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DESIGN AND PRACTICAL APPLICATION OF BULK MATERIALS HUMIDITY TRANSDUCERS

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Abstract: Considers the design of an unusual control of the moisture content of bulk materials. Physical models of capacitive transducers, which form the basis for the development of in-line moisture meters for grain and grain products, have been developed.As a result of experimental studies, the static and dynamic characteristics of the developed devices, as well as normalized metrological characteristics, were determined. The values of the maximum permissible errors of grain moisture measurement devices in the range $W \in [3....20]$ % were determined and the arithmetic mean error of the measuring device was calculated, which are within the limits established by ND and amount to ± 0.3%.

Key words: moisture measurement, measurements, humidity, error, grain, industry.

In the world, in all spheres of industrial production and economic management, at the present stage of scientific and technological progress, special attention is paid to the modernization and development of measuring instruments that control the quality parameters of products. In this regard, at industrial enterprises producing grain products, the measurement and control of grain moisture is carried out using improved methods and instruments, including automatic devices for accelerated moisture control. Therefore, the development of intelligent measuring instruments with the introduction of modern information technologies in moisture control devices for grain products is of great importance.

Scientific research is being carried out in the world aimed at improving the automatic control, accuracy and speed of intelligent measuring and control devices for controlling grain moisture, improving the converters used in them. In most of these scientific studies, special attention is paid to the creation of instruments and devices with converters for continuous automatic monitoring of the moisture content of grain products. In this regard, one of the important tasks is to create a digital device based on a microprocessor with a capacitive converter for continuous automatic monitoring of the moisture content of grain products, which is distinguished by advanced functionality, high sensitivity, speed, accuracy and reliability.

There are many methods and devices for controlling the moisture content of bulk materials. There are a sufficient number of modern methods that allow you to effectively and quickly measure the moisture content of various materials, including bulk materials. The most relevant and proven methods of change include direct options that destroy the selected material for the procedure. It is for this reason that they have found their application in various instruments that are designed to carry out precise measuring work. Also, great attention should be paid to the following examples of methods. This is a conductometric method, capacitive, nuclear magnetic resonance, and also microwave. If we are talking about the radioactive version of the method, then it is worth noting that it will require a fairly serious and original device to use.

Studies have shown that a number of methods and flow converters for bulk materials have been developed on the basis of the following physical principles of dielcometric, conductometric, optical, thermal and other physical principles.

The developed continuous automatic moisture meters for bulk materials have good metrological characteristics, a wide measurement range, and high speed. However, most transducer designs are very complex, costly, have complex measurement circuits, and require highly skilled personnel to maintain. For a wide application of in-line moisture meters, reliable and simple in terms of design measuring transducers are required. A number of works have shown that in the field of dielcometric (capacitive) transducers there are diverse, simple and effective designs: plane-parallel (cube, square, and others); cylindrical in combination with plane-parallel structures; coaxial (pipe in a pipe, rod in a pipe) and others.

For the development of the primary measuring transducer, two most widely used types of capacitive structures were selected: the first is plane-parallel, the second is coaxial. A plane-parallel capacitive transducer is very effectively combined with designs for bulk materials with a cuvette that is transported using a belt conveyor. The second design is coaxial, which is installed vertically with a hopper and bulk material is transported using a special driven auger.

Both developed designs are well combined with modern microprocessor measuring circuit and generally provide high sensitivity, accuracy and versatility.

In order to substantiate the raised problem and the possible novelty of the coaxial capacitive converter, it is advisable to consider in more detail its analogues and prototypes.

A capacitive moisture sensor for bulk materials [1] containing an external cylindrical electrode, an internal conical electrode, a weight-measuring spring and a housing in which the elements of the capacitive sensor are located was investigated. The disadvantages of this device is unsuitability for automatic continuous monitoring of the moisture content of bulk materials and limited functionality. A capacitive moisture sensor for bulk materials [2] containing a housing, fixed electrodes, a vibrating electrode, and an electromagnet has been studied. The disadvantages of this device are unsuitability for automatic continuous monitoring of the moisture content of bulk materials and limited functionality. [3] The closest in technical essence to the developed moisture meter is a device containing a pipeline with inlet and outlet fittings, a heater made in the form of a screw, a gearbox, an electric motor, bearings, slip rings, two temperature-sensitive capacitive cells, two generators, a frequency mixer and a recording device in the form of a frequency meter. The disadvantages of this device are the presence of a rotating heater based on the screw, which is a complex and not sufficiently reliable design and limited functionality.

In the capacitive converter developed by us, the pipeline is made of a dielectric material, on the inner surface of which a temperature-sensitive capacitive cell is installed in series after the hopper, the outer cylindrical capacitive electrode is coaxial to the inner rod capacitive electrode, the lower end of which is rigidly connected to the upper end of the rod axis vertically installed below the coaxial capacitive electrodes screw, the lower rod axis of which passes through the bearing installed in the outlet part of the pipeline and then through the second bearing installed in the base of the housing, while on the lower rod axis of the screw there is one slip ring connected to the view of one of the frequency generators, and the electric motor through the gearbox connected to the end with the lower rod axis of the screw.Also, the design of the capacitive transducer of bulk materials allows you to continuously monitor the humidity and temperature of the bulk material, which increases the reliability and accuracy of measurement.

The essence of the converter is illustrated by the drawing: in fig. 1 shows a section of the design of a capacitive moisture meter for bulk materials.

The capacitive transducer of bulk materials contains a pipeline 1 made of dielcometric material, a hopper 2, an external capacitive electrode 3, an internal capacitive electrode 4, a temperature-sensitive capacitive cell 5, an auger 6, a lower rod axis of the auger 7, bearings 8 and 9, a contact ring 10, a gearbox 11, electric motor 12, frequency generator 13 and 15, amplifiers 14 and 16, microprocessor 17, indicator device 18, housing 19, moisture meter outlet pipe 20.

Capacitive transducer of bulk materials works as follows. Bulk material through the hopper 2 enters the cavity of the pipeline 1 and passes through the capacitive cell 5 then through the measuring section, consisting of an indivisible cylindrical capacitive electrode 3 and an internal rod electrode 4, is transported down to the outlet of the moisture meter 20 by means of a screw. As a result of the interaction of wet dry material with cylindrical coaxial electrodes 3 and 4, the capacitance between these electrodes changes and the oscillatory circuit of the generator 15 receives a signal from the electrode 3 and electrode 4 through the rod axis 7 and the contact ring 10. Next, the signal from the generator 15 through the amplifier 16 is fed to the input of the microprocessor 17. The signal about bulk material temperature measurement occurs in capacitive cell 5, then it goes to the input of the generator 13 and through the amplifier 14 goes to the input of the microprocessor 17, which sends these signals to the indicator device 18 to display the results of monitoring the temperature and humidity of the bulk material. An auger 6 is used as a device for transporting bulk material, the lower rod axle 7 of which is connected through a gearbox 11 to an electric motor 12, and the upper part of the axle is articulated with the internal electrode 4 of the coaxial capacitive cell 3 and 4.

Due to the fact that the pipeline is made of a dielectric material, on the inner surface of which a temperature-sensitive capacitive cell is installed in series after the hopper, the outer cylindrical capacitive electrode is coaxial to the inner rod capacitive electrode, the lower end of which is rigidly connected to the upper end of the rod axis of the screw vertically installed below the coaxial capacitive electrodes , the lower rod axis of which passes through the bearing installed in the output part of the pipeline and then through the second bearing installed in the base of the housing, while on the lower rod axis of the screw, high accuracy and reliability of automatic control of the moisture content of bulk materials in a continuous flow is ensured.[3]

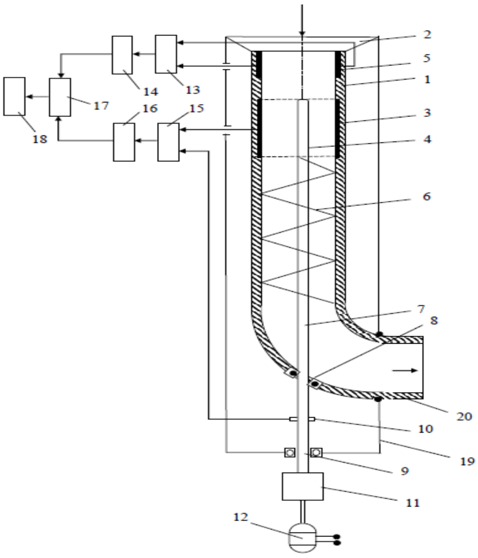

Fig. 1 Construction of the in-line capacitive moisture meter for bulk materials

1 - dielcometric pipeline, 2 - hopper, 3 - external capacitive electrode, 4 - internal capacitive electrode, 5 - temperature-sensitive capacitive cell, 6 - screw, 7 - lower rod axis of the screw, 8.9 - bearings, 10 - contact ring , 11 - gearbox, 12 - electric motor, 13.15 - frequency generator, 14-16 amplifiers, 17 - microprocessor, 18 - indicator device, 19 - housing, 20 - moisture meter outlet pipe.

This design received a patent from the Intellectual Property Agency of the Republic of Uzbekistan [4].It is shown that among the capacitive transducers for automatic control of the moisture content of grain and grain products, two simple designs of capacitive sensors of a plane-parallel type and a coaxial type are very effective in terms of accuracy and sensitivity, the circuits of which are shown in Fig. 2 a and b.

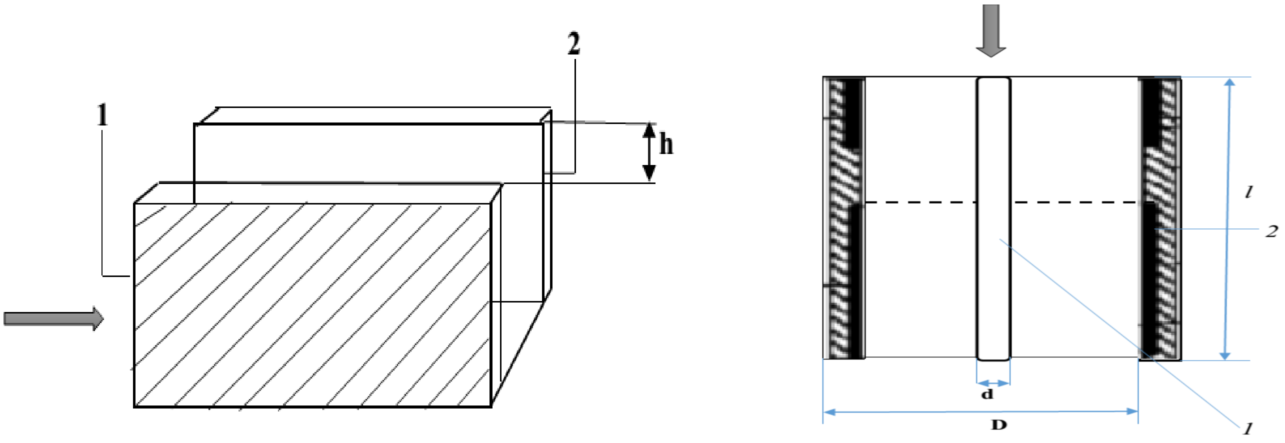

Fig. 2. Physical models of capacitive transducers that form the basis for the development of in-line moisture meters for grain and grain products:
a) plane-parallel type b) coaxial type, 1,2-electrodes

Such a characteristic of a transducer (belonging to the category of plane-parallel) as capacitance can be calculated using the formula shown below (1):

$$C_0 = [\textstyle\sum_I^r \varepsilon_r g_r + \sum_I^a \varepsilon_a g_a], F, \qquad (1)$$

Where ε_r- dielcometric permeability of the material located within the main gap; ε_a- dielcometric permeability of the material outside the main gap; g_r- spatial property of the field located within the gap, m; g_a- spatial characteristic of the field component located outside the field, m.

Among the capacitive sensors, which are classified as coaxial, are those that are a collection of conductors. Each individual conductor here is an electrode that has a cylindrical shape. There are always two conductors that are in each other. [5]

To calculate the capacitance of a coaxial sensor, which includes cylinders, denoted as d and D, you need to use the following approach. First, you need to take into account that these sensors overlap each other by a length,

$$l \gg \frac{D-d}{2}$$

secondly, we must take into account that our calculations will be carried out without taking into account the edge effect. If the space that is localized from one inner surface to another significantly exceeds the diameter present in the cylinder located inside, then it is necessary to calculate the capacity of the system using the formula presented below (2):

$$C = \varepsilon_0 \varepsilon_i g_V = \varepsilon_0 \varepsilon_i \frac{2\pi l}{in\frac{D}{d}}, F \qquad (2)$$

If the space that is localized from one inner surface to another does not exceed the diameter present in the cylinder located inside, then it is necessary to calculate the capacity of the system using the formula presented below (3):

$$C = \varepsilon_0 \varepsilon_i g_V = \varepsilon_0 \varepsilon_i \frac{(D+d)}{(D-d)} = \text{, F,} \qquad (3)$$

Where ε_i is the permittivity of the material inside the gap; g_V is the spatial property of the field, m; l - The length of the segment on which the cylinders overlap, m; d is the diameter of the cylinder located in the inner space m; D is the diameter of the cylinder located in the outer space, m. Accordingly, provided that $h \leq 0.1$ a and $h < 0.1$ b, then you can find the capacity present in the capacitor equipment by referring to the formula below (4):

$$C_0 = \varepsilon_0 \varepsilon_{\text{В}} g_I \text{, F} \qquad (4)$$

The variability of the mass of the material leads to the variability of its thickness or density, depending on the design of the conveyor. In both cases, a change in mass leads to a change in the informative parameter - attenuation or phase shift, and hence to an error in measuring moisture content with a microwave moisture meter. The thickness of the material has a direct effect on the attenuation and phase shift, and the density - through the dielectric parameters ε' and ε".

It is known that the main electrophysical characteristics of dielcometric moisture meters are: the dependence of dielcometric permeability on humidity, temperature, electric current frequency, density of the medium under study, the influence of particle size distribution, etc., which have a perturbing effect on the accuracy of the moisture meters. Let us consider the influence on the dielectric characteristics of disturbing influences associated with changes in the properties of the measurement object. With the help of prepared samples (samples), several measurements were carried out using the proposed capacitive measuring device and for each**h**tsa received the frequency valuesof the measuring generator.

With the developed measuring device, we carried out several measurements at different calibration frequencies.

As a result of theoretical and experimental studies, the static characteristics of the developed device were determined for different values of the calibration frequencies fcal=774.173 kHz and fcal=766.200 kHz, as well as normalized metrological properties. The limit values of the permissible errors of the device in the range $W \in [3....20]$.The results of the experimental study are given in table. 1, 2. Based on the results of the experimental study, graphs of the dependence of the output frequency of the measuring generator (Fig. 3-6) were plotted and the arithmetic mean measurement errors were calculated.

Table -1.Instrument readings at calibration frequency f_{cal}=774.173 kHz, msample=170 g

N №	Averagevalue∑W,%	*f1*,kHz	*f2*,kHz	*f3*,kHz	Averagefrequency ∑,kHz
1 1	3.10	666.653	666.633	666.644	666.643
		3.00	3.20	3.10	
1 2	5.00	660.661	660.652	660.644	660.652
		5.10	5.00	4.95	
3 3	7.85	654.544	654.725	653.698	654.322
		7.84	7.86	7.85	
4 4	10.15	642.886	642.961	644.550	643.465
		10.16	10.13	10.15	

5 5	12.65	631.568 12.65	631.558 12.64	631.570 12.66	631.565
6 6	13.75	622.366 13.73	622.523 13.77	622.380 13.75	622.423
7	17.25	599.899 17.25	599.971 17.26	599.991 17.24	599.953
8 8	20.25	571.419 20.26	571.409 20.24	571.425 25.25	571.417

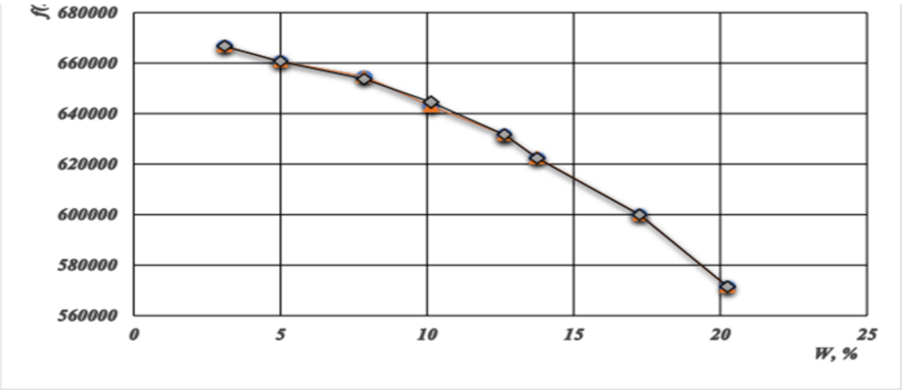

Fig. 3.output frequency graph f_{cal}=774.173 kHzfrom humidity W % grain

Table-2.Instrument readings at calibration frequency f_{cal}=766.200 kHz, msample=170 g

№	Average value ∑ W,%	*f1*,kHz	*f2*,kHz	*f3*,kHz	Averagefrequency ∑,kHz
	5.00	656.925 3.20	656.203 3.00	656.171 3.10	656.433
	7.85	648.623 7.84	648.627 7.86	648.627 7.85	648.625
	10.15	639.921 10.15	638.243 10.16	639.365 10.14	639.176
	12.65	624.872 12.66	623.406 12.64	624.129 12.65	624.135
	13.75	616.214 13.75	618.457 13.77	617.203 13.74	617.291
	17.25	590.172 17.24	591.700 17.25	590.786 17.26	590.886

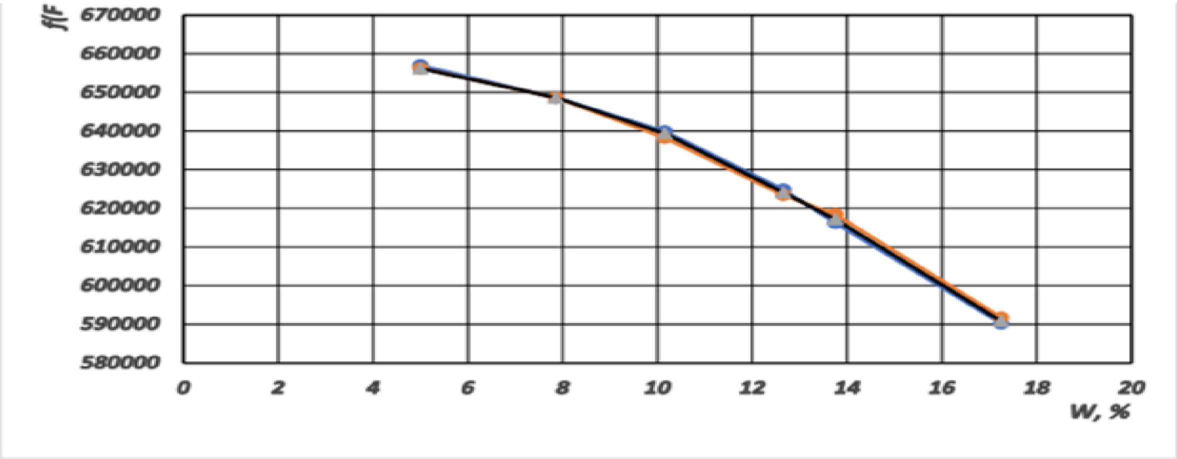

Fig. 4.output frequency graph f_{cal}=766.200 kHz from humidity W % grain

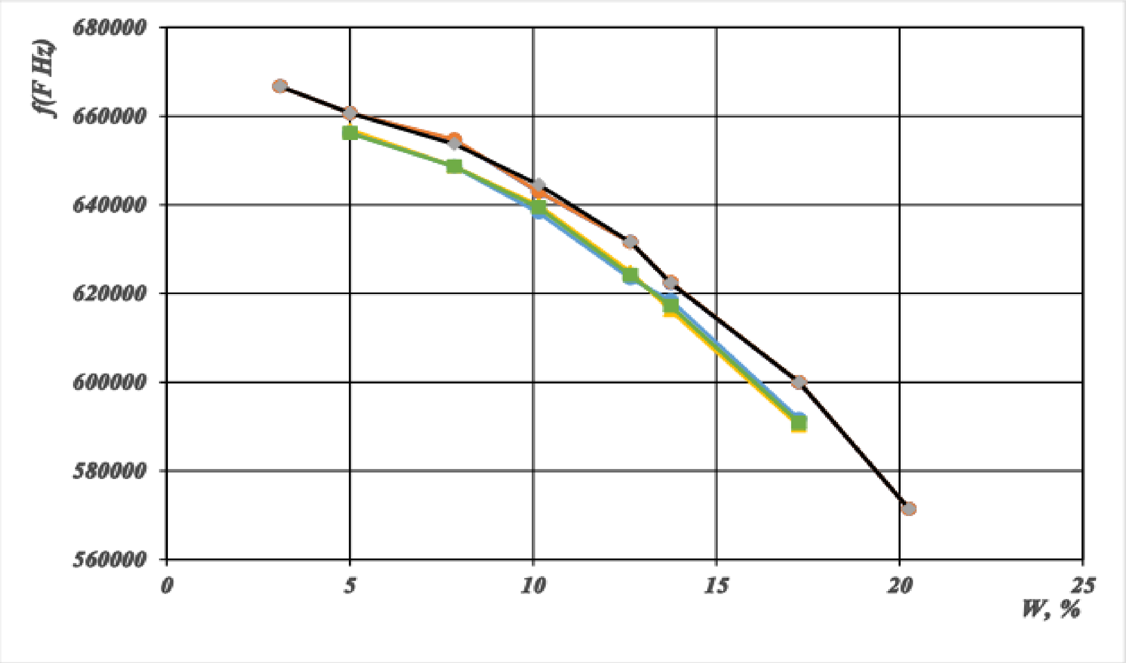

Fig.5. Comparison graph of the dependence of the measuring generator f_{cal}=774.173 kHz and f_{cal}=766.200 kHz on moisture content W % grain

As a result of experimental studies, the static characteristics of the developed device were determined at different values of the calibration frequencies f_{cal}=774.173 kHz and f_{cal}=766.200 kHz, as well as normalized metrological properties. The maximum permissible errors of the device for measuring grain moisture in the range W[3.…20] % and calculated the arithmetic mean error of the measuring device is within the limits established by ND [6] and is ±0.3%. This makes it possible to improve the measurement accuracy.In Chapter II, in the section on improving the method and type of transducers for continuous monitoring of the moisture content of bulk materials, we developed the design of a flow capacitive moisture meter for bulk materials.The results of the experimental study are given in table. 3. Based on the results of the experimental study, plots of the dependence of fig. 8 andthe dynamic characteristics of this device are determined.

Table 3

τ(s)	**W (20%)**	**W (16%)**	**W (13%)**
2	4.1	3.4	2.7
4	10.9	9.2	7.4
6	14.5	13.2	10.5
8	17.2	14.9	11.3
10	19.3	15.6	12.2
12	19.7	15.8	12.6
14	19.8	16.1	12.8
16	20.1	16.1	13.1

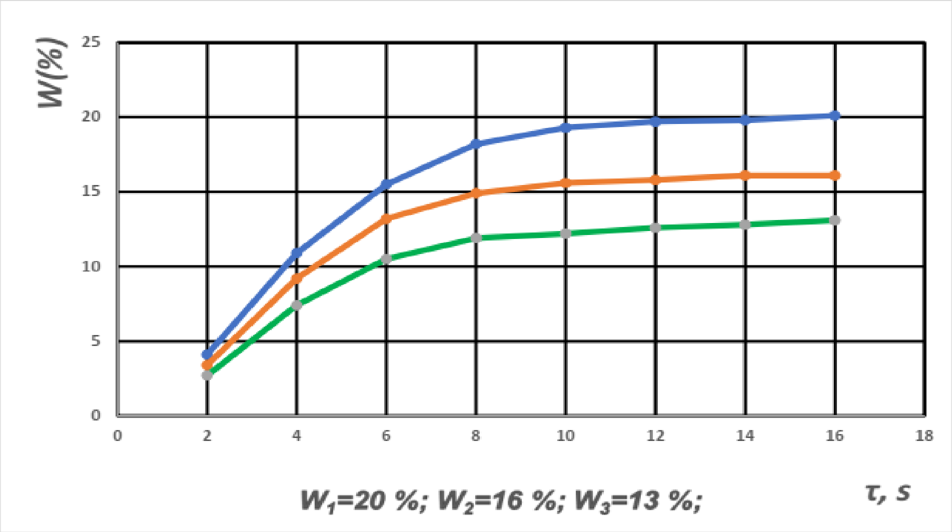

Fig. 6. Dynamic characteristic of the dependence of time on humidity of the design of a flow capacitive moisture meter for bulk materials for exemplary grain with moisture

W1=20%, W2=16%, W3=13%

From the presented graph, built according to the results of this experiment, we see that the function of the device versus time is visible in equation (5):

$$y = 0.011x3 - 0.435x2 + 5.767x - 5.8214 \qquad (5)$$

According to the results of the experiment, it can be seen from the graph that the dynamic characteristic of this device can reach a stable measuring constant at 10 s.

Software products developed by us taking into account the specifics of the object under study and allow you to quickly receive, process, calculate data and display ready-made information on the display in the form of a decimal code. The novelty of the algorithm and program for monitoring the information processing process is confirmed by the certificates of the Intellectual Property Agency of the Republic of Uzbekistan No. DGU 06312 dated 03.05. 2019

As a result of experimental studies, the static and dynamic characteristics of the developed devices, as well as normalized metrological characteristics, were determined. The values of the maximum permissible errors of grain moisture measurement devices in the range W[3.…20] % were determined and the arithmetic mean error of the measuring device was calculated, which are within the limits established by ND and amount to ± 0.3%.

Literature

1. RF patent SU1695212A1 /20, 12.1988 Capacitive moisture sensor for bulk materials // JaparidzeT.D.. [and others].
2. Patent RF (SU) 543291/30, 01.1980 Capacitive sensor for measuring the moisture content of bulk materials // Vutsen V.A. [and etc.].
3. R.R.Kuluev, P.R. Matyakubova. Development of a humidity control device for bulk and liquid materials based on the capacitive method // Priborostroenie-2019. Proceedings of the 12th international scientific and technical conference November 13-15, 2019.BNTU, Minsk, Republic of Belarus, 2019.P.181-182.
4. P.M.Matyakubova, R.R.Kuluev, Kh.A.Usmanova,A.Turgunbaev. Capacitive moisture meter for bulk and liquid materials // Patent for invention of the Republic of Uzbekistan. IAP 06856 dated 03/24/22
5. V.P.Bukhgolts, E.G.Tisevich.Capacitive converters in systems of automatic control and management.M., "Energy", 1972.
6. GOST 8.434-81 GSI "Moisture content of grain and products of its processing"