Automation of Technological Processes for Controlling Grain Moisture in the Flowu

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Abstract – **The paper deals with the problems of grain wounding requires large energy costs, requiring a multi-stage process of grain processing, installation and perfect and reliable automation systems for the storage and processing of raw materials, theoretical and experimental studies and the results of the use of the microwave method in measuring the moisture content of grain and grain materials. The method under consideration is based on the principle of selective absorption of microwave radiation energy by water in materials and its derivatives. By the degree of absorption of radiation, the concentration of moisture is judged. The paper investigates the amplitude and phase methods of the passing wave in free space.**

The influence of the elastic properties of the material under study on the electrical characteristics of the microwave wave, suggesting fundamentally new ways of measuring the attenuation and phase shift of the electromagnetic wave, including discrete conversion of the signal of the primary converter, which does not require rigid metrological support and the use of a phase shift, is substantiated. Information on the values of the thickness of the material is analyzed in order to correct the influence of this value, consisting of two parameters: the signal of the passing wave, the attenuation and phase shift which characterizes the humidity and the additional signal - the phase wave reflected from the front surface of the materials and carrying information about its thickness.

Keywords – automation, control, humidity, ultra-high-frequency method, air-material, passing, reflected, wave, attenuation, phase shift.

I. INTRODUCTION

In the modern economy, there is fierce competition between various light industry enterprises, including grain processing plants. Only the introduction of an automated management system can improve the efficiency of management of an economic object, and consequently, the growth of the competitiveness of the enterprise.

The grain processing industry is quite complex in its structure. Grain storage requires a lot of energy. All this, as well as the multi-stage process of grain processing, leads to the fact that for the successful operation of the enterprise it is necessary to install perfect and reliable automation systems for the storage and processing of raw materials. The very technology of grain processing and storage appeared several centuries ago. All this time it was improved and modified, obeying the modern conditions of the enterprise. At the moment, factories use long-proven rubbing mechanisms, percussion devices. However, they require fully automated, perfect control [1].

Every year the number of controlled and managerial departments of the grain processing enterprise is growing. They are required at elevators, feed milling sectors, flour mills, etc. Now the operator can no longer cope independently with the management of the production process in order to achieve its effective operation. Automated grain storage and processing complexes come to his aid. That is why the issue of implementing ICS in this industry is much more relevant than it may seem at first glance.

The most complete possibilities of automation of a grain processing enterprise can be realized by optimizing the management of technological processes based on the use of an automated control system that represents the optimal set of automatic devices and an operator that provide the most effective management of the enterprise.

One of the possible options for improving the efficiency and quality of work of specialists, rational use of grain and increasing the efficiency of flour milling production as a whole is the introduction of automated quality control systems for accounting. The need for automation of agricultural enterprises is confirmed by statistical data. It is proved that organizations with a high and even medium level of mechanization suffer impressive economic losses [2]:
1. Grain production - at the stage of consumption and the stage of processing up to 25% and up to 10%, respectively. With direct production, losses are up to 48%;
2. Dairy cattle breeding - the level of losses up to 53%;
3. Production of root tuber and fruit and vegetable products - up to 75% and up to 57%. Long storage, post-harvest

processing, growth stage - at these stages of the farm, functioning with root tubers, lose up to 75% of production.

Automation is focused on minimizing product losses and reducing the cost of manufacturing agricultural food. Industry 4.0 belongs to the fourth industrial revolution, it is a way of producing products thanks to digital transformation. Internet of Things technology makes 4.0 possible, and the smart mill a reality. Equipment in the process industry is getting smarter and provides the critical data needed to improve productivity. The flour milling industry must switch to the use of this technology, otherwise it will be left behind. Regulatory compliance, recall procedures, food safety and innovation drive change to meet the demands of the times.

To rationally use raw materials and ensure the safety of the most valuable substances and components in them and their products of industrial processing, as well as to create the necessary conditions for the course of technological processes in optimal modes with the maximum yield of high-quality finished products, it is necessary to periodically monitor the moisture content of raw materials [3].

The purpose of our research is aimed at analyzing the microwave method for measuring the moisture content of grain and grain materials in the technological process. Determining the degree of influence of the inconstancy of the mass of the controlled material on the informative parameter of the microwave field to select the method that provides the greatest accuracy. The paper investigates amplitude and phase methods of the passing wave in free space.

In this regard, the introduction of the Internet of Things technology, as well as conducting research on the problems of building automatic and automated grain quality control systems in grain processing industries seems to be an urgent task.

II. Material and methods

Nowadays, digital transformation and the Internet of Things have become buzzwords that everyone uses in their speech without realizing their meaning. The use of digital transformation in quality control as incoming, as well as in the storage and processing of grain – this means that obtaining primary information using sensors and control mechanisms in everything, which makes it possible to monitor all equipment remotely, as well as provide real-time information about how it works.

The main task is to measure the quality of the finished product. There are various methods of control. However, the majority of grain processors prefer indirect measurement methods, in particular dielcometric methods based on the measurement of dielectric characteristics of grain crops. The construction of devices based on this method occupies more than 60% of the manufactured measuring instruments [4].

Also, there are tools that allow you to measure quality in real time, for example, flour. One such tool is the Parten NIR DA 7300, which provides measurement of moisture, protein and weight levels directly from the pipe. Using the values obtained from DA 7300, it is possible to control the mixing of different batches of grain or flour to maintain standardized characteristics. It's a well-known tool, there are competitors producing similar things. However, in practice there is something else, even in large flour mills that earn millions of US dollars a year, there are necessarily laboratory assistants

who run around and around with samples and results. The choice of the method of product quality control is one of the main and urgent tasks facing the engineers of automation systems, this is not all, the main thing is the choice of the sensor. For these conditions, there are sensors on the machines themselves that optimize reliability, and sensors that monitor the product, improving quality.

The study of methods for automatic measurement of the electrophysical characteristics of grain and grain materials, as well as the design and development of instrumentation, the implementation on the basis of a modern element base as part of the subsystem of measuring and information support of the automated process control system seems to be an urgent and little-studied task in the field of moisture meters.

The study and analysis of modern physical methods for measuring humidity led to the conclusion that for bulk solid materials the most promising is the ultrahigh-frequency method based on the interaction of microwave radio waves with moisture-containing solid bulk material [5-6].

The transition to the microwave range is caused by the desire to improve the characteristics of moisture measuring devices, in particular, to increase their accuracy, as a result of reducing the error from the influence of the chemical composition and other parameters of the material on the measurement result.

III. Outcomes

Analysis of a number of scientific studies [7-8] and literary analysis of a number of sources [9-10] in the field of moisture meters, and of all the variety of measurement methods, high-frequency moisturemetry is one of the most promising. As practice and world-class analysis of solving the problem shows, the use of microwaves to measure humidity provides a number of decisive advantages. The current variety of existing moisture meters of various designs and purposes, including the use of various physical principles, including dielectric spectroscopy, have not yet been resolved by removing a number of problems in this area. However, a perfect and universal microwave moisture meter has not yet been created in instrumentation, but there are a number of attempts to get closer to solving this problem.

In production conditions, losses are still high due to the lack of perfect express devices for reliable and accurate determination of the electrophysical properties of grain material control.

The National Research University "Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" conducts a number of studies to improve the development of methods and devices for monitoring the composition and properties of substances, including moisture meters, their expansion of the scope of application and suitability for mass serial production. The main requirements for moisture-measuring systems are: improving the technical characteristics of moisture meters, reducing the cost of their development compared to existing analogues and creating moisture meters based on microwave methods of high accuracy [11, 12].

To solve these problems, the humidity of the materials under study (attenuation of the electromagnetic wave), temperature and other influencing uninformative parameters (clogging, omission, influences of electrolyte content, density

unevenness, etc.) for various materials of the agro-industrial complex [13, 14] are taken as an informative parameter. As an object of research, solid bulk grains were used, as well as products of their processing. To remove moisture and other characteristics of the agro-industrial complex studied for various materials, while we examined the developed installation according to the bridge scheme operating at a frequency of 30 MHz [15], the structural diagram of which is shown in Figure 1.
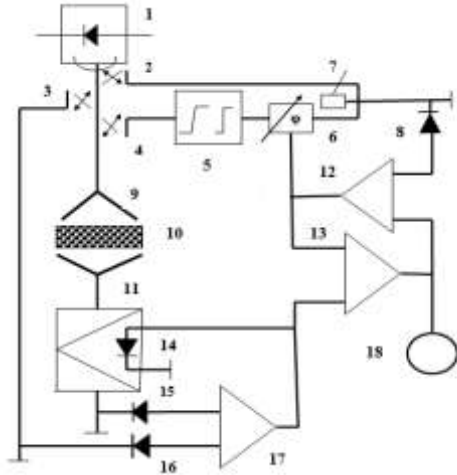

Fig. 1. Functional diagram for measuring the moisture content of materials in the technological process

1-generator, 2,3,4-guide valves, 5- ferrite valve, 6- phase shifter, 7- double waveguide bridge, 9- transmitting antenna, 10- controlled material, 11- receiving antenna, 12,13,17- selective amplifier, 8,14,15,16 - detector 14-compensating attenuator, 18-indicator.

Consider the microwave method for the case of measuring the moisture content of materials by the thickness of the layer of materials in the stream.

To obtain information about the values of the thickness of the material in order to correct the influence of this value, consider two parameters: the signal of the passing wave (attenuation and phase shift), which characterizes the humidity and an additional signal - the phase wave reflected from the front surface of the materials and carrying information about its thickness.

The amplitude and phase of the wave reflected from the material can be determined from [16] through the reflection coefficient and its phase according to the equations $A_{1,2}$ $\varphi_{1,2}$

$$A_{1,2} = (\alpha_1 - \varphi_2)^2 + (\beta_1 + \beta_2)^2 \qquad (1)$$

$$A_{1,2} = (\alpha_1 - \varphi_2)^2 + (\beta_1 + \beta_2)^2 \qquad (2)$$

where: is the attenuation coefficient and phase constants of air and material $\alpha_1, \beta_1, \alpha_2, \beta_2$. The total power loss of an electromagnetic wave passing through a layer of material is. For homogeneous materials.

$$A = -10 lg \frac{F_{past}}{F_{falling}}$$

$$\Delta A = 8,68 \alpha l \text{ and (2) } \Delta \varphi = l(\beta - \frac{2\pi}{\lambda})$$

The statement in (2) of the expressions and (considering the fact that the materials in question are magnetic permeability) leads to the following formulas for calculating the attenuation in decibels and the phase shift (relative air) in radians:

$$\alpha \beta \mu \approx 1 \, A\Delta\varphi$$

$$A = 8,68 \frac{2\pi l}{\lambda} \sqrt{\varepsilon \cdot 1 / 2(\sqrt{1 + tg^2\delta} - 1} \qquad (3)$$

$$\varphi = \frac{2\pi l}{\lambda} \sqrt{\varepsilon \cdot 1 / 2(\sqrt{1 + tg^2\delta})} \qquad (4)$$

where: λ is the wavelength in free space;
Constant spread is expressed as γ

$$\gamma = \alpha + j\beta = j\frac{2\pi}{\lambda}(\varepsilon' - \rho - j\varepsilon'')^{1/2} \qquad (5)$$

The amplitude of a reflected wave is different from zero if at least one of the inequalities of. In practice, these two inequalities are always met when controlling the moisture content of materials $\alpha_1 \neq \alpha_2, \beta_1 \neq \beta_2$.

Suppose that the following condition is also met: the distance from the transmitting antenna to the specified boundary of the controlled material is constant. This condition is met, for example, if the electromagnetic wave propagates from top to bottom, and the controlled material lies on a stand, or conveyor belt (Figure. 2.)
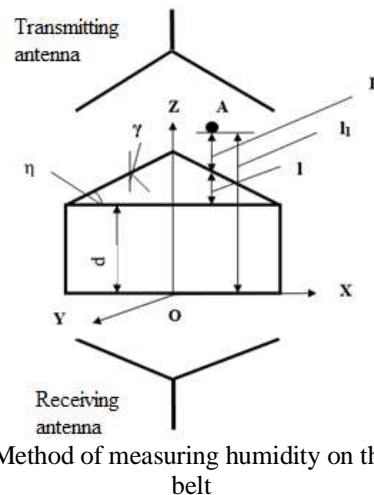

Fig.2. Method of measuring humidity on the conveyor belt

Let's express the phase difference between the incident and reflected wave of the incident and the arbitrary point A located between the transmitting antenna and the material at a distance of l_1 from the stand through the parameters of the material.

Let L be the distance from point A to the leading boundary of the material.

Then. Let's express the value $L = Xtg\eta$ l due to the angle of the slope. η

$$l = (\alpha - x)tg\eta \qquad (6)$$

Then the thickness of the material on the transporter tape is determined by the formula:

$$H = l_1 - xtg\eta = (\alpha - x)tg\eta + d \qquad (7)$$

Determine the average thickness of the material by integrating (7) from 0 to A by dividing by α. Then

$$H_{cp} = l_1 - \frac{\alpha}{2}tg\eta \qquad (8)$$

Phase difference of incident and reflected waves at point A

$$\Delta\varphi = arctg\frac{2(\alpha_0\beta - \alpha_0\beta_0)}{(\alpha_0^2 + \beta_0^2) - (\alpha^2 + \beta^2)} - \varphi_H \qquad (9)$$

where a phase shift determined by the electrical characteristics of the material

$$\varphi_{1,2} = arctg\frac{2(\alpha_0\beta - \alpha_0\beta_0)}{(\alpha_0^2 + \beta_0^2) - (\alpha^2 + \beta^2)}$$

φ_H - Phase raid in the air at a distance of 2L.

Let's determine the flow of electromagnetic energy using the expression for the incident flow φ_H

$$\overrightarrow{\Pi} = 2\int_0^a \int_0^e \overrightarrow{E_x}dxdy \qquad (10)$$

Let's denote:

$$L = Xtg\eta; l = (\alpha - x)tg\eta \text{ where } \overrightarrow{E_x} = E_0l \qquad (11)$$

Flow vector of (10) and (11)

$$\overrightarrow{\Pi} = 2E_0b\frac{e^{-\alpha_0 atg\eta + j\beta_0 atg\eta}}{-\alpha_0 tg\eta + j\beta tg\eta} \qquad (12)$$

Find the flow phase raid at a distance of $2\overrightarrow{\Pi}$ L

$$\varphi_H = arctg\frac{e^{-\alpha_0 tg\eta}\sin\beta_0 atg\eta}{e^{-\alpha_0 atg\eta}\cos\beta_0 atg\eta - 1} + arctg\frac{\beta_0}{\alpha_0} \qquad (13)$$

Using the expression (8) and (13) let's write

$$\Delta\varphi_{1,2} = arctg\frac{2(\alpha_0\beta - \alpha_0\beta_0)}{(\alpha_0^2 + \beta_0^2) - (\alpha^2 + \beta^2)} arctg\frac{e^{-\alpha_0 tg\eta}\sin\beta_0 atg\eta}{e^{-\alpha_0 atg\eta}\cos\beta_0 atg\eta - 1} + arctg\frac{\beta_0}{\alpha_0} \qquad (14)$$

In the expression (14), the first term is a function of the humidity of the material, i.e. the value unknown, the second component is a function of the thickness of the material, therefore also unknown, the third component function of the air parameters is a known quantity. The phase difference can be measured. The expression (14) contains two unknown quantities and, therefore it does not have an unambiguous solution $\square\varphi$ $W(\alpha, \beta)$ $H_{cp} = (a, tg\eta)$ [17].

However, from the measured attenuation, it is possible to determine the humidity in the first approximation, i.e. parameters and material. In this case, a rough value of the thickness of the material is used, determined by (13) sloping. Then, according to the known values and (14), the exact value of the thickness of the material is determined. In the second approximation, the moisture content of the material is determined taking into account its thickness by a predetermined interdependence α β $\varphi_{1,2} = 0$ α β $(a, tg\eta)$

$$W = f(A, H_{cp}) \qquad [18].$$

For the experimental study of this method, a plant for raw cotton without the need to weigh the sample [19-21] was developed and implemented, the scheme of which is shown in Fig. 2.

The installation allows you to measure in free space the attenuation of the wave passing through the material and the phase of the wave reflected from it. It is based on the principle of a balanced bridge containing in one arm the material under study and balancing the phase shifter. The waveguide switch switches alternately to the measuring circuit of the channel output, the passing and reflected waves [22-23].

IV. FINDINGS

When considering this task and which is facing the introduction of a modern automated control system, is to create such a production for the storage and processing of grain, which would minimize the loss of raw materials at the enterprise as a result of its improper storage and untimely delivery for alteration, and would also work with the lowest energy costs, produce products of the highest quality at the lowest cost [24].

Studies to measure both informative parameters of attenuation A and phase shift allows to determine and describe the mathematical moisture characteristics for various φ $A(W)$ $\varphi(W)$ bulk grain production materials.

For special conditions of humidity control in the technological process, we have developed and implemented a method for measuring the moisture content of materials [25].

REFERENCES

[1] Gulyaev, G.A. Automation of post-harvest processing and storage of grain / G.A. Gulyaev. -M.: Agropromizdat, 1990. 240 p.

[2] Borodin, I.F. The relationship between the electrical parameters of the grain mass and humidity: sb. nauch. Tr. / I.F. Borodin, V.N. Stolbov, V.I. Zaginailov. M.: MIISP, 1977. T. 14. Vol. 13. pp.12–14.

[3] Gulyaev, G.A. Automation of grain moisture control / G.A. Gulyaev, Yu.P. Sekanov.: nauchno-tehn. bull. M.: VIM, 1978. - Vyp. 7. 12 p.

[4] Balykhin M.G., Borzov A.B., Blagoveshchensky I.G. Methodological foundations of creating expert systems for monitoring and forecasting the quality of food products using intelligent technologies. Monograph -M.: Frantera, 2017. 394 p.

[5] Kalandarov, P.I. Estimate of Precision of Thermogravimetric Method of Measuring Moisture Content: Estimate of Precision and Effectiveness Gained with the Use of the Method in the Agro-Industrial Complex Measurement Techniques, 2021, 64(6), pp.522-528

https://doi.org/10.1007/s11018-021-01963-9

[6] Kalandarov, P.I., Abdullayev, K.K. Features of the technology of anaerobic processing of biotails using humidity control devices

IOP Conference Series: Earth and Environmental Sciencethis link is disabled, 2022, 1043(1), 01201

[7] Kalandarov, P.I., Abdullaeva, D.A. Innovative approach to the development of hydroponic green feeds IOP Conference Series: Earth and Environmental Sciencethis link is disabled, 2022, 1043(1), 012012

[8] Savosin, S.I., Soldatov, V.V. Automation of grain moisture control during its storage. Vestnik FSOU VPO MSAU No3.2008. pp.28-30.

[9] Bozorov, E. Electric pulse treatment of trees as an environmentally friendly mechanism for protection of orchards IOP Conference Series: Earth and Environmental Sciencethis link is disabled, 2020, 614(1), 012043

[10] Nikolaev, A., Logunova, O., Garbar, E., Arkulis, M., Kalandarov, P. Estimation of The Surface Quality Of Galvanazed Steel: The Method Of Decomposing The Image Into Layers ACM International Conference Proceeding Series, 2021, pp. 23–27

[11] Structural-parametric modeling as a tool for determining the quality criterion in the warehouse of bulk storage of flour. Blagoveshchenskaya M.M., Karelina E.B., Serpakov S.A., Blagoveshchensky I.G., Klekho D.Y. Storage and processing of agricultural raw materials.2015.№4 A.36-39.

[12] Klokov Yu.V. Theory of moisture removal. About heating of food products in the microwave EMF "volumetrically" // Storage and processing of agricultural raw materials. 2003. N7. pp. 29-31.

[13] A. A. Kovaleva, R. I. Saitov, A. S. Zaporozhets, E. G. Parfyonova / Methods of calibration of serial microwave moisture meters. "Measuring Equipment", 2017, No. 3, pp. 72 - 76.

[14] Krichevsky, E.S. Theory and Practice of Express Humidity Control of Solid and Liquid Materials / Krichevsky, E.S., Benzar, V.K., Venediktov, M.V. // M.: "Energia", 1980. 240 p.

[15] Microwave thermovlagometry / P. A. Fedyunin [et al.]. M.: Mashinostroenie, 2004. 230 p.

[16] Berliner, M. A. Measurements of humidity in the microwave range/M. A.Berliner. M.: Energiya,1973.157 p.

[17] Kalandarov, P.I., Iskandarov, B.P. Physicochemical measurements: Measurement of the moisture content of brown coal from the angrensk

deposit and problems of metrological assurance. Measurement Techniques, 2012, 55(7), pp. 845–848.

[18] Kupfer K, editor. Electromagnetic aquametry. Electromagnetic wave interaction with water and moist substances. Berlin: Springer; 2005. 530 p. DOI: 10.1007/b137700.

[19] Lisovsky, V. V. Microwave humidity control in technological processes of the agro-industrial complex / V. V. Lisovsky, I. A.Titovitsky. Minsk. BGATU, 2013.399 p.

[20] Kalandarov P. I. High-frequency moisture meter for measuring the moisture content of grain and grain products // Measuring technique. 2022. № 4. pp. 65–71. https://doi.org/10.32446/0368-1025it.2022-4-65-71.

[21] I. Krichevsky E.S., Volchenko A.G. Control of humidity of solid and bulk materials / Krichevsky E.S., Volchenko A.G. M.: Energoatomizdat, 1980. 165 p.

[22] S. R. Ubaydulayeva and A. M. Nigmatov, "Development of a Graph Model and Algorithm to Analyze the Dynamics of a Linear System with Delay," 2020 International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM), Sochi, Russia, 2020, pp. 1-6, doi: 10.1109/ICIEAM48468.2020.9111939.

[23] S. R. Ubaydullayeva, D. R. Kadirova and D. R. Ubaydullayeva, "Graph Modeling and Automated Control of Complex Irrigation Systems," 2020 International Russian Automation Conference (RusAutoCon), Sochi, Russia, 2020, pp. 464-469 doi: 10.1109/RusAutoCon49822.2020.9208076.

[24] S. R. Ubaydullayeva, R. T. Gaziyeva and O. J. Pirimov, "Graph Models and Algorithm for Studying the Dynamics of a Linear Stationary System with Variable Delay" pp. 431-436, doi: 10.1109/RusAutoCon52004.2021.9537328.

[25] Kalandarov, P.I., Mukimov, Z.M., Nigmatov, A.M. Automatic Devices for Continuous Moisture Analysis of Industrial Automation Systems Lecture Notes in Mechanical Engineering, 2022, стр. 810–817.