightening, dust level and internal reflection in the lenses (usually having values within 0.003 ... 0.005).

The background current F_4, originates from the frame dispersion of the optical elements and internal side surfaces of the lens construction. Because of the complex shape and different level of roughness of the internal surfaces, the background current could be calculated according to the methods exemplified in the paper [4] by the following formula:

$$F_4 = F' k' \frac{\rho \tau_1^2}{1 - \rho' \tau_1} ,$$

where: F' - incoming light current from the

k' - radiator in the optical system; k - coefficient reporting the shape, the internal construction of the lens, the place and the quantity of the diaphragms and the correlation between the area of the internal surface of the lens construction and the outgoing opening - the diameter (defined according to method [4]):

ρ' - coefficient of diffuse reflection of the internal planes of the stop and the side surfaces of the internal lens construction (usually varies within 0,02 ... 0,08).

The calculations show that F_3 and F_4 are composing parts of F_2, 0,2 and 0,4 respectively. Experimental research proves that the light currents of the background currents F_3 and F_4 on the plane of the analyzer have regular and symmetrical nature, and because of that regularity in many cases they do not influence significantly the working ability of AC making the choice of electric regime difficult in respect to the work of the photo receiver of the analyzer.

The total background current F_2 could be concentrated, irregular and equal to the absolute value of F_1, i.e. the background current F_2 formed as a result of summed Frenel's reflections of the optical planes of the lenses, and then F_2 becomes the main part in the general background current of noises. As a result of some researches it is proved that the asymmetry of the background current arises when there is insufficiently accurate adjustment of the lens and the emitter, and namely when there is a tilt of the optical elements and shift of the source toward the optical axis of AC.

The characteristic definition of the light noises and the reasons for their origin lead to the following statements:

1. In order to increase the accuracy and reliability of work with photo electrical and auto collimating devices it is necessary to increase the intensity of the useful light current F_1- that forms the auto collimating image of the scale and decrease of the total light current of the noises by their absolute value.

2. The formulae (2) ... (6) show, that when there are regular values of $B_1 S_1$ and S_2, the useful light current F_1 could augment, thus augmenting also ρ_1 and τ_1 and the total background current should decrease, thus decreasing ρ' and *r*.

3. The main internal light noises, leading to a decrease in reliability and accuracy of photo electric auto collimating devices, are in fact the total background current, arising as a result of Frenel's reflection of the optical elements of the AC lens.

The methods of defining the internal noises in auto collimating devices which are presented in this paper, are applied when developing the Auto collimator for adjustment of product 9B813 for the needs of “Vazovski Mashinostroitelni zavodi”- Sopot.

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