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Analysis of the Main Measurement Error, Moisture Content of Raw Cotton and Its Processed Products by Thermogravimetric Method

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Abstract: The article examines the problem of developing the methodological foundations of the influence of various parameters on the measurement accuracy, as well as the adoption of a technical solution that allowed describing the function of converting an informative parameter in an electric field and the function of influencing the accuracy of the instrument readings of the main informative and uninformative parameters of the measurement process. The influence of the physical and mechanical properties of raw cotton and the behavior of the material under study in a high-frequency electromagnetic field is considered. The principle of operation of high-frequency measuring systems is described, based on the presence of a relationship between the dielectric constant of the controlled material and its humidity in the electromagnetic field. The state of moisture control of raw cotton and products of their industrial processing of local varieties grown in the Republic of Uzbekistan is analyzed. The issues of the error of the thermogravimetric method of measuring humidity (informative parameter) are discussed as the main direct model method, as well as a number of sources of measurement errors (uninformative parameters), including moisture absorption properties, drying criterion, sample weighing, raw cotton composition, as well as the degree of influence of various interfering factors on the accuracy of determination and measurement of the value of the mass moisture ratio of raw cotton and its primary processing products. The application of humidity control devices at the enterprises of the agro-industrial complex is described, which will allow to stabilize technological processes, improve the quality and quantity of products, as well as improve working conditions in industrial premises. An assessment of the thermogravimetric method for measuring humidity and recommendations for the use of indirect measurement methods based on the implementation of the method and the selection of the optimal number of measured parameters of the object of study, ensuring maximum accuracy of determining the desired value, are given.

Keywords: Thermogravimetric Method, Raw Cotton, Mass Moisture Ratio, Error, Measurement, Moisture Meter

1. Introduction

Raw cotton is one of the main types of agricultural products of Uzbekistan, is important in the country is economy. One of the main indicators of cotton quality is the mass ratio of moisture.

Numerous methods for measuring the moisture of solid, bulk and liquid materials are known. Methods for measuring humidity are usually divided into direct and indirect, and in direct methods the material is directly separated into dry matter and moisture with further determination of the moisture content in the material. In indirect methods, a value functionally related to the moisture content of a material requiring pre-calibration [1, 2] is measured in order to establish a relationship between the moisture content of the material and the measured physical correlated quantity.

One of the main methods for direct measurements of the mass ratio of moisture (MRM) is the drying method (thermogravimetric), which is also the main method for estimating the error of indirect measurement methods that requires pre-calibration.

The essence of the thermogravimetric method is to separate moisture and material when drying the sample in

special devices to a certain weight. This method is quite well and comprehensively studied by many researchers.

Analysis of the literature confirms that the use of the above primary sources of information in the measurement of the technological parameters of the moisture control process of the materials in question makes it necessary to correct the latter by eliminating the random components of the error. However, often the results of such measurements cannot be applied in the control of the technological process due to the existing eliminated error, which is the cause of unreliable information [3-7].

The purpose of this study is to analyze the existing thermogravimetric method of measuring the moisture content of raw cotton and products of their industrial processing, to substantiate the method of evaluation considering the accuracy of the measurement of the materials under study and the synthesis of moisture control partings.

To achieve this main goal, it involves the solution of little-studied research tasks, in particular, it is necessary to conduct a theoretical study measuring the accuracy of weighing the material under the method under consideration, to substantiate the systematic methodology of the material under consideration and its electrophysical parameters, i.e. Moisture content in granular materials should be measured by determining the dielectric constant, while measuring the electrical capacitance in a high-frequency electrostatic field that is created in the material without destroying its structure.

2. Material and Methods

In this article, we consider its main errors related to raw cotton and products of its primary processing.

One of the main indicators of cotton quality is the MRM. The determination of this indicator is carried out by thermogravimetric method using moisture meters based on various methods of measuring humidity.

The moisture sorption properties of raw cotton depend primarily on its industrial and breeding variety, growing conditions and other factors affecting the amount of residual moisture after drying.

Drying cotton for the purpose of determining the MRM is the process of desorption of moisture from the material, which ends with the achievement of a dynamic equilibrium between moisture in the cotton material and moisture contained in the air in the form of water vapor. But, as is known from the theory of moisture sorption by capillary-porous materials, equilibrium humidity does not depend on the drying time, but is determined only by the moisture sorption properties of materials, temperature and relative humidity of the air. Therefore, the fluctuation of these factors can lead to fluctuations in the residual MRM of the cotton material and is therefore an error in the measurement of the MRM.

Another source of method error is the selected criterion for the end of drying. Since it sometimes takes a very long drying time to achieve the actual dynamic equilibrium, under real conditions the MRM is limited to some approximation when measuring. Drying does not end when the actual equilibrium is reached, but when a certain decrease in the rate of change of mass to the established weight, on the order of 0.01 g, from the original mass of the sample is reached. Therefore, the measurement error in this case will depend on the accuracy of the separation of moisture and dry matter, i.e. on the selected criterion for the end of drying.

The source of the third kind of measurement error of the MRM may be the composition of raw cotton. As is known from [8], raw cotton is a complex three-component system consisting of seeds, fiber and sororities. These components have different moisture sorption properties. Their quantitative ratio in the analyzed sample may vary, and, therefore, randomly affect the moisture content of samples taken from the total mass. The degree of this influence with the existing sampling method of control will characterize with some error the representativeness of the sample.

On the basis of theoretical and experimental studies, it is necessary to develop sampling methods and the accuracy of measuring raw cotton MRM at high frequencies that meet state standards, as well as on the basis of the physical and mechanical properties of the material under study, to develop recommendations and formulate tasks for the constructive and circuit development of a high-frequency humidity control device that meets the requirements of industrial operation.

3. Results

For a more detailed consideration of the components of this error, we will express the MOV of raw cotton through its generalized characteristics of fiber, seed and sor. In this case, the MRM of the three-component system can be represented as follows, W_B W_C, W_Z

$$W = W_C(1-Z)(1-\mathrm{B}) + W_B(1-Z)\mathrm{B} + W_Z \cdot Z. \quad (1)$$

Where Z is the clogging of raw cotton equal to the ratio of the dry mass of the litter to the total dry mass of the raw cotton. B is the yield of the fiber equal to the ratio of the dry mass of the fiber to the dry mass of the raw cotton, is the sum of the masses of the dry fiber and seeds. $m_{\text{cz}} m_{\text{cx}} m_{\text{cx}}\, m_{\text{cx}}$

Whereas the MRM of the components is respectively equal to:

$$W_B = \frac{m_{\text{вв}}}{m_{\text{св}}}100\%,\ W_{\text{C}} = \frac{m_{\text{вс}}}{m_{\text{сс}}}100\%, W_B = \frac{m_{\text{вз}}}{m_{\text{сз}}}100\%.$$

Num Where is the mass of moisture in the fiber,$m_{\text{вв}}$

$m_{\text{вс}}$ - the mass of moisture in the seeds,

$m_{\text{вз}}$ - the mass of moisture in the litter,

m_{cc} - The mass of the dry seed.

By differentiating equation (1), having previously expressed it in partial derivatives, it is possible to determine the unevenness of the MRM between the samples, in which all the parameters of, B, Z randomly vary. $\Delta W W_B, W_{\text{C}} W_3$:

$$\Delta W = \sqrt{(\frac{dW}{dW_C})^2 \Delta W_C^2 + (\frac{dW}{dW_{\text{в}}})^2 \Delta W_{\text{в}}^2 + (\frac{dW}{dW_3})^2 \Delta W_3^2 + (\frac{dW}{dB})^2 \Delta B^2 (\frac{dW}{d3})^2 \Delta 3^2} \quad (2)$$

Where, are partial derivatives respectively of MOV, seeds, fiber, sor, etc. $\frac{dW}{dW_B}\frac{dW}{dW_C}, \frac{dW}{dW_3}$ ....

ΔW_B,,,,, changes in the values of MOV, seeds, fiber, etc., or$\Delta W_C \Delta W_P \Delta B \Delta 3$

$$\Delta W = \sqrt{[(1-3)]^2 \Delta W_C^2 + [B(1-3)]^2 \Delta W_B^2 + 3^2 + \Delta W_3^2} + + [W_B - W)(1-3)\Delta B^2 + [W_C(1-B) + W_B B - W]^2 \Delta 3^2 \quad (3)$$

Whereas the MRM of cotton material is equal to:

$W_x = W_C(1-B) + W_B B$, then from (3) we get the magnitude of the fluctuation of the MOV between the samples of raw cotton, depending on the presence of weeds in it. Considering the state of the fiber and seeds to be balanced, we will write down

$$\Delta W' = \sqrt{(1-3)^2 \Delta W_x^2 + 3^2 \Delta W_3^2 + (W_x - W_3)^2 \Delta 3^2} \quad (4)$$

The first and second terms of this equation show the effect of the change in the composition of the litter on the measured value of the MRM. This is primarily due to green weeds, the amount of which during machine cleaning is $1 \div 3\%$, but their MRM can reach 250 percent or more.

The third component of equation (4) is related to the uneven distribution of litter in the material. The value of the MRM of organic litter is on average $\div 510\%$ higher than the MRM of pure raw cotton for the first two varieties. For lower varieties of cotton, this difference can reach large values.

From the analysis, it follows that in order to reduce the unevenness of the MRM between samples, it is advisable to clean it of weeds before drying. This will significantly reduce the measurement error, but increase the analysis time. It can also be shown that in raw cotton peeled from litter, the fluctuations in the MRM between samples will depend on the state of dynamic equilibrium of the fiber and seeds. To do this, taking (3) $3 = 0$ we get

$$\Delta W'' = \sqrt{(1-B)^2 \Delta W_C^2 + B^2 \Delta W^2 + (W_B - W_C)^2 \Delta B^2} \quad (5)$$

The value depends on the total moisture content of the cotton material and with an MOV of 8% is [8]. With an MRM of 35%, it reaches 1% or more. $\Delta W'' 0{,}2 \div 0{,}3\% \Delta W''$

To eliminate the margin of error, $\Delta W''$cotton fiber must be kept under certain conditions before drying until the equilibrium of the MOV in the fiber and seeds occurs. According to [9], the natural process of moisture redistribution can last from 6 to 9 days or more. Therefore, to accelerate it, the seeds are crushed before drying or exposed to microwave energy [10]. In the latter case, the process of redistribution of moisture between the fiber and seeds takes several seconds, but the preparation process also increases the overall analysis time of a raw cotton sample by thermogravimetric method [11, 12].

The source of the measurement error of the MRM may also be the weighing of samples in wet and dry states [13], depending on the relative error of the measurement of the initial mass of the sample $_{\text{Cm}}$ and the value of the K (W) moisture content in the sample at *Cm = const.*

The value of this component of the error can be determined by the formula:

$$\Delta W = \sqrt{(\frac{dW}{dm_{\text{н}}})^2 \Delta m_{\text{н}}^2 + (\frac{dW}{dm_c})^2 \Delta m_c^2} \quad (6)$$

Where $\frac{dW}{dm_{\text{н}}}, \frac{dW}{dm_{\text{c}}}$ - are the partial derivatives.

$m_{\text{н}}, m_{\text{c}}$ - wet and dry mass respectively.

$\Delta m_{\text{н}}, \Delta\, m_{\text{c}}$ - permissible errors in weight weighting.

When you consider that the MOV of raw cotton is equal to

$$W = \frac{m_{\text{н}} - m_c}{m_c} 100\%$$

then, substituting the specified equation in (6) and making some transformations, we get

$$\Delta W = \sqrt{\frac{\Delta m_{\text{н}}^2}{m_c^2} \Delta m_{\text{н}}^2 + \frac{m_{\text{н}}^4}{m_c^4} \Delta m_c^2} \quad (7)$$

Whereas the weighting of the samples is carried out with the same precision in both wet and dried state, it is possible to write$\Delta m_{\text{н}} = \Delta m_c = \Delta m$ substituting in (7) and given that, we get$\Delta m \frac{\Delta m}{m_{\text{н}}} 100\% = \text{C}_m$

$$\Delta W = C_m \frac{m_{\text{н}}}{m_c} \sqrt{1 + \frac{m_{\text{н}}^2}{m_c^2}} \quad (8)$$

Having made some transformations and considering that

$$\frac{100}{100} \left[\frac{m_{\text{н}}}{m_c} - 1\right] = \frac{W+100}{100}$$

equation (8) can be represented as follows:

$$\Delta W = C_m (\frac{W+100}{100}) \sqrt{2 + \frac{2W}{100} + \frac{W^2}{100^2}} \quad (9)$$

after all this we finally get $\left(\frac{W+100}{100}\right) \sqrt{2 + \frac{2W}{100} + \frac{W^2}{100^2}} = K(W)$.

$$\Delta W = C_m K(W). \quad (10)$$

Where *K(W) is* the coefficient characterizing the change in error ΔW, depending on the moisture content of the sample at

$$C_m = const.$$

Since the drying of raw cotton by the thermogravimetric method is carried out in special dryers in which the coolant is heated air, as a result, the accuracy of measuring the MRM will also depend on the constancy of the temperature of the coolant and the temperature gradient in the volume of the working chamber [14].

The effect of the temperature of the drying agent on the accuracy of the MOV determination can be estimated using the k coefficient.

$$k = \frac{W_{(t \pm \Delta t)} - W_t}{\Delta t} \quad (11)$$

Where is the value of the MOV at the temperature of the coolant $W_{(t \pm \Delta t)} t \pm \Delta t$.

W_t *is* the value of the MOV at the temperature of the coolant t.

This coefficient k, according to [15], is ± 0.03% / deg. for the conditioned value of the MOV, and at a higher value it increases and at W = 25% reaches the order of ± 0.09% / deg.

If we consider that in the modern model SSM 3M temperature difference is 1.5 ±°C, then the variation in the coefficient k (at W = 25%) is $\pm 0,135\%$.

4. Conclusion

Based on the foregoing, we conclude that in order to equip the cotton ginning industry with means of monitoring and assessing the quality of raw materials at all stages of the technological process, preference should be given to moisture meters based on indirect measurement methods, leaving the thermogravimetric method the role of an exemplary one [16-18].

However, other methods of measuring MRM based on chemical methods of analysis [19, 20] are usually in the stages of study, or are complex, analysis with their help takes a long time and, as is obvious, are not suitable for express measurement of moisture of raw chlorine and products of its primary study.

The analysis of the research results shows that the use of the thermogravimetric method according to the standard methodology (sample weight 2-3g) when controlling large volumes of material leads to an error of more than 10%. The results obtained by thermogravimetric determination of the mass fraction of moisture will be very unreliable and, in the future, cannot be used for calibration of express humidity control devices. This, in turn, will lead to the fact that it is impossible to consider the basic principles of the construction of devices for measuring the moisture content of granular materials, considering the specifics of the agro-industrial complex.

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