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TECHNOLOGICAL CONTROL OF HUMIDITY IN THE PROCESS OF HYDROTHERMAL PROCESSING OF GRAIN

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Abstract:
The paper considers information and the concept of humidity, as well as its role in regulation and management, where the role of humidity is an indispensable component in all stages of the technological process of grain processing. The primary transducers of humidity converted into an electrical quantity are analyzed, the basis of which is a capacitive sensor-capacitor, in the electric field of which there is a certain volume of grain, an approximation of a real physical object by its electrical model. To select a method, indirect methods based on measuring the humidity of the dielectric constant of the material under study are analyzed, which is based on the dielcometric method, the results present the developed functional scheme of the measuring unit of grain moisture sensors, and the question of designing and building devices for monitoring the moisture content of grain and granular materials based on this method is recommended, metrological characteristics are given A prototype of a grain moisture meter based on the dielcometric method, as well as its advantages and disadvantages.

Keywords: Humidity, measurement, control, method, transducer, capacitance, dielcometric method.

INTRODUCTION

Technological control of the humidity of some products of the agro-industrial complex (AIC), in particular, grain and grain products, is carried out in conditions of sharp disequilibrium caused by the rapid course of chemical reactions, various convective flows of unevenness in density, etc. Therefore, the known methods of controlling the kinetics of chemical reactions, restructuring the structure of non-equilibrium dispersed systems do not allow controlling the course of technological control of these processes and the quality of the produced Products. However, it is possible to increase the efficiency of technological control of moisture of dispersed heterogeneous systems for automating their production of finished products through the use of indirect, non-destructive measurement methods. However, also when developing electronic devices for measuring systems, it is important to know how their characteristics are affected by the change in the parameters that form their elements.

In the process of hydrothermal processing of grain, it is necessary to regulate it by humidity. For these purposes, it is necessary to conduct a discrete ornon-continuous measurement of grain moisture before grinding, in this regard, the complex scientific and technical problem of studying methods of automatic measurement and instrumentation seems relevant and timely.

HYDROTHERMAL TREATMENT OF GRAIN

Let's analyze the properties of the grain. Grain is a complex body consisting in its structure of natural high-polymers, or biopolymers, the main ones, which are proteins and carbons. In the hydrothermal treatment of grain, moisture penetrating into the inside of the grain causes a number of complex processes, as a result, the watering of biopolymers leads to their swelling of varying degrees. Which leads to a difficult-spinning state of grain, especially at the beginning of the process of agitation. As a result of hydrothermal treatment of grain, its density and strength, i.e. resistance to destruction, decreases, as a result, the energy consumption for grinding decreases. Therefore, with changes in humidity and temperature, it is possible to ensure a directed change in the technological properties of the grain over time. At the same time, the main factor in the hydrothermal treatment of grain is humidity, temperature. By changing the parameters of hydrothermal treatment, it is possible to regulate the

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moisture transfer and thereby change the technological properties of the grain [1].
Scientific research and testing of a sample of a mock-up for measuring humidity in the process of hydrothermal processing of grain was carried out in the industrial conditions of GALLA-Alteg JSC.

MATERIAL AND METHODS

One of the promising methods of technological control of humidity of multiphase materials is the dielcometric method, based on the interaction of an electric field with matter. Due to the simplicity of design, reliability, accuracy and ease of use, dielcometric information and measuring systems are widely used to analyze the propertiesof substances, liquids in the chemical, food and other processing industries. The resolution of the shortcomings mentioned above allows you to develop a method and a measuring and computational system for determining the moisture content of solid dispersed bulk materials.
The problems of building automatic and automated systems for controlling the properties of grain and products of their industrial processing and the characteristics of bulk materials require the solution of a whole range of tasks, the most common and significant of which are: finding the most effective methods for the primary measuring conversion of the electrophysical properties of materials subject to automatic control into an output signal, which would allow achieving the required reliability, accuracy and speed of the measurement process.

DEVELOPMENT OF THE PRIMARY MEASURING TRANSDUCER

As a primary measuring transducer, a capacitive primary transducer was developed, which provides a flat remote sensor of a metal-ceramic structure of a cylindrical shape made of titanium alloy, which makes it possible to use it as a embedded sensor for a long time without deterioration of its parameters. The electrodes of the sensor are coaxially pressed into the ceramics of the sole of the base, and the peculiarity of this sensor is that the electromagnetic field in it really exists only in a relatively thin interelectrode region, which excludes the measurement results from the influence of the completeness of the filling with ceramics, and, accordingly, the volume and weight of the filling on the moisture measurement result of the material sample do not have. To prevent the wet measured material from sticking in a static state in the workplace in the measurement of grain moisture, its temperature, as well as relative humidity and grain temperature, the sensor electrodes are equipped with electric heating, for which there are grooves in the sole of the sensor base for laying the heating element.

Outcomes

When using the sensor as a primary transducer, it made it possible to create a prototype of a dielcometric express high-frequency (HF) moisture meter for grain and grain products [2, 3, 4]. The proposed design of the device made it possible to measure the moisture content of grain samples on a conveyor belt and screw auger for a long time without deterioration of the parameters with a minimum error of the measured permittivity, hence humidity. The technical conditions of the measurement process on the conveyor belt are similar to the process of measuring the moisture content of grain in the silo in the laying state, with the only difference that with a continuous flow of material being measured by the sensor, when this sensor is laid in the silo, it is more in a static state than in motion. At the same time, the depth of immersion of the sensor electrodes together with the outer surface of the sole within the working limits of the density of the measured material of the transported grain mass practically introduces a minimum error in the value of the humidity index, since the connection of the high-frequency coaxial cable (plume) of the connection of the measuring part of the express device with the ring electrodes eliminates the vertical component of the electromagnetic field between the electrodes of the sensor E_{emf}.

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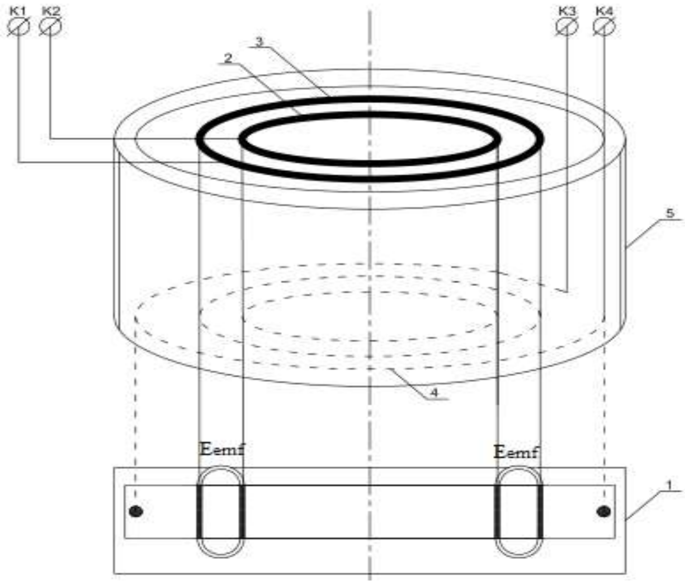

Fig.1. Device of the primary measuring transducer of grain moisture

Where: 1-sensor sole made of durable dielectric; 2,3 – metal (titanium) ring electrodes; 4-ring heating line; 5-Housing embedded humidity control system sensor

In figure 1, using contacts K_1 and K_2, the connection of the ring electrodes made of titanium with the input of the measuring generator of the device is made through the coaxial cord of the ring electrodes, and with the help of contacts K_3 and K_4 , the connection of the heating element of the ceramic sole of the base of the sensor to the electrical power source is connected.

During the measurement process, the controlled material is in close contact with the surface of the metal ring electrodes, in which the high-frequency voltage of the measuring generator is supplied, and as a result, the dielectric constant parameter corresponding to the humidity of the controlled material is determined. At the same time, the formal functional dependence of the dielectric characteristics of the material on its humidity can be considered as a primary conversion, and the output signal of the primary measuring transducer is a useful output signal of the measuring device [5].

The nature of the interaction of the electromagnetic field with the wet material is determined by the values of the complex dielectric and magnetic permeability with the obligatory consideration of polarization phenomena. As is known [6, 7], there are four types of polarization: electron, atomic, orientational and volumetric. Polarizability is a complex quantity that exhibits resonant properties, and in the electromagnetic field for the polarization of each of these species there is a certain range of frequencies where energy losses are maximum. When measuring humidity, the following values are used: the complex dielectric constant consists of real and imaginary parts, and: when measuring humidity, the following values are used: the complex permittivity ε consists of real ε' and imaginary ε'' parts, moreover: $\varepsilon = \varepsilon' - j\varepsilon''$; ε - is the permittivity, $tg\delta$ - is the tangent of the dielectric loss angle and the specific conductivity σ, as well as the circular frequency of the field ω are related to with the following dependencies:

$$\varepsilon = \varepsilon';\ \varepsilon'' = {}^{\sigma}/_{\omega};\ tg = {}^{\varepsilon''}/_{\varepsilon'} = {}^{\sigma}/_{(\omega\varepsilon)} \quad (1)$$

For the dielcometric circuit of the meter, the variable capacitance of the transducer corresponding to the humidity of the controlled material is defined according to [8] as:C_k

$$C_k = C\left[\left(1+\frac{r_n'}{r_m'}\right)^2 + \frac{1}{\omega^2 r_m' C^2}\right], \quad (2)$$

where C_k is the variable capacitance corresponding to the humidity of the material being measured, C is the capacitance of the reference generator against which the dielectric constant in the sensor is measured, is the equivalent resistance of conduction losses; is the equivalent resistance of polarization losses; r_m ' r_n 'ω is the circular frequency.

A high-frequency electric field is created by a generator with a useful power *of ±100 V,* with a frequency of *40 MHz.* It should be noted that the calibration characteristic, in fact, is a mathematical model of the object of measurement obtained from the results of specially organized experiments, and the questions of metrological accuracy are questions of the adequacy of the model with the results of experiments with a given confidence accuracy of their description [9].

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The measurement of the moisture content of granular materials by the capacitive method is based on the linear dependence of the output signals of the primary moisture meter transducer on humidity and various influencing factors (interference) [10], including temperature T, degrees of heterogeneity S and maturity Z, storage conditions and processing U of grain. In this case, the measurement of the output signal Y is described by the equation:

$$Y_{(p)} = Y_{c(p)} + Y_{R(p)}.$$

The static characteristic of the measuring instrument is its calibration characteristic - the approximate dependence of experimental measurement results on humidity $Y = f(W)$, where *f (W) is* the function to be determined during calibration. Let's analyze this, let's analyze this, let's obtain Y_1, Y_2, Y_3 as a result of measurements for various values W_1, W_2, W_3, .

Due to measurement errors, the value of Y_i differs from the true value of *f(Wi),* i.e.

$$Y = f\left(W\right) + \Delta_i,$$

where Δ_i is the measurement error.

Similarly, the measurement of the output signal will be recorded in the following form:

$$dY = \frac{dY}{dW}dW + \frac{dY}{dT}dT + \frac{dY}{dZ}dZ + \frac{dY}{dU}dU. \quad (3)$$

The first term of the expression (3) determines the sensitivity of the measured parameters to moisture, and the remaining terms determine the errors caused by the change in factors. The measurement of humidity depends on how much the moisture-measuring system as a whole and the primary converter of the moisture meter ensure the fulfillment of the conditions [5, 7]:

$$\frac{dY}{dW} \to max;\ \sum\left(\frac{dY}{dZ};\frac{dY}{dT};\frac{dY}{dU}\right) \to min. \quad (4)$$

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Minimization of the error is achieved provided that the sensitivity of the measuring device to changes in humidity $S_W \frac{dY}{dW}$ is maximum, and the sensitivity to uninformative parameters (interference) $S_n = \frac{dY}{dZ};\frac{dY}{dT};\frac{dY}{dU}$ minimal.

Figure 2 shows the functional diagram of the measuring channel with a sensor of dielcometric RF - a moisture meter designed to measure the moisture content of the grain, the value of which is determined by a capacitive primary transducer 1, made in the form of a embedded sensor installed in the grain mass and connected through thermal suspension using a coaxial cable with an electronic part of the measuring RF generator 2, the frequency of which varies in accordance with the moisture content of the grain, since the primary transducer-sensor is included in its oscillatory circuit. The principle of operation is as follows: from the output of the generator, the HF signal enters the input of the signal generator unit 3, which produces a rectangular signal with a pulse repetition frequency equal to the frequency of the measuring HF generator.

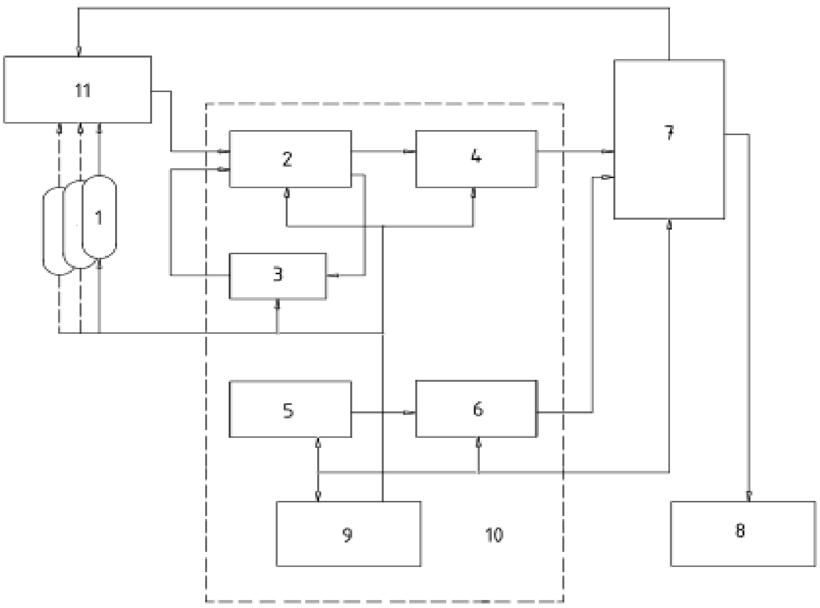

Fig.2. Functional diagram of the measuring unit of grain moisture sensors

Where: 1-sensor humidity; 2-measuring generator; 3-stabilizer; 4.6-blocks of signal formation; 5-pole HF generator; 7-computer; 8-control controller; 9-power supply; 10-block of measuring and reference information; An 11-logical data transfer order node.

The HF reference generator 5, assembled from elements identical to the element of the measuring HF generator 2, sends to the input of the signal generation unit 6 a signal of a constant (reference) frequency equal to the frequency of the measuring HF generator, in the case of a bullet value of the humidity of the controlled component (resonant mode of operation). In this case, the signal of the reference HF generator in the signal generation unit 6 is subjected to the same processing as the signal of the measuring HF generator in the signal generation unit 3. Both output signals from blocks 3 and 6 are transmitted to the arithmetic node of the control computer, which, as a result of comparing them by frequency, fixes the frequency difference proportional to the grain moisture parameter monitored by the sensor, which is recorded by the digital-analog converter of the computer after a pause corresponding to the algorithm of the moisture-measuring system, switched on by command from the signal distributor 9, representing rectangular pulses, of a low frequency of the order of 1Hz, issued alternately at a certain interval for switching electrical purposes, recording the frequency of signals of the measuring and reference HF generators, as well as indicating on the digital scoreboard of the information system the humidity value recorded in the computer memory until the next countdown and archival recording.

Signal distribution unit 6 in a place with a low frequency clock generator 7 and a frequency divider 12 act as an electronic switch operating in conjunction with the control computer, the mode of operation of the sensor is discrete - continuous with a time of setting readings of the order of 10 seconds, and the provided range is grain moisture measurements of 8.0-18.5% when the operating temperature of the object changes from -5 ° C. The limit of permissible values of the basic error is 0.8% (abs).

DISCUSSION

With the development and improvement of technology, humidity sensors, as a measuring device, have undergone numerous changes and modernizations, due to which today they are presented in a wide variety [11, 12]. Depending on the method of transmitting and displaying data on moisture measurements, they are divided into analog and digital. Analog devices belonging to the early designs of measuring devices have a dial display of humidity values, and digital devices are a more modern technical solution, since the information in them is displayed on the display and transmitted on an electronic communication channel [13, 14]. The humidity sensor considered in this article with a measuring system that can provide the output of a useful signal in a certain preset sequence from the nth number of sensors, using a control computer of an automated information complex, and the type of output interface for connection to work: MODBUS RTU.

After state certification, the developed device is recommended to be used in any production conditions [15].

Metrological characteristics of the device.
Measuring range ...... 8,0–18,5 %
Limit of permissible values of the basic error ..... 0,8 % (abs.)
Operating temperature range .... (–5...+50) °C
Sample mass ...... 100 g
Time to establish testimony .... 10 s
Operating mode .... discrete-continuous
Analog output signal .... 4–20 mA
Output interface type .... MODBUS RTU

FINDINGS

For technological control of humidity in the process of hydrothermal processing of grain, a dielcometric method based on measuring the moisture content of materials by their dielectric parameters, depending on the moisture content of the grain, is more optimal. Their advantages include [16, 17, 18]:

1. High sensitivity to moisture content in the material.
2. Wide material moisture measurement range (0÷100%).
3.Dielcometer moisture meters have a relatively simple design of humidity converter and measuring device.

The disadvantages of dielectric methods for measuring humidity include:

1. The results of moisture measurement by these methods depend on the density and thickness of the material under study.
2. Relatively low noise immunity from random dielectric characteristics of the controlled material and intermediate medium.

The use of automatic moisture control and control systems in hydrothermal grain processing will make it possible to apply an automated humidification system using high-precision grain moisture meters, as well as water and grain consumption, in general, it will make it possible to stabilize the output moisture content of the grain [19]. In turn, such an approach to the automatic system of regulation and management will allow rational use of grain and increasing the efficiency and energy saving of flour milling production, as well as obtaining maximum profit when meeting the demand for the company's products [20].

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