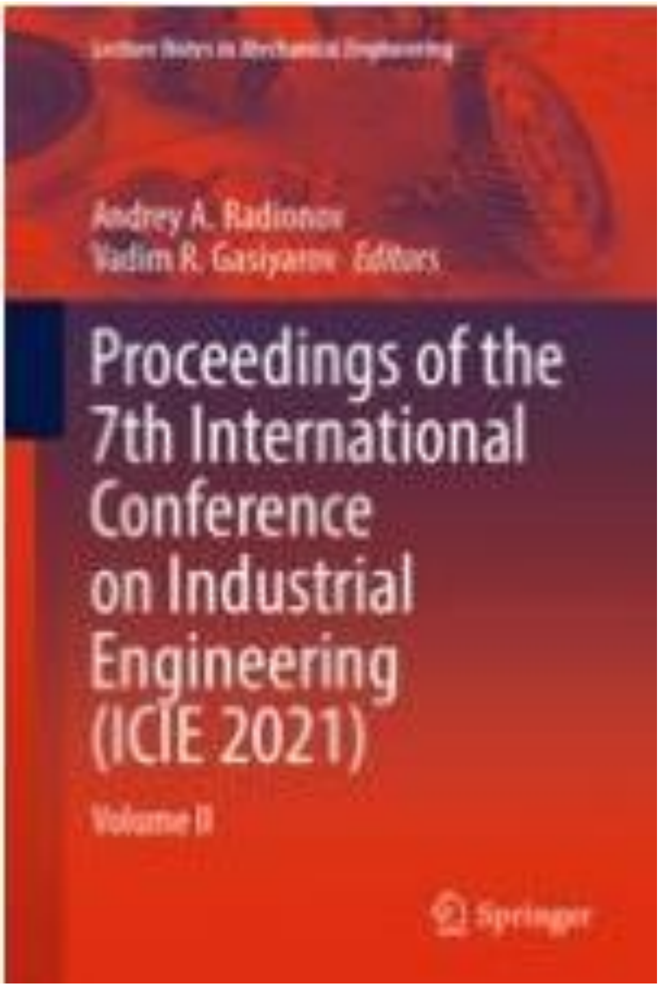

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Automatic devices for continuous moisture analysis of industrial automation systems

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Abstract This article is devoted to the hydrothermal property of grain and describes its behavior during cold processing in factory conditions, where it is necessary to measure the moisture content in the grain with instruments and control technological processes. Scientific approaches are considered and recommendations given on the adoption of specific and poorly studied research tasks in the field of grain moisture measurement in the technological process. Mathematical models of the dielectric permittivity of heterogeneous wet systems and ways to improve the reliability and accuracy of the results of monitoring the humidity of materials by the dielkometric method. The issues of designing a high-frequency method and designing on its basis on humidity control devices of capacitive measuring transducers. As well as the requirements for the selection of the method and grain humidity control devices, their hardware designed to control grain humidity in technological processes that ensure their stable operation as part of the automated process control system are considered.

Keywords Grain, Humidity, Control, Automation, Hydrothermal Treatment, Cooling.

1. Introduction

One of the main elements of the APCS in the grain processing industry is the technical maintenance of industrial control systems, ensuring that all the functions of APCS and composed data devices, sensors and control devices of technological parameters of the investigated materials.

In accordance with the technological regulations of hydrothermal processing (HP) of grain before grinding, the grain is moisten with cold water at a temperature of 18-25^{o}C temperature, and cooled for a certain time in accordance with the task of the technology. Known [1] that for varietal milling of wheat, washing either the grain or wet peeling is a mandatory operation, so that the first moistening carried out in this equipment. One of the main processes of improving the quality of products is preparation for grinding hydrothermal processing of grain, as a result, the quality of finished products is improved, energy consumption costs are reduced, the sanitary and hygienic condition of workshops and working conditions of service personnel are improved. It should be noted that the problem of hydrothermal processing of grain is still poorly studied and an urgent problem [2].

Analysis of the properties of existing systems of hydrothermal grain processing and control of its Humidity in the technological process showed that, nevertheless. There are additional opportunities to improve the control systems of technological parameters, which will increase the efficiency of the use of Autonomous systems of instrument support for humidity control and the use of devices as part of the automated process control system [3].

2. The model of monitoring of grain moisture

2.1. Analysis of the condition of hydrothermal treatment

One of the problematic issues, as well as the enterprises of the milling industry of the Republic of Uzbekistan. In the absence of instrumental methods of determination of properties of grains, which leads to incomplete use of the technological properties of local varieties of grain, with the result that not allows to establish the optimal modes of preparation and grinding of grain.

This in turn requires efficient operation of the enterprise in the current market conditions, first of all, creation at the enterprise of increase of efficiency of technological processes, organization, perfect control and production control [4]. The technological process of industrial processing of grain and grain products is shown in figure 1.

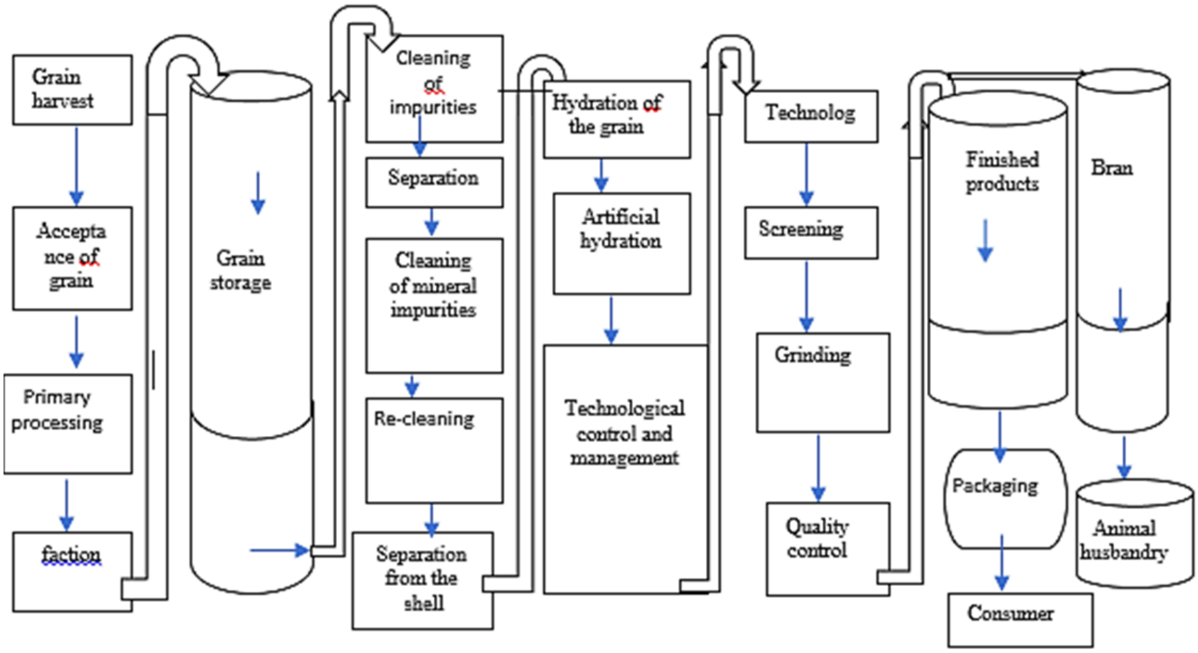

Fig. 1. Technological process of industrial grain processing

To improve the efficiency of technology, control organization, quantitative accounting of raw materials, products, process control, it is necessary to introduce an automated control system for process control.

If the goals for rapid and tight control of raw materials and manufactured products, exact monitoring of technological regulations on the control over the actions of technological personnel, improve personal responsibility of operators for decisions resulting in losses, the alternative to computerized control systems, probably not [5].

2.2. The behavior of the moisture content of the grain in the electromagnetic field

The main condition for successful implementation of the problem is the establishment of analytical dependencies between the physical and electrical characteristics of the grain at a frequency taking into account the heterogeneity of the structure, borehole depth, volume mass, granulometric and electrolytic composition, i.e. frequency-humidity characteristics [6]. Special attention paid to the study of the influence of contact electrical conductivity between particles, taking into account roughness, the height of micro-roughness, the number of contact points, etc. It is also necessary to develop a methodology for finding the parameters of separation of informative (useful) and uninformative (disturbances, interference) signals, as well as frequency optimization for frequency separation of parameters. Taking into account the information obtained the design of measuring transducers and measuring circuits of humidity control devices should developed. Each of these measurement methods has certain modifications; however, their main goal is to increase the accuracy of measurements [7].

2.3. The choice of method of measurement

The criterion for selecting a measurement method for constructing control devices based on them should be the accuracy that the selected method can provide. It is hardly possible to formalize such a criterion in the form of a mathematical expression, but it is obvious that the main component in it remains the accuracy of measurement [8]. The absence of many of the above-mentioned humidity monitoring devices on the market today once again indicates an objective, proven lack of obvious advantages for any of the methods [9,10].

The next task is to choose the method and design of the instrument for measuring grain moisture. For materials such as grain, electrical measurement methods are more optimal, in particular high-frequency technological control devices, where the frequency range is from $5 \cdot 10^3$ to $5 \cdot 10^7$ Hz [11]. As a sensor for discrete measurements, we have chosen a coplanar sensor. The peculiarity of such sensors [12] is that the field in them actually exists only in a relatively thin near-electrode region, which frees the measurement results from the influence of the completeness of the fill, and accordingly, neither the weight nor the volume of the filled sample affect the measurement result [13].

According to the theory of heterogeneous polarization, two types of concentrated media are considered. Weakly concentrated media considered, in which the sizes of inhomogeneities are small in comparison with the distances to the nearest elements of the system [14]. Highly concentrated media contain such inclusions that significantly affect the properties of the entire material. Matrix systems characterized by the presence of a common phase – the matrix, which is interspersed with unrelated particles that make up the second phase.

All grain components have capillaries and pores with a wide continuous range of sizes. Therefore, grain communications the capillaries is the main form of communication with an average moisture of the molecular mechanism of moisture movement in the capillaries depends on the size. If the radius of the capillary is significantly greater than the free path of the water molecule (λ), which occurs in the case of transport in macro capillaries, then the mass flow density is determined from [13] by the Poiseuille formula:

$$n = \frac{r^2}{8\mu}\frac{dP}{dX} = \frac{r^2}{8\nu}\left(\frac{P_1 - P_2}{L}\right) \tag{1}$$

For the case of microcapillaries ($r \leq 0{,}1\mu$), the transfer will be determined by the molecular regime. In this case, the mass flow density could be determine by the formula:

$$n = \frac{1}{\pi r^2}\frac{dM}{d\tau} = \frac{8}{3}\sqrt{\frac{\mu}{2\pi kT}} \cdot r\frac{P_1 - P_2}{L} \tag{2}$$

where $\frac{dM}{d\tau}$ is the steam flow velocity.

Due to the complexity and variability of the capillary-porous characteristics of the grain and the influence of the history of sorption processes, the sorption isotherms obtained by different authors have a significant difference.

Depending on the form of binding energy and the type of material, moisture can be in the form of free water, capillary bound (physical-mechanical bond), adsorption bound (physical-chemical bond) and chemically bound, in this case we are dealing with free bound water. The permissible moisture content of water in the grain should be in the range of 12.0-16.5% [15].

2.4. Instrumentation for grain moisture control

Because of the conducted research, a grain moisture-monitoring device was developed and put into operation, working in laboratory conditions and in the technological process at the grain processing enterprise of JSC “G'ALLA-ALTEG” in Tashkent.

The prototype of the humidity control device structurally made in the form of two parts – a Converter and an electronic unit. The moisture meter Converter made in the form of a coaxial capacitor, which has a rack with a sealing device. The Converter cylinder is three-layer: there is a heat shield between two thin-walled steel tubes. A temperature sensor made of copper wire with a diameter of 0.03 mm is mount in the bottom of the coaxial capacitor; the resistance of the sensor at normal temperature is about 700 Ohms. In the permanent filling device of the microprocessor, software control is recorded, the process of measuring and processing the results. To select the regression control coefficients for the grain, the corresponding program start address code is dialed on the control panel.

The regression equation for the material under consideration has the form

$$W_n = a_1 N^2 + a_2 N + a_3 \tag{3}$$

where W - n is the moisture content of the material inpercentage; N is the average value of the level of informative signals, mA; a_1, a_2, a_3 are constant coefficients. The duration of one determination of humidity is 10-15 seconds.

3. Methods of research

The main condition for the successful implementation of the problem is the establishment of analytical dependencies between the physical and electrical characteristics of the grain at frequency, taking into account the heterogeneity of the structure, borehole depth, volume mass, granulometric and electrolytic composition, i.e. frequency-humidity characteristics. At the same time, special attention should be pay to the study of the influence of contact electrical conductivity between particles, taking into account roughness, the height of micro-roughnesses, the number of contact points, etc. It is also necessary to develop a methodology for finding the parameters of separation of informative (useful) and uninformative (disturbances, interference) signals, as well as frequency optimization for frequency separation of parameters. Taking into account the obtained information, the design of measuring transducers and measuring schemes of moisture-measuring systems developed.

In experimental research in the field of high frequency dielectric properties of such materials are grain, you need to solve the following little-known problem [5]:

- Definition and analysis of the conversion of primary measuring high-frequency Converter; for this it is necessary to experimentally investigate the dependence of dielectric properties of the investigated products from humidity the most important influencing factors.
- Construction of an electrical model of the primary Converter based on the obtained experimental data, with an optimal approximation of the real characteristics of the materials under study.
- Implementation of the obtained data by designing high-frequency humidity monitoring devices for grain and grain products and testing them in laboratory and production conditions.

In the process of preparing grain for grinding into flour, they try to give it properties that most contribute to obtaining the desired results. The process of hydrothermal processing of grain characterized by technological regulations, i.e. the sequence and installation of appropriate technical means by a set of parameters of their operation: the degree and multiplicity of humidification, the type of moisture carrier (steam, water), its temperature or pressure, etc. Analysis of the complex systems of hydrothermal grain processing processes includes the following technological operations:

- moisture of grain in the process of washing in the washing machine;
- dosed step-by-step humidification in special humidifiers of various designs;
- moistening of grain in the process of wet peeling;
- seduction aging of grain in special bins to absorb and distribute moisture in the anatomical parts of the grain in accordance with their structural features; this process is accompanied by a decrease in the strength of the endosperm as a result of the appearance of microcracks.

In the Republic, about 6 million tons of grain are processed annually, based on this, a group of leading specialists of the Tashkent state agrarian University analyzed the determination of the humidity of the TRP process at the enterprise of JSC “GALLA-ALTEG” between the first and second cooling. To prepare the grain for grinding, a TRP is carried out, where it is necessary to measure the moisture content of the grain mass and add a calculated amount of water to obtain a certain moisture content of the grain. As a result, there is a continuous convergence of grain moisture in the technological line of mills. The purpose of our research was to study the effect of grain moisture before grinding on the quality and quantity of flour produced in the conditions of JSC "GALLA-ALTEG" in Tashkent. One of the main tasks of the research was to determine the effect of grain moisture before the first batch system on the yield of flour and on the main indicators of its quality.

The studies conducted in the following sequence:

1. Determination of the quality of grain coming to the enterprise;
2. Determination of the quality of the batch of grain coming to the mill;
3. Measurement of grain humidity: up to moisture, the first and second moisture grain moisture at 1 torn the system, and changing the quality of the resulting flour and first grade;
4. Definition of white flour and first grade with belsnor.

4. Conclusions and recommendations

Based on the performed analysis, we can state the following:

1. The analysis shows that in the known works not enough attention given to the development of universal analytical models of the dielectric properties of heterogeneous systems in General and dispersed moisture-containing bodies in particular. One of the main reasons for the satisfactoriness of the known mixture formulas when applied to wet materials is the lack of consideration of the influence of the types and forms of moisture binding on the electro physical properties of the material.
2. When designing dielkometrical means of technological control of parameters of heterogeneous systems, it is sufficient to cover the range from infrared to tens of megahertz, since it is in this frequency range that the factors of internal polarization manifest themselves.
3. The permittivity Model for grain, which takes into account the temperature of the material, allows you to estimate the degree and nature of the influence of the factor on the total error of measuring grain moisture and, therefore, possible to introduce the necessary corrections to the measurement result.

4. The results of the study

The moisture meter passed laboratory tests in the metrological laboratory of JSC "G'ALLA-ALTEG". The results of the experimental data presented in "table 1“. Metrological characteristics carried out in accordance with the specified method in [16].

Table 1. Effect of grain moisture on flour whiteness (experimental data)

№	To moisturize %	Humidity %			Flour whiteness, conventional unit RZ-BPL
		I Seduction %	II Seduction %	I ragged system %	
1.	8,6	13,2	15,0	15,4	42
2.	9,0	13,4	16,2	16,4	46
3.	9,8	13,8	16,0	16,5	46
4.	9,2	13,6	14,0	15,2	41
5.	8,9	12,2	16,0	16,2	44
6.	9,1	13,2	14,8	15,0	40
7.	9,4	13,8	16,3	16,4	46
8.	9,1	13,2	15,0	15,5	41
9.	9,4	13,4	15,8	16,2	45
10	8,4	12,8	15,0	15,5	42

The device is available for operation and measurement of humidity, in laboratory conditions, with the following metrological characteristics:

- humidity measurement Range. 8...18.5%;
- measurement Error: for discrete measurements up to 1.5%;

- measurement Speed. At the speed of grain movement and flow, the measurement interval is from 5-10 seconds.
- operating mode: discrete-continuous
- output interface Types: (4...20mA, MODBUS RTU) must connect to the ACS systems. The devices under consideration can provide automatic receipt, transmission, conversion, comparison and use of information about grain moisture for the purpose of monitoring and controlling production processes [17].

5. Conclusions

Based on the results of the work the scientific novelty lies in the method of estimating the hydrothermal condition of the grain, allowing continuous process monitoring and the process of moisture redistribution in the grain volume. In investigated analytical models based on electrical equivalent circuit, taking into account the electrical connection of controlled substance with a common point of the measuring circuit.

Based on the dielectric constant for grain, studies of humidity control during hydrothermal treatment in the technological process in the factory were carry out. The results obtained satisfy the producers. The analysis of scientific sources [18-20] shows that the use of this device in the construction of automated control systems once again confirms the increase in the economic efficiency of enterprises, thanks to the introduction of new, more advanced technical automation tools.

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