It has been shown [5] that the limiting writing density can be defined from the inequality \( \xi_{rs}(P_w) < \xi_{ew} \), where \( \xi_{rs}(P_w) \) and \( \xi_{ew} \) are correspondingly the dependence of the DRI in the playback signals on \( P_w \) and the value of the effective detection window as referred to \( T_k \).

Figure 2 shows graphs for \( \xi_{rs}(P_w) \) computed on the basis of (4) for the worst code combination in the sense of the largest DRI for the playback signals for the signals \( E_{pu}(t) \) (curve a) and analogous graphs for \( \xi_{rs}(P_w) \) for modified phase modulation (MPM) signals (curve b), the MNZC method (curve c), and the signals in the MPP recording method (curve d).

Calculations by the method given in [5] have been made with the relationships in Fig. 2 and show that modified group modulation with MPP signal delay enables one to obtain an increase in writing density in relation to the MPM by 85-90\%, by 40-50\% relative to MNZC, and by 5-10\% relative to MPP on processing the playback signals from the turning points in a magnetic recording system of medium quality.

**LITERATURE CITED**


**INSTRUMENTAL ERRORS OF AN AUTOMATIC DEVICE FOR CHECKING ANALOG MEASURING INSTRUMENTS**

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Automatic checking of analog measuring instruments is an important metrological task; there are various lines for designing such devices, one of the most promising of these being the use of TV cameras to read the data from the scale [1]. In [2], a device was proposed for automatic checking in which the information on the pointer positions and test marks on the scale was obtained by means of a nonstandard circular scan. When the beam moves in a circle in the field of the scale, the intersection with the images of the marks and the pointer provide pulses, and as the time of motion around the circle is proportional to the angle, the angular position of the scale marks can be determined from the time intervals.

The pointer position can be determined by scanning the beam around a circle of smaller radius passing outside the scale field. The differences of the corresponding readings characterize the errors and are used in checking the errors in reading from the scale. Here we consider the major instrumental errors in such a system, arising from sweep distortion and discrepancy between the center of the sweep and the center of curvature of the scale.

Figure 1 shows a scheme for the origin of the error, where 1 is the sweep ellipse in mark coordinate determination, 2 is a circular sweep, and 3 is the sweep ellipse in determining the pointer coordinate.

The sweep shape is distorted on analog realization because the quadrature voltages in the deflecting systems are unequal. The sweep becomes elliptical, and in general, because of phase distortions, the ellipse is turned through some angle \( \psi \) (Fig. 1). Also, the center \( 0' \) of the ellipse may not coincide with \( 0 \), the center of curvature of the scale, because the instrument is inexactly oriented with respect to the camera. Then the angular position of a scale mark will be determined by measuring the arc \( AB \) on the basis of the angle \( \beta_{mm} \), which does not coincide with the true angle \( \alpha \). The difference between these angles determines the error in measuring the mark position. A similar error arises in measuring the position of the pointer \( \beta_{p} \). The error during checking arising from the measurement method may be de-
fined for an ideal instrument, in which the positions of the marks and pointer coincide. Then the relative reduced error of the device is

$$\delta = \frac{\beta_p - \beta_m}{\beta_{\text{max}}}.$$  (1)

As the positions of mark and pointer are measured with the position of the instrument unchanged relative to the camera, the error of (1) will be much less than those in measuring the mark and pointer positions separately.

We now consider a method of determining \(\delta\). As \(O'\) with coordinates \((\Delta x, \Delta y)\) (Fig. 1) leads to the measurement of \(\beta_m\) instead of the true angle \(\alpha\) relative to the start of the scale, and this angle is formed by the straight lines \(O'A\) and \(O'B\), we find that points \(A\) and \(B\) are those of intersection between the ellipse with the zero mark and the test one. One can find the coordinates of \(A\) and \(B\) by solving the equation for the ellipse with the one for the straight line passing through the center \(O\) (OA or OB). The solution is best sought in a coordinate system \(\{x, y\}\) rotated relative to the initial one through an angle \(\varphi\):

$$\frac{(x-\Delta x)^2}{a^2} + \frac{(y-\Delta y)^2}{b^2} = 1$$

$$y = \tan \left( \frac{3}{4} \pi - \varphi - \alpha \right) x.$$  (2)

The coefficients \(a\) and \(b\) in (2) define the semiaxes of the sweep ellipse; we solve (2) for \(a = 0\) to find the coordinates of point \(A\).

Knowing the coordinates of points \(A\{x_A, y_A\}\) and \(B\{x_B, y_B\}\) and those of the center of the ellipse \(\{\Delta x, \Delta y\}\), we can determine the inclinations of OA and OB in this coordinate system, and then the tangent of \(\beta_m\). The final expression for \(\beta_m\) is

$$\beta_m = \arctg \left[ \frac{(y_A - \Delta y)(x_B - \Delta x) - (y_B - \Delta y)(x_A - \Delta x)}{(y_A - \Delta y)(y_B - \Delta y) - (x_A - \Delta x)(x_B - \Delta x)} \right].$$  (3)

where

$$x_A = \frac{b^2 \Delta x + a^2 \Delta y \tan \left( \frac{3}{4} \pi - \varphi - \alpha \right) - ab \sqrt{b^4 + a^2 \tan^2 \left( \frac{3}{4} \pi - \varphi - \alpha \right) - \Delta x \tan \left( \frac{3}{4} \pi - \varphi - \alpha \right) - \Delta y}}{b^2 + a^2 \tan^2 \left( \frac{3}{4} \pi - \varphi - \alpha \right)};$$

$$y_A = \tan \left( \frac{3}{4} \pi - \varphi - \alpha \right) x_A;$$

$$x_B = \frac{b^2 \Delta x + a^2 \Delta y \tan \left( \frac{3}{4} \pi - \varphi - \alpha \right) - ab \sqrt{b^4 + a^2 \tan^2 \left( \frac{3}{4} \pi - \varphi - \alpha \right) - \Delta x \tan \left( \frac{3}{4} \pi - \varphi - \alpha \right) - \Delta y}}{b^2 + a^2 \tan^2 \left( \frac{3}{4} \pi - \varphi - \alpha \right)};$$

$$y_B = \tan \left( \frac{3}{4} \pi - \varphi - \alpha \right) x_B.$$

The semiaxes of the ellipse in (3) are

$$b = R^{1/2};$$

$$a = R^{1/2} - \Delta b,$$  (4)

where \(R\) is the radius of the lower boundary of the scale, \(s\) is the length of a mark, and \(\Delta b\) is the difference between the semiaxes of the ellipse.

It is best to take the values in accordance with (4), because then one has a maximal value for the permissible deviation of the scan center from the center of curvature of the scale while the beam intersects all the scale marks.