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Methods of Reducing the Influence of the Forms of Communication Moisture to Error Converter

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ABSTRACT: The article deals with the results of experimental studies on samples of raw cotton with different holding time after wetting them to determine the nature and extent of the effect on changes in forms of communication moisture on the measurement of moisture by microwave methods. The article also concludes that measuring humidity of the surface layer material, it is possible to correct the measurement result by its integral humidity.

It is proved as well, while implementing of repeated measurements, simultaneously with reducing the influence of homogeneities it is possible to reduce the error due to the prehistory of humidity state of the material.

KEYWORDS: moisture, error transducer, forms of communication moisture, the microwave hygrometry, dielectric characteristics, standard deviation, raw cotton, temperature, frequency.

I. INTRODUCTION

Humidity is one of the main objects of the measured properties in many technological fields, determining the quality of products. Physical, biochemical, mechanical and technological properties of raw materials and products and the timing of their storage and equipment performance depend on humidity. Humidity at various stages of production and transportation also influences the production costs.

The role of moisture measurement of raw materials and finished products in industry (chemical, food, construction, building materials, and other related industries) is well known and hardly need any clarification on this issue.

Therefore, at present one of the most important areas of Analytical Instrumentation is the development and research of new advanced methods and instruments for materials humidity control, allows to solve the problem of technological processes of agriculture, as well as used for scientific studies on the structure and properties of moist materials. In the manufacture of various products, which includes the processes of drying, dehydration or moisture, humidity parameter is the most important factor to determine the condition of maximum production of the desired product from a given unit of raw material quality, the level of energy consumption and optimal performance of the equipment.

Hygrometry is a particular case of measurement of substances: humid substance as a measurement object is regarded as a binary mixture consisting of water and solids (although the latter may also be a mixture). The aim is to establish a measurement of the moisture content in the wet stuff .

At the heart of most types of transducers humidity are studies of the dielectric properties of the material in a wide frequency range of electromagnetic waves.

As it’s known, the correct choice of the primary operating frequency of the transmitter humidity for each material is one of the key factors in achieving the highest metrological characteristics of developed moisture meter.

The peculiarity of the properties of water plays an important role in physiological processes. Its dielectric properties are determined in most cases in the study of the interaction of an alternating electromagnetic field and the

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wet material.

It is known that each molecule has polar under certain conditions, self-resonant frequency. It is advisable to analyze the frequencies at which the resonance properties are manifested water dipoles. First basic properties of water molecules presented in the form of a dipole, rotating in an external alternating field sufficiently disclosed in Debye's works [1]. It is theoretically proved that the critical frequency corresponding to the maximum energy absorption in water at normal temperature is in the microwave frequency range.

Graphic interpretation of these findings are dependencies, listed in Figure 1.

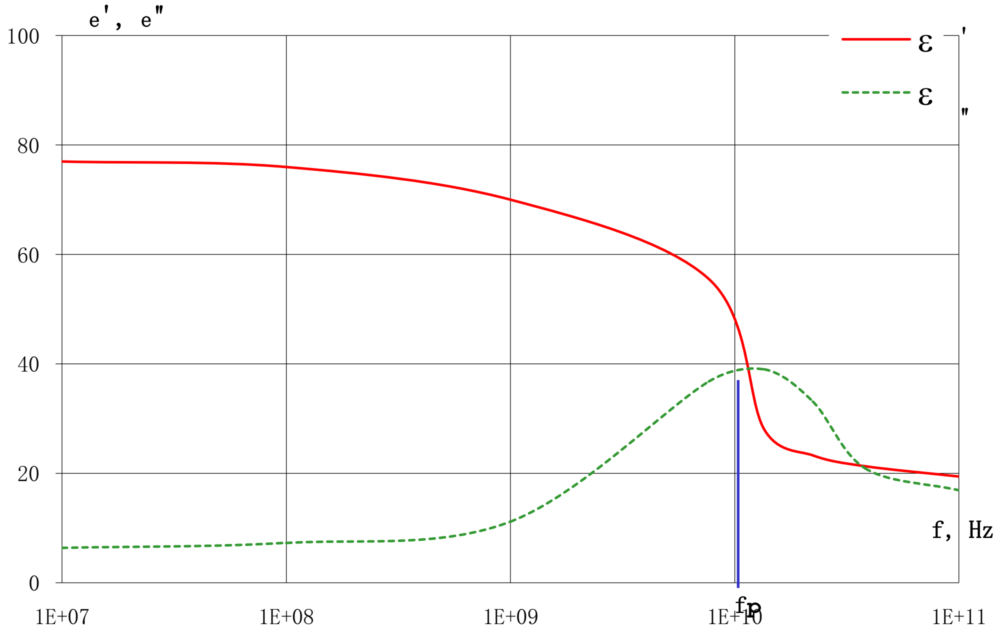

Fig.1. Dependence of the dielectric characteristics ε', ε" water on the frequency of the electromagnetic field

The presence of the absorption maximum in the dispersion curve of water in the centimeter range confirms the advantage of microwave method over other electrical methods.

This phenomenon is provided by the above-mentioned properties of the water molecule dipole in an electric field. Due to this molecule in an alternating field come to oscillation. Resonance occurs when the oscillation period of the external field near the relaxation time (rebuilding) of water molecules.

Resonating frequency of radio wave passing through the wet material experiences the greater attenuation and retardation the high er the content of water molecules in the substance. Attenuation is a decrease in the amplitude of vibration waves, and delay - to the phase shift.

In accordance with the theory of dielectrics, studied materials in the electromagnetic field do not show in the dehydrated state of frequency and temperature anomalies. Therefore, we conclude: all the dependencies that are observed in the materials in the wet state in the interaction of electromagnetic fields are inherent in the water, because Water makes up the bulk of the wet material. Thus, the electromagnetic field interacts with the water molecules contained in the material, changes its electrical characteristics. This change, which characterizes the humidity, underlies all developed f methods for measuring humidity at super high frequencies.

II. STATEMENT OF THE PROBLEM

In recent years, the microwave hygrometry gained rapid development [2]. Its theoretical foundations are deeply developed, and created a number of microwave moisture meters for fiber, bulk solids and liquids. Developers' interest in the field of moisture metering to the super high frequency method is explained by such advantages as the ability of non-contact measurement of the integrated humidity, the possession of a significantly higher sensitivity to the free water in the material, other than its components, as well as physical and chemical properties and structure.

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But equally important advantage of microwave method to which little attention is paid till nowadays, is the versatility. Nowadays developed hydrometers are highly specialized and in each case, developers are guided by certain material. Thus the design and optimization of the structure of the hydrometer as a whole are reduced to minimize measurement error by adjusting the type of sample generator (transmitter) and its main parameters.

The water contained in the materials as in the free and bound states. Moisture forms of communication with the material may be different physico -mechanical (capillary), adsorption (monomolecular and polymolecular), chemical [3]. Each form of communication has its own specific energy of the moisture from the material. Lowest binding energy is free water, the greatest - chemically bound

Moisture in the material with different values - of the binding energy on - different effects on informative parameter for measuring relative humidity conductometric methods.

Consider the model of interaction of the microwave with a damp cloth, containing i - forms of communication moisture. We write the weakening of microwave energy as a result of this interaction as follows:

$$N = \sum_{i=1}^{n} S_{W_i} W_i + N_c \qquad (1)$$

where, N- weakening microwave energy transmitted through the sample material , dB;

N_C - weakening in the dry skeleton material dB;

S_{W_i} - Sensitivity to moisture parameter N i-th forms of communication, dB / % ;

Wi - a moisture content of the i-th shape communication %.

Moreover,

$$\sum_{i=1}^{n} W_i = W \text{ - const}, \qquad (2)$$

where W - moisture content .

Assume that the dependence on humidity for attenuation of all types of communication, the linear material with moisture , i.e.

$S_{W_i} = \text{const}$ (i = 1,2, ... n).

We differentiate the expression (1) for Wi and passing to finite increments , we obtain

$$\Delta N = \sum_{i=1}^{n} S_{W_i} \Delta W_i \qquad (3)$$

to change the overall attenuation (ΔN) with varying amounts of moisture on the form of connection i ΔWi. Typically, the transition takes place between close to the binding energy of a form of continuity - from weaker to stronger ties , and vice versa. Reducing the amount of water forms a communication ΔW, other means increase by the same amount. Then , based on this (3) can be written as

$$\Delta N = \sum_{i=1}^{n-1} \left(S_{W_{i+1}} - S_{W_i} \right) \left| \Delta W_i \right| \qquad (4)$$

Expression (4) takes place after the wetting material, when the transition moisture from the weaker to the stronger bonds. With intensive heating of the material, the reverse transition, and the expression (3) takes the form

$$\Delta N = \sum_{i=1}^{n-1} \left(S_{W_i} - S_{W_{i+1}} \right) \left| \Delta W_i \right| \qquad (5)$$

As follows from (4) and (5) change is zero attenuation at all ΔW≠0 - only when,

$$S_{W_1} = S_{W_2} = \ldots = S_{W_n}$$

However, in practice we have the relation

$$S_{W_1} > S_{W_2} > \ldots > S_{W_n}$$

Therefore, with the passage of time after wetting material should expect a decrease attenuation at constant moisture content (4) otherwise - to increase it The expression for the phase shift of the wave transmitted through the material has a similar form. Error phase method of this factor are described as

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$$\Delta\varphi = \sum_{i=1}^{n-1}\left(S_{\varphi_{i+1}} - S_{\varphi_i}\right)\left|\Delta W_i\right| \qquad (6)$$

$$\Delta\varphi = \sum_{i=1}^{n-1}\left(S_{\varphi_i} - S_{\varphi_{i+1}}\right)\left|\Delta W_i\right| \qquad (7)$$

To quantify the amount of error and ΔN and Δφ need to know the sensitivity S_{W_i}, S_{φ_i}, and ΔW.

However, the current state of the theory of water-containing heterogeneous systems makes it impossible to quantify the indicated quantities. Known as the dependence of these quantities on the binding energy (moisture content) [3,4].

There is currently no rapid method for determining the amount of moisture forms of communication and effective ways to reduce the impact of volatility ratio of bound and free water in the material on the measurement error of its humidity. To solve this problem, we proposed to use a ratio between the integrated (bulk) material and surface humidity and algorithmic methods to reduce the specified accuracy through the use of the dispersion of results of multiple measurements .

Mentioned influence is characteristic for all types of transducers, as it is the very essence of the method laid down as a function of ε = f (W) and does not depend on the type of transformation the dielectric characteristics of the material in the informative parameters of the primary transmitter. Therefore being futher considered ways to reduce this effect can be applied to all types of converters.

III. METHODS FOR SOLVING

Using an optional parameter to exclude the influence of the forms of communication moisture in the material to the measurement error.

The proposed method is based on the following: if you change the humidity of the material (for example, when wet) first moisture gets on the surface layers of the material and will be in a free state. Then the penetration of water into the macro and micropores (physico-mechanical coupling), the absorption of water molecules molecules of the substance, etc. will be followed. The water from the surface of the material penetrates gradually into and the humidity of the surface layer decreases with time.

Thus, the moisture of the surface layer material characterizes the prehistory of its humidity condition, ie, change in it the forms of communication moisture. Therefore, measuring the humidity of the surface layer of the material, the measurement result of its integrated humidity can be adjusted.

In bulk solids and fibrous materials near-surface moisture content of the particles can be measured by different probe, patch micro strip sensors resonator transducers.

IV. THE RESULTS

To determine the nature and extent of the impact of changes in forms of communication moisture on the measurement of moisture microwave methods, as well as identifying the functional dependence of the surface moisture of the material from the prehistory of its humidity condition experimental studies on samples of raw cotton with different holding time after wetting them were conducted. Measurements were performed at 10 refolding sample 5, 15, 34, 58, and 82 hours on 4, 5, 6 days was determined in parallel samples for humidity exemplary installation Uz-8 [3]. During the experiments, the temperature can not be maintained constant, as temperature effect on the samples affects the process of redistribution of moisture on the forms of communication. Therefore, when measuring the temperature of the sample was controlled by a built-in sensor and taken into account when processing the results.

Surface moisture was measured with a surface-micro strip sensor [4,5]. These results confirm the impact of the prehistory of humidity state of the material on conversion error [6,7]. From the results it follows that when measuring the amplitude of a microwave humidity transducer relative error of this factor can be up to 6-7%.

Were calculated regression equation of the following types

$$W = f_1\,(N, T), \qquad (1)$$

$$W = f_2\,(N, S, T). \qquad (2)$$

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Equation (1) takes into account the parameters are functionally related to the volume humidity (N) and temperature (T) of the material, the equation (2) incorporates besides the surface moisture (S) material. The dependences obtained are the following:

$$W = -1.63\ 10^{-5}\ N^2 + 0.05\ N + 69\ 10^{-3}\ T - 0.6 \qquad (3)$$

$$W = 5.5\ 10^{-8}\ N^3 + 1.4\ 10^{-4}\ NT + 5.96\ 10^{-5}\ NS - 6.3\ 10^{-5}\ N^2 - 2.54\ 10^{-2}N - 1.210\ ^{-2}S - 1.95\ 10\ ^{-2}T + 15.6 \qquad (4)$$

Table 1 shows the values of the standard deviation of measurement results from the regression line, and the maximum correlation coefficients from said bias factor.

Table 1

Type the primary transmitter	parameters used	σ_N %	η	δ_{max}% (relative)	regression equation
amplitude	N, T N, S, T,	0.77 0.30	0.99 0.99	11.5 4.1	3.39 3.40

Analysis of the results in research shows that when using the optional parameter measurement error can be reduced by a factor of 2.5.

The use of multiple measurements to eliminate the influence of moisture in the form of communication material on the measurement error. Analysis of the results of previous experiments revealed the existence of dependence of the dispersion standard deviation of measurement results from prehistory humidity state of the material. This dependence is due to the fact that the material only wetted unevenly over time moisture is distributed more evenly throughout the material. Thus, as shown above, there is a redistribution of moisture and forms of communication.

Thus, the implementation of multiple measurements while reducing the influence of irregularities becomes possible to reduce the error caused by humidity state histories material.

We have calculated the regression equation based on the variation of the results of observation:

$$W = 1{,}49\ 10^{-7}\ N^3 + 3.64\ 10^{-5}\ NT - 4.26\ 10^{-5}\ NV_N - 2.14\ 10^{-4}\ N^2 + 0.11N - 4.36\ 10^{-2}V_N - 2.2\ 10\ ^{-3}T - 4.66, \qquad (5)$$

Where

$$V_N = t_{0.95} \cdot \frac{\sigma_N}{N} \qquad (6)$$

Table 2 shows the comparative characteristics of regression equations based on the standard deviation and without.

Characteristics of the regression equation

The parameters used	σ_W %	η	Equation
N, T N, σ_N, T,	0.767 0.57	0.993 0.996	3.39 3.41

V. CONCLUSION

Thus, the results of multiple measurements can reduce the effect of 1.5 times the moisture forms of communication. It is necessary to provide sufficient accuracy in determining the rms deviation in the case of calibration of the meter, and the measurements. In the case of said residual error factor can be determined from (5)

$$\Delta W = (4.26\ 10^{-5}N + 0.044)\ \Delta V_N \qquad (7)$$

Viewed correction method can be most easily implemented for bulk materials. For fibrous materials, such as cotton, as shown by analysis of the data table. 1 and 2, it is more effective to use an additional parameter - the surface moisture of the material. For an example, the values of the regression coefficients and correlation of the results of measurement of humidity of different varieties of cotton. Graphic dependence of these data is shown in Fig. 2.

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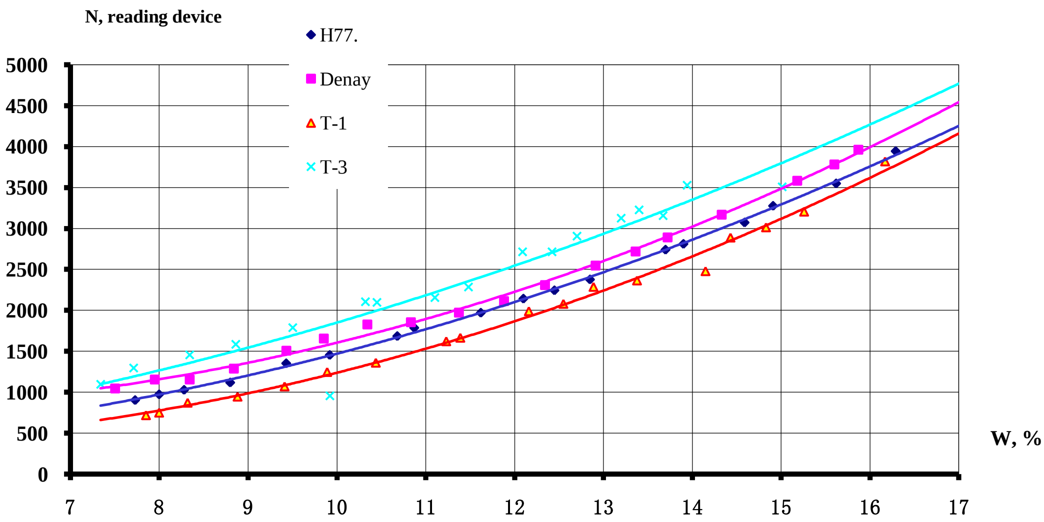

Fig. 2 Dependence of the device from moisture for different varieties of raw cotton.

They are approximated by regression equations of the second order. The value of the latter shows a high degree of conformity approximating dependence and experimental data in all cases

$$W = A\,N^2 + B\,N + C.$$

It is obvious from the plot (Figure 2) that graduation characteristics have approximately the same form. Depending on the degree of divergence of the regression between different species of cotton is 0, 25% (abs.). From this perspective, we put forward a proposal to create a method based on microwave multipurpose device for most bulk (grains and cereals) and fiber (cotton and food processing) products

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