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Automation of Technological Processes for Controlling Grain Moisture in the Flowu

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Abstract – **The article provides a theoretical analysis of the microwave method for measuring humidity, discusses the problems of instrumentation of the method under consideration, and proposes a scheme for an experimental setup. Loose cotton materials were chosen as objects of study. The emission of an electromagnetic wave during measurement and evaluation of the electrophysical characteristics of the materials under study in the established range is analyzed, which requires a study of functional dependence amplitude and phase shift from the mass ratio of moisture, mathematical models for various bulk cotton materials are obtained, describing the combined effect of humidity, material density on attenuation and phase shift of the passing wave.**

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

I. Introduction

In theoretical and experimental studies of the physical properties of materials, heterogeneous media are most often encountered. These are cotton materials (raw cotton, cotton seeds) consisting of cellulose, water and air containing seeds and impurities of organic and inorganic origin [1].

In accordance with the theory of dielectrics, the studied materials in the electromagnetic field, including raw cotton, do not detect temperature and temperature anomalies in the dehydrated state. Therefore, it can be considered that the observed anomalous dependencies in raw cotton are inherent in water, which is one of the main components of this type of raw material in its natural state. An electromagnetic wave that acts reciprocally with water molecules, changes its electrical characteristics, depending on the state of aggregation. This change, which characterizes the mass ratio of moisture, is the basis of all developed methods of measurement at ultrahigh frequencies [2].

II. Material and methods

Studies and analysis of modern physical methods for measuring the moisture content of various materials of the agro-industrial complex have led to the conclusion that for these materials the most promising is the diesel method based on the measurement of moisture at ultrahigh frequencies.

In the microwave range, primary measuring transducers are electromagnetic systems with distributed parameters, the functioning of microwave moisture meters is based on the dielcometric method [3]. Studies of the electrical properties of bulk materials such as raw cotton, cotton seeds, grain-wheat, grains of masssignificantly expands the existing understanding of the factors affecting its electrical properties They allow you to implement scientifically based methods for calculating the parameters of primary converters and measuring circuits of humidity control devices based on the microwave method [4].

III. Results and discussions

Let us consider the influence of the physical and mechanical properties of raw cotton on the intensity of the passage of an electromagnetic wave from the material understudy.

Suppose that a flat electromagnetic wave falls on a sample of the material under study with conductivity $\sigma \neq 0$ perpendicular to its surface. When itpasses through the studied sample, there is also a loss of energy, which is characterized by dielectric losses caused by thermal the motion of particles under the action of an applied electromagnetic field, dispersion on inhomogeneities, as well as the phenomenon associated with the simultaneous existence in a homogeneous medium of several oscillations obeying the principle of superposition. Let us confine ourselves to the case when there are no magnetic losses $\mu = 1$. Then the plane wave equation of the form [5] is valid

$$E = E_0 \cdot e^{-\alpha z} \cdot e^{-\beta z} \qquad (1)$$

Turning to instantaneous values, considering the scattering coefficient, equation (1) can be represented as

$$E = E_0 \cdot e^{-\alpha z} \cdot \cos(\omega t - \beta z) \cdot F. \quad (2)$$

where:

E –electric field strength at the output of the sample;

E_0- electric field strength at the sample inlet;

α- attenuation coefficient;

β- phase coefficient;

z is the thickness of the specimen.

The first factor of the wave equation (2) characterizes the attenuation of the electromagnetic wave, and the second - the phase velocity of propagation along z and the loss of phase.

Cotton materials have elastic properties, so as long as the pore size of the dry material is small compared to the wavelength and evenly distributed in the sample volume, the scattering and interference of the electromagnetic wave on inhomogeneities can be neglected. In this case, neglecting the second and third factors in equation (2), we determine the attenuation and energy loss coefficient α per unit length dz.

To do this, considering that the power p is proportional to the square of the amplitude of the electric field strength E, and the change in power along the sample under study per unit length is, we write equation (2) in the following formdz Δp

$$p = p_o \cdot e^{-2\alpha z} \quad (3)$$

where:

p- power at the output of the sample;

p_o- power at the input of the sample.

Differentiating (3) with respect to z, we get

$$\alpha = \frac{\left|\frac{dp}{dz}\right|}{2p} = \omega\sqrt{\frac{E_a}{2}\left(\sqrt{1+\mathrm{tg}^2\delta} - 1\right)}, \quad (4)$$

where:

α- attenuation coefficient;

$\frac{dp}{dz}$-power loss per unit length;

E_a- absolute value of the dielectric constant;

tg δ- dielectric losses.

Let us decompose (4) according to the degree $\mathrm{tg}^2\delta$ and neglecting the values of the higher order, since for dry raw cotton tg $\delta \ll 1$, we then get

$$\alpha = \omega\sqrt{\frac{E_a}{2}\left(1 + \frac{1}{2}tg^2\delta - \frac{1}{2\cdot 4}tg^4\delta + \cdots - 1\right)} =$$
$$= \frac{\omega}{2}\sqrt{E_a tg^2\delta} = \frac{\sigma}{2}\sqrt{\frac{1}{E_a}}. \quad (5)$$

Equation (5) shows that attenuation α in an isotropic medium with conductivity $\sigma \cong 0$ does not depend on frequency and has practically no effect on energy loss.

Conductivity, σaccording to [20] is determined by the magnitude of losses $tg\delta$ and dielectric constant ε, i.e.

$$\sigma = \omega\varepsilon_a tg\delta \quad (6)$$

Then, using Maxwell's equation, the $^{dp}/_{dz}$ power loss per unit length dz, given (6), can be represented by

$$\frac{dp}{dz} = \omega\sqrt{\varepsilon_a} tg\delta |\varepsilon|^2 dv \quad (7)$$

where v *is* the volume of cotton material occupied.

Equation (7) characterizes the power losses in a dielectric with conductivity, $\sigma \neq 0$ which are associated with the orientation of the dipoles of water molecules under the action of the applied electric field E, or in other words, with the tangent of the angle of relaxation dielectric losses.

As the mass ratio of the moisture content of the component σ *и* $tg\delta$ increases, increasing the power p. From this it follows that with a low moisture content in raw cotton, all water molecules are in a bound state. Water loses mobility and, as a result, the dielectric constant decreases ε. The weakening of microwave energy practically does not occur. With an increase in moisture content in raw cotton, moisture begins to predominate with physical forms of communication. In our research, we are dealing with a loosely bound form of moisture.

In the meantime, it plays an important role in the ultra-high frequency control method of heterogeneous wet systems. For water in a free state at room temperature, in the frequency range of the dielectric constant, Hz values are taken [6]. $10^5 \leq f \leq 10^8$

$$\varepsilon \approx 81.$$

According to experimental data [2], the wavelength corresponding to the critical frequency at a temperature is equal to. The value is considered to be equal to 5.5, although, according to some researchers, the values of 4.5 or 4.9 are more accurate. $t = 20^o C$ $\lambda_0 = 1{,}74 см$ ε_∞

At this stage of the study, a single-parameter measurement method was studied, and a frequency of 9.3 GHz was adopted for its implementation. The mass sample weight was 800 g, the bulk density was 116 $\frac{\mathrm{kg}}{\mathrm{m}^3}$.

The main informative parameter is the attenuation and phase shift of the electromagnetic wave in the material under study.

$$A = f(W, \rho)$$
$$\varphi = f(W, \rho)$$

where:

A-attenuation of microwave energy;

φ- phase shift of microwave energy.

W is the mass attitude in the mess;

ρ- bulk density of raw cotton.

When measuring the moisture content of materials in an alternating flow, the main task is to determine 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 the amplitude and phase methods of a passing wave in free space [7].

The inconstancy of the mass of the material leads to the inconstancy of its thickness or density, depending on the design of the transport. In both cases, the change in mass leads to a change in the informative parameter - weakening or phase shift, and therefore to an error in measuring the humidity of the microwave moisture meter. The thickness of the material has a direct effect on attenuation and phase shift, and the density through the dielectric constant [8].

Without considering the influence of other material parameters (temperature, pubescence, etc.) on the measurement result, the conversion equations for the amplitude and phase measuring device can be written in the form

$$A = f_1(W, m)$$

$$\varphi = f_2(W, m)$$

where m is the mass of the material in the control zone.

The influence W of and m on A и φ is expressed from the following ratios

$$dA = \frac{\partial A}{\partial W} dW + \frac{\partial A}{\partial m} dm$$

$$d\varphi = \frac{\partial \varphi}{\partial W} dW + \frac{\partial \varphi}{\partial m} dm \ .$$

Let's express

$$\frac{\partial A}{\partial W} = S_{AW} \frac{\partial \varphi}{\partial W} = S_{\varphi W}$$

$$\frac{\partial A}{\partial m} = S_{Am} \frac{\partial \varphi}{\partial m} = S_{\varphi m}$$

where and S_{AW} $S_{\varphi A}$, accordingly, the sensitivity of the amplitude and phase methods to moisture.

S_{Am} and, accordingly, the sensitivity of the $S_{\varphi m}$ amplitude and phase methods to the mass of materials.

The calibration measured by amplitude and phase moisture meters is determined from the ratio

$$W_A = A/S_{AW}; \ \ W_\varphi = \varphi/S_{\varphi W} \ .$$

When the mass of the controlled material deviates from the value at which the calibration was performed, the attenuation and phase shift change accordingly.

$$dA = S_{AW} dm; \ d\varphi = S_{\varphi W} dm \ .$$

This is perceived as a change in humidity measured by moisture meters

$$dW_A = \frac{dA}{S_{AW}}; \ dW_\varphi = \frac{d\varphi}{S_{\varphi W}}$$

or

$$dW_A = \frac{S_{Am}}{S_{AW}} dm; \ dW_\varphi = \frac{S_{\varphi m}}{S_{\varphi W}} dm \ .$$

That is, the errors in measuring humidity by amplitude and phase moisture meters and due to fluctuations in the mass of the controlled material depend on the ratio of the sensitivity of these methods to mass and humidity [9].

In order to determine what information, the electromagnetic wave carries and how it can be used to study and evaluate the electrical characteristics of the material under study, it is necessary to investigate the functional dependence of attenuation on the mass ratio of humidity in the real range of the mass ratio of humidity.

In an experimental study in the field of ultra-high frequency of dielectric properties of materials such as raw cotton, cotton seeds, grain and grain products, it is necessary to solve the following little-studied problems [10]:

- determination and analysis of conversion functions of the primary measuring high-frequency transducer; To do this, it is necessary to experimentally investigate the dependence of the dielectric properties of the products under study on the moisture content of the most important influencing factors.
- construction of an electrical model of the primary converter on the basis of the experimental data obtained, with an optimal approximation of the real characteristics of the materials under study.
- implementation of the data obtained through the development of high-frequency moisture control devices for dispersed and heterogeneous materials and their testing in laboratory and production conditions.

To implement this problem, we have developed an experimental setup based on the microwave method [11]. The block diagram of this installation is shown in figure 1.

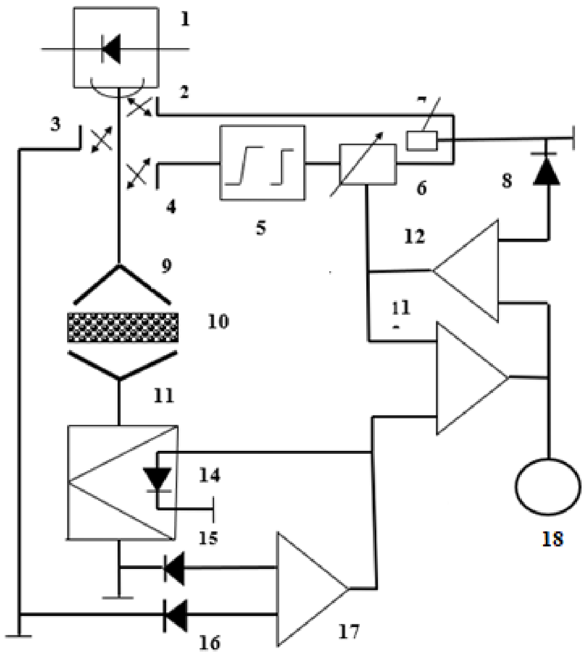

Fig. 1. Block diagram of an experimental microwave installation for measuring the moisture content of materials in a technological process

The principle of operation of this installation is as follows: the electromagnetic wave in the microwave range is created by the generator 1, and with the help of directional couplers 2,3,4 passes through the ferrite valve 5 enters the phase shifter, then through the double waveguide bridge 7 and the detector 8 enters one of the inputs of the amplifier 12, which is connected by the second input with the output of the selective amplifier I 13 and the indicator 18, which serves to determine the phase shift during the passage of the microwave wave through the controlled material 10. In this case, the phase changed signal is received by the receiving antenna 11, passing through the compensating attenuator 14, which attenuates the electromagnetic signal to the level necessary for transmission to the second input of the selectively amplifier 13 for indication. The microwave wave, passing through the guide coupler 3 and the detector 16, is fed to the second input selectively of the amplifier 17, the first input of which is attenuated by the attenuator and detected by the element 15 is supplied to the first selectively amplifier 17 and there is a comparison of the input and output signals, with the help of which the attenuator 14 is adjusted. The controlled process of passing a microwave wave through an experimental setup ensures the accuracy of measuring the humidity value in an automated microwave moisture meter.

The installation makes it possible to measure in a wide range with sufficient accuracy the attenuation and phase shift introduced by the material, located in the free space between the transmitting and receiving antennas.

In order to determine what information, the electromagnetic wave carries and how it can be used to study and evaluate the electrical characteristics of the materials under study, it is necessary to investigate the functional dependence of attenuation on the mass ratio of humidity in the real range of the mass ratio of humidity.

Processing of the results of the experiments showed that the humidity characteristics are adequately described by polynomials of the 2nd degree

$$A = 0{,}55W^2 - 0{,}116W + 1{,}742$$

$$\varphi = 0б425W^2 + 3{,}127W + 255{,}7.$$

On the basis of theoretical studies, it was concluded that in the general course of the logical curve there is a section with a linear dependence of the attenuation of the electromagnetic wave on the mass ratio of moisture of the material under study. Therefore, the first series of experiments was carried out in order to establish a measurement range in which the transformation function "attenuation-mass ratio of humidity" would obey a linear law, as well as to select a measurement range for further research.

IV. Findings

Based on the analysis, the following can be stated:

1. The analysis shows that in the known works insufficient attention is paid to the development of universal analytical models of the dielectric properties of heterogeneous systems in general and dispersed moisture-containingbodies in particular. One of the main reasons for the unsatisfactory nature of the known formulas of the mixture when applied to wet material is the lack of consideration of the influence of types and forms of moisture bonding on the electrophysical properties of the material.
2. When designing dielcometric means of technological control of the parameters of heterogeneous systems, it is enough to cover the range from infrared to tens of megahertz, since it is in this frequency range that the factors of the polarization structure are manifested.
3. The model of the dielectric constant for bulk materials (raw cotton, cotton seeds, grain), which considers the temperature, material, allows us to assess the degree and nature of the influence of the factor on the total error in measuring the moisture content of the materials under consideration and, therefore, can be used to introduce the necessary corrections into the measurement result.
4. Experimental studies on the installation for measuring both informative parameters of attenuation and phase shift made it possible to determine and describe mathematically the $A(W)$ moisture characteristics $\varphi(W)$ for various bulk materials of the agro-industrial complex.
5. As a result of a complete factorial experiment, with the improvement of the experiment planning methodology, mathematical models for various loose cotton materials were obtained, describing the combined effect of moisture, density of the material on the attenuation and phase shift of the passing wave.

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