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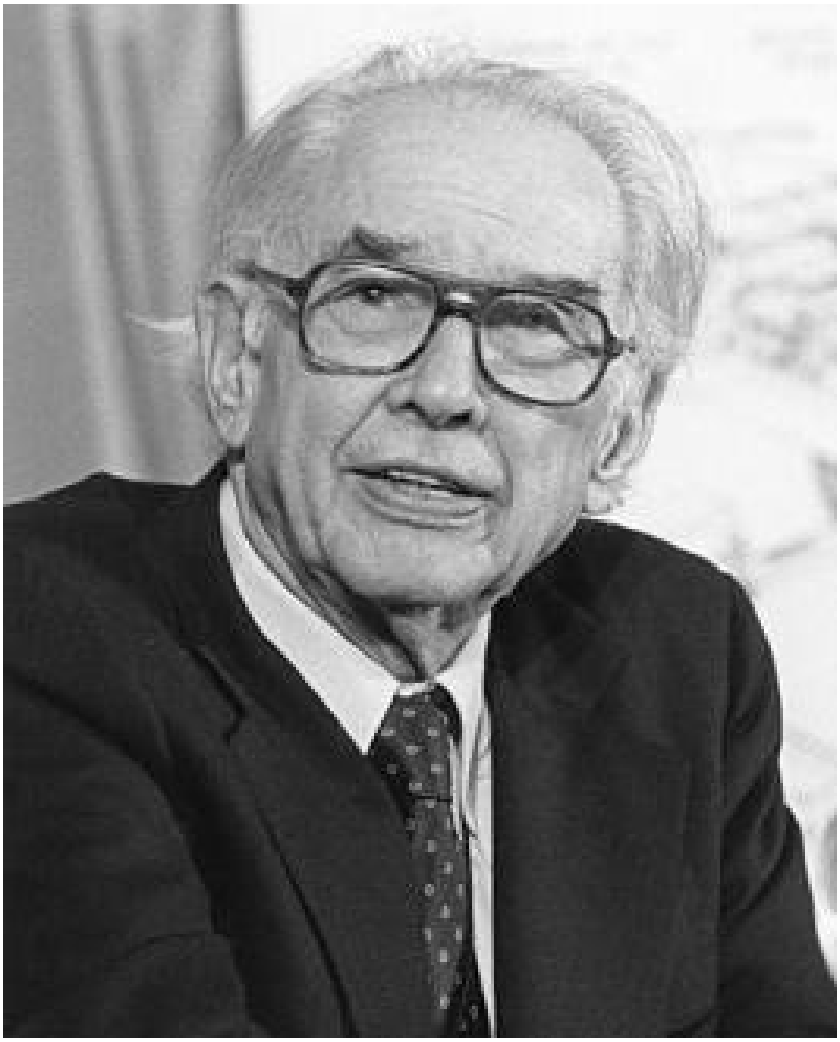

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CONTROL THEORY

CONTROL SYSTEMS 2

CONTROL SYSTEMS 3

Use of Elements and Algorithms of Intelligent Support in the Automation of Technologies for Control and Quality Management of Bulk Materials

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***Abstract*—The article deals with the choice of criteria for efficiency, applicability in measuring technology, analytical and construction, on the basis of which a methodology for assessing the quality of structures of measuring devices of moisture of materials of the agro-industrial complex is proposed. The standard deviation of the random error characterizing the accuracy of measurements is shown. A complex efficiency criterion is discussed, including the dominant particular parameters: accuracy, reliability, cost, allowing to solve the problem of optimal design of humidity control devices for the materials under consideration. As an optimal option, a differential measuring device is analyzed, which practically eliminates random and systematic errors and makes it possible to design a multiparameter measurement method that considers the features of a heterogeneous environment, such as bulk grain materials of the agro-industrial complex**

Keywords*— design, efficiency criteria, moisture of materials, moisture measurement, error, standard deviation, accuracy, reliability, measuring device

I. Introduction

Currently, an extensive material has been accumulated that illuminates the physical foundations of moisture-measuring (high-frequency, ultra-high-frequency) method of measuring the moisture content of various materials of the agro-industrial complex (AIC), numerous designs of measuring devices have been used and proposed for implementation [1-10].

Analysis of literary sources [11-15], as well as a number of scientific studies [16-20] aimed at the development of methods and synthesis of measuring transducers of agricultural materials, there are no data on such important issues of modern instrumentation as the use of efficiency criteria, on the basis of which the quality of measurements is assessed and the structures of moisture measuring devices are optimized.

The construction of private and complex criteria for the effectiveness of information converters (IC) is one of the most important and complex stages of external design [21]. External design of IC is understood as the design of external parameters characterizing the accuracy of measurement, speed, reliability and cost, each of which can be considered as a particular indicator of the quality of IC [22].

Due to the fact that particular indicators characterize the quality of IC only from a certain angle and do not give a sufficiently complete picture of its effectiveness as a whole, in practice they use a complex (generalized) criterion of efficiency $Q = (\text{эффект})/(\text{затраты})$, which connects in the required proportions the main, most important functional and cost particular indicators, such as "accuracy-cost" or "speed-cost" [23].

Various information criteria are used to characterize IC. This is an entropic error, the speed of information transmission, information ability, etc., which have a certain metrological color [24].

On the basis of these information criteria in the theory and technique of information transformation, generalized

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criteria for the effectiveness of IC are designed, which, along with the accuracy of measurements, also allow to consider the reliability and cost of converters [25].

II. PROPOSED METHODOLOGY

Automation of production processes, and especially where perishable raw materials are processed, requires the use of express methods for controlling its basic parameters, providing the desired expected effect from the introduction of automation systems. There are still losses due to the lack of means of express determination of the moisture content of raw materials.

For the choice of method and synthesis on their basis, the IC of material moisture control and control of technological processes of industrial processing of agricultural materials allows us to conclude that humidity plays a dominant role in the formation of the quality of the final product and the optimization of technological processes at various stages of its processing.

For these purposes, in practice, most researchers use the electric (dielcometric) method of measuring the moisture content of bulk materials of the agro-industrial complex. The dielcometric method for measuring the humidity of the materials in question is based on the dielectric constant of the material. Recently, the main task in most cases was given to technical tasks and, to a lesser extent, to scientific ones: the study of the properties of the studied materials as objects of automatic control, the justification of the type of devices and their metrological parameters, based on their properties and grade of agricultural materials and the conditions for their collection, transportation, storage and industrial processing.

Studies of the electrical properties of the grain mass significantly expand the existing understanding of the factors affecting its electrical properties and make it possible to implement scientifically based methods for calculating the parameters of primary transducers and measuring circuits of humidity control devices [26].

Outcomes

To meet the basic requirements of the considered method and build a comprehensive criterion for the effectiveness of IC in [27], a heuristic algorithm for the synthesis of partial parameters of the following type is proposed.

$$Q = \frac{R^{-q_R}[\frac{3600}{(\lambda_0+\lambda_{\text{ПИ}})}]^{q_H} \cdot B^{q_B} x^{q_T}}{\prod_i [(C_0)_i + (C_{\text{ПИ}})_i q_i}. \quad (1)$$

Where:

- ✓ R is an estimate of the average information performance, characterizing the amount of information about the converted signal into a unit of time, when the measurement accuracy is taken as the dominant parameter;
- ✓ B – IC performance (number of conversions per second);
- ✓ x is an uninformative characteristic of accuracy;
- ✓ C_i- cost parameters;
- ✓ q_R, q_B, q_H, q_T - Boolean variables that take the value 1 if the corresponding parameter is dominant, and the value 0 - otherwise. Moreover, variables q_R, q_T, q_B, q_i- must satisfy the following ratios:

$$q_R \wedge q_T = 0, \quad q_R \wedge q_B = 0, \quad q_i \wedge q_j = 0,$$
$$q_T \wedge q_H \wedge q_B \wedge q_i = 0,$$

where $\wedge$ - is the symbol of the logical conjunction operation.

Algorithm (1) allows you to obtain a broadcriterion for the effectiveness of IC, which have the properties of prostate representativeness and versatility, which will later be used in the engineering assessment of the quality of the structures of measuring devices. Mass moisture ratio (MMR) is one of the main qualitative indicators of AIC materials, it is advisable to take the accuracy of measurements as the main particular parameter when building complex efficiency. At the same time, accuracy is a vector parameter determined by the static and dynamic components of the resulting error. The resulting error in this case can be considered as the output signal $W_{(t)}$ of some multifaceted nonlinear dynamical system, the input signals of which are the convertible signal $U_{(t)}$. To characterize the error$W_{(t)}$, we will use such functionalities that reflect individual properties of the error that are of interest in a particular situation. Such functionalities include, in particular, modules of maximum relative and reduced errors, confidence interval, modulus of relative and reduced errors of standard deviation (SD), dispersion of error, etc. [27].

On the basis of the SD, a number of authors [28], in the field of measuring instrumentation - P.N. Novitsky, in the field of analytical instrumentation in the design of fluorescent analyzers - Prof. I.V. Korablev and Prof. M.V. Kulakov, the deviations of the real characteristics of devices from the nominal ones, due to such random factors as the change in the radiation power of the electromagnetic wave, the variation in the transmission coefficients of receivers and radiation amplifiers, etc., i.e. the studied factors caused by the instability of the parameters of the scheme and the intrinsic noise of the IC, on the basis of which the quantitative statistical criterion of the quality of IC is formed - the SD of random error.

Currently, very effective methods forsuppressing systematic error have been developed, for example, the method of periodic verification of two points of the instrument scale, often performed automatically [28] or this error is considered during calibration, or by the substitution method, etc.

From the point of view of the application of coex and the conditions under which this criterion most fully characterizes the quality of IC, we will use the model presented in Fig. 1.

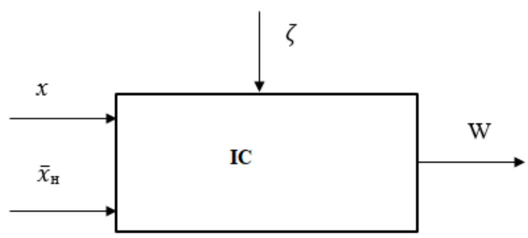

Fig.1. Converter Information Model

Where:

- ✓ x is the measured value;
- ✓ W – measured output signal;
- ✓ $\bar{x}_n$ – uninformative influencing factors;
- ✓ $\bar{\zeta}$ – IC's own noises.

From Fig.1 it can be seen that the output signal of IC depends not only on the measured value x but also on the parameters of IC, the conditions under which the conversion is carried out (temperature, pressure, ambient humidity, etc.), i.e. uninformative parameters $\bar{x}_n$ ($\bar{x}_n + x = 1$) and own IC noise. $\bar{\zeta}$

Considering the listed characteristics of the transformation functions, we will write in the following form

$$W = f_1(x, \bar{x}_n, \bar{U}, \bar{\zeta}). \quad (2)$$

Where $\bar{U}$ determines the IC parameters and external measurement conditions. The type of function f_1 depends on the method of analysis and the structure of the IC. The ratio (2) is a mathematical model of the IC. This model may be adequate to the real IC when measurements $\bar{U}$ change significantly slowly than transients are established in IC, i.e. when there is at least a quasi-static measurement regime. When quasi-static is performed, vectors $\bar{x}_h$ $\bar{U}, \bar{\zeta}$ are random variables. Therefore, under real conditions, the response of W IC is a random value (even with a fixed but unknown *value of x*). This fact leads to the involvement of statistical criteria for the quantitative assessment of the quality of IC.

If the deterministic function $\widehat{W}$ *(x)* is called the nominal (average) value of IC, which characterizes the transformation *of x* to W_B of nominal conditions, i.e. when the vectors $\bar{x}_h$ have $\bar{U}$ a nominal value $\hat{\bar{x}}_{of\ n}$, $\hat{\bar{U}}$, and there is no eigenstate noise ($\zeta = 0$), then provided that there are few deviations $\overline{\triangle x_H} = \bar{x}_n - \hat{\bar{x}}$; $\overline{\triangle U} = U - \hat{\bar{U}}$; of the nominal conditions ($\delta x_H = \frac{\Delta x_H}{\bar{x}} \ll 1, \delta U \ll 1$) the expression (2) at fixed x can be decomposed into a series by the powers of the increments $\bar{x}_h$, $\bar{U}, \bar{\zeta}$.

Limiting ourselves to linear approximation (due to the smallness of deviations $\bar{x}_H$, $\bar{U}, \bar{\zeta}$) in the vicinity of the nominal point with coordinates $\hat{\bar{x}}_H$, $\hat{\bar{U}}$, , $\bar{\zeta}$ we get

$$\Delta W = W - \hat{\bar{W}} = \frac{dW}{dx_H}\left|\hat{\bar{W}} \cdot \overline{\triangle x_H} + \frac{dW}{dU}\right|\hat{\bar{W}} \cdot \overline{\triangle U} + \frac{dW}{d\zeta}\left|\hat{\bar{W}} \cdot \zeta \right. \quad (3)$$

Where: ΔW- uncontrolled deviations of the signal W from nominal $\hat{\bar{W}}$, caused by random factors $\overline{\triangle x_H}$, , $\overline{\triangle U}$ ζ.

The value ΔW characterizes the error IC reduced to its output. with a fixed x , the error ΔW causes an error in the evaluation of the measurements of the value x

$$\Delta W = \frac{dW}{dx} = \hat{S} \cdot \Delta x.$$

Where:

- ✓ $\hat{S} = \frac{dW}{dx}|\widehat{W}$ – nominal sensitivity of IC.
- ✓ $\Delta x = x - \bar{x}$ - Absolute error in estimating x.

A quantity Δx (as well as ΔW) a random one; the properties of this quantity in static mode are characterized by a mathematical expectation of M $\{\Delta x\} = \Delta C$ i.e., the probability of a quantity. The current mean determines the systematic error of the set of similar IC and the measure of scattered quantities Δx about ΔC

$$M\{[\Delta x - M\{\Delta x\}]^2\} = \delta^2 \Delta x,$$

the positive value with which

$$\sigma_{\Delta x} = \sqrt{M\{[\Delta x - M\{\Delta x\}]^2\}}$$

is called the SKO of random error IC [30]. Indicators ΔC and $\sigma\Delta x$ - quite fully determine the properties of IC and in accordance with GOST 8.009-84 are standardized metrological characteristics.

Currently, there are quite effective ways to suppress systematic error ΔC, so the presentation is allowed $\Delta C = 0$. In this case, the main criterion for the quality of measurements will be the SD of random error $\sigma_{\Delta x}$, which characterizes the potential accuracy of IC.

Other most important external parameters of the IC can be speed and reliability. However, if accuracy is the dominant parameter, then the speed may not play a dominant role due to the fact that at a given input signal of the IC it is uniquely related to dynamic errors, which are considered when assessing the accuracy of the IC.

It follows that performance can only be dominant when accuracy does not play a dominant role.

The reliability of IC can be considered in relation to catastrophic and permanent (degradation) failure.

III. CONCLUSIONS

From the analysis of patent and scientific and technical literature [33-35] it can be noted that on the basis of the construction of measuring circuits, analog devices for monitoring the humidity of agricultural materials are divided into single-channel, with a direct reading of the physical quantity, bridge, operating in differential mode and compensatory, with a zero-measurement method.

It follows that the construction of structural diagrams in analytical instrumentation and, consequently, the method of assessing the quality of luminescent analyzers with some changes can be used to assess the quality of measuring instruments based on the dielcometric method for various materials of the agro-industrial complex. At the same time, we believe that it is advisable to assess the effectiveness of structures on the basis of a comprehensive performance criterion, which includes the SD criterion as a particular external parameter. This most fully characterizes the developed and further design of measuring instruments.

Based on the analysis of existing methods and devices for controlling the humidity of agricultural materials, the criteria for assessing the accuracy of measuring transducers of the electrophysical properties of bulk materials have been substantiated; a methodology for calculating their transformation characteristics has been proposed; a mathematical model of the primary transducer of the capacitive sensor of technological parameters has been obtained, on the basis of which the conditions for achieving the highest sensitivity of the conversion characteristics of the primary transformation have been obtained. Converter.

The evaluation is based on a comprehensive efficiency criterion, including the dominant single indicators: accuracy, reliability and cost of the designed humidity control devices both in discrete mode and as part of an automated system of technological processes.

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