ISSN 2063-5346

ACOUSTIC DEVICE FOR EXPRESS DETERMINATION OF SEED COTTON GRADE

Akhmedov Akmal

Article History: Received: 02.07.2023 Revised: 15.07.2023 Accepted: 23.07.2023

ABSTRACT:

The results of research on the creation of a new device for the express determination of seed cotton grade on the acoustic principle of measurements without preliminary ginning of seed cotton samples are presented.

A theoretical analysis of the process of passage of sound vibrations through a sample of raw cotton was carried out and an analytical dependence of the output signal of the device on the coefficient of maturity of the fiber, on the parameters of the medium and the design parameters of the measuring chamber of the device was derived.

The regression analysis method was used to construct equations of the calibration dependence for various breeding varieties at frequencies of 150 Hz and 200 Hz.

Key words: acoustic device, measurement, seed cotton , sample, seed cotton grade, measurement error.

position at work - chief researcher of the "Paxtasanoat ilmiy markazi" JSC

scientific degree - Candidate of Technical Sciences

academic title - senior researcher

DOI:10.48047/ecb/2023.12.9.248

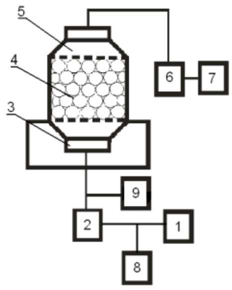
Introduction

In accordance with the national standard of the Republic of Uzbekistan "O'z DSt 615:2008 Seed cotton. Specifications", the grade of seed cotton upon acceptance from cotton-growing farms is evaluated by an organoleptic method in terms of color and appearance by comparing samples taken from the received batch with samples of external kind. The method is subjective, not accurate enough. Therefore, if there are disagreements in the assessment of the grade by the classer method, the grade is determined in the laboratory according to newly selected samples instrumentally by the maturity coefficient on the LPS-4 device of fiber samples weighing 7.9-8.0 g.To do this, the selected sample of raw cotton is passed through the paintwork materials, and a part of the raw cotton weighing about 150 g is taken from the cleaned sample, which is passed through the PPV laboratory gin-fiber cleaner. Then the obtained fiber is weighed and tested on the LPS-4 device in 4 replicates. Then, according to the conversion table, the grade of raw cotton is determined by the coefficient of maturity of the fiber. The method is lengthy, the time of testing one sample, taking into account the preparation of the fiber sample on the FPV device, is about 20-25 minutes, which leads to transport delays while waiting for the analysis results. Therefore, it is advisable to develop a new modern device for variety control by the coefficient of maturity of raw cotton samples without ginning on large samples, weighing about 150 g, with a measurement time of no more than 1-2 minutes, which is the task of this work.

Description of experimental installation.

The block diagram of the measuring installation of the PAN-1 device prototype is shown in Figure 1. The principle of operation of the block diagram is as follows.

Sinusoidal electric oscillations generated by the sound generator 1 are amplified by the power amplifier 2 and with the help of the acoustic head 3 are converted into sound oscillations, which are directed to the raw cotton sample 4 in the measuring chamber. The sound vibrations passing through the sample are converted by means of a microphone 5 into an electrical signal, which is amplified by a low-frequency amplifier 6 and fed to a millivoltmeter 7, which measures the value of the signal passed through the sample and attenuated. The voltage on the coil of the acoustic head is monitored using a voltmeter 8, and the frequency of sound oscillations is monitored using a frequency meter 9



1-sound generator; 2-power amplifier 3-acoustic head; 4-sample of raw cotton in the measuring chamber; 5-measuring microphone; 7-millivoltmeter; 8-frequency meter; 9-voltmeter.

Figure 1 - Block diagram of the experimental unit PAN-1.

Theory of the method. When sound vibrations pass through a sample of seed cotton enclosed in a measuring chamber, the latter is attenuated. A sample of seed cotton appears to be a porous isotropic two-component medium consisting of seed nuclei and a fibrous cover. Moreover, the fibrous part takes an active part in the attenuation of sound vibrations, the seeds practically do not resist the passage of sound vibrations due to their small specific surface compared to the fibrous mass, but by their presence, occupying empty space, they contribute to a decrease in the porosity of the fibrous component. With a constant mass of the raw cotton sample and the volume of the measuring chamber, with an increase in the coefficient of maturity, the thickness of the double wall of the fiber increases, the number of fibers per unit mass of the sample and the volume of the measuring chamber decreases. In this case, the specific surface of the fiber decreases, and the resistance of the sample to the propagation of sound vibrations decreases and the sound pressure at the input of the measuring microphone increases, which is converted into an electrical signal proportional to the pressure of sound vibrations.

The relationship of the output signal U with the attenuation coefficient and sample thickness is described by the following relationship [1]:

$$\boldsymbol{U = U_0 e^{-\alpha l}} \qquad (1)$$

Here l is the thickness of the raw cotton sample layer, equal to the height of the measuring chamber, cm.

As shown in [2], for fibrous materials at low frequencies of sound vibrations, there is the following relation for the attenuation coefficient:

$$\alpha = \frac{(1-\varepsilon)}{\varepsilon} \cdot \frac{1}{T} \sqrt{\frac{\pi \mu B^2 f}{c \chi \rho_0 C_0^2}} \qquad (2)$$

here ε - sample porosity;

T - is the linear density of the fiber, mtex;

μ - air viscosity, St;

f - frequency of sound vibrations, Hz;

c - dimensionless correction factor;

χ - elasticity factor, which determines the ratio of air elasticity in pores to air elasticity in free space outside the sample;

ρ_0 - air density in pores, g/m^3;

C_0 - speed of sound in free atmosphere, m/s;

$B = \rho \overline{\Pi}$ - coefficient equal to the product of cotton fiber density $\overline{\Pi}$ and its average perimeter.

Between the linear density and the maturity coefficient Kз there is a relationship close to linear:

$$\boldsymbol{T = D\, K_з} \;, \qquad (3)$$

here D - constant factor.

The porosity of the medium ε is defined as the ratio of the volume of air in the pores to the total volume:

$$\boldsymbol{\varepsilon = \frac{V - V_C - V_B}{V - V_C}} \qquad (4)$$

here V – is the sample volume equal to the total volume of the measuring chamber, cm^3;

V_C – is the volume of cotton seeds without residual lint, cm^3;

V_B – is the volume of the fibrous cover (residual lint) on the seeds, cm^3, which can be expressed by the following formulas:

$$\boldsymbol{V_B = \frac{B_в \cdot m}{\rho}} \qquad \boldsymbol{V_C = \frac{(1 - B_в) m}{\rho_C}}, \quad (5)$$

here $B_в$ - fiber content,

m - is the mass of the seed cotton sample in the measuring chamber, g;

ρ_C - seed density excluding residual lint.

Substituting formulas (5) into (4), after simple transformations, we obtain:

$$\boldsymbol{\varepsilon = \frac{\rho \rho_C V - m\left[\rho(1 - B_в) + B_в \cdot \rho_C\right]}{\left[V\rho_C - m(1 - B_в)\right]\rho}} \qquad (6)$$

Substituting (5) into (2) , after simple transformations, we obtain

$$\boldsymbol{\alpha = \frac{\rho_C \cdot m \cdot B_в}{V\rho\rho_C - m\left[\rho - B_в \cdot (\rho - \rho_C)\right]} \cdot \frac{A}{K_з}} \;, \qquad (7)$$

Here $A = \sqrt{\dfrac{\pi \mu B^2 D^2 f}{c \chi \rho_0 C_0^2}}$.

Substituting (7) into (1) and denoting the volume of the measuring chamber through the diameter d and the height of the measuring chamber, we have after simple transformations

$$U = U_0 \exp[-\frac{B_в \cdot m \cdot l}{\frac{\rho \cdot \pi \cdot d^2 l}{4} - m \cdot [\frac{\rho}{\rho_C} + B_в \cdot (\frac{\rho}{\rho_C} - 1)]} \cdot \frac{A}{K_з}] \quad (8)$$

In formula (8), the content of the fibrous part Bв essentially characterizes the fibrous index and is a constant value for a particular selection variety of raw cotton. The values ρ and ρ_C are also constant. Then we note that at a constant sample mass m and the dimensions of the measuring chamber *d* and *l*, with an increase in the maturity coefficient, the value of the output signal should increase exponentially. Taking the logarithm of equation (8), with a constant mass and volume of the measuring chamber and a signal level Uo, we obtain the following relationship between the logarithm of the output signal and the fiber maturity factor

$$\ln U = A_0 - A_1 / K_з \quad , \quad (9)$$

Here $A_0 = \ln U_0$ and

$$A_1 = \frac{B_в \cdot l \cdot A \cdot m}{\frac{\rho \pi d^2 l}{4} - m \cdot [\frac{\rho}{\rho_c} - B_в \cdot (\frac{\rho}{\rho_c} - 1)]} .$$

It follows from formula (9) that a linear relationship should be observed between the logarithm of the output signal and the reciprocal of the maturity coefficient.

Equation (9) is used in the construction of calibration dependences of an acoustic device for variety control in terms of the maturity coefficient for breeding varieties at a constant weight of the tested seed cotton sample and the optimal bulk density of the measured samples.

To select the optimal bulk density of the raw cotton sample, let us set the bulk density of the fibrous part of the raw cotton sample as the most active component, since the seeds play a passive role in the attenuation of sound vibrations due to their small specific surface. The bulk density of the fiber in the measuring chamber must comply with the requirements of the international standard ISO 2403, similarly to micronaire devices, which is $\delta = 0.16–0.3$ g/cm^3.

With measuring chamber diameter *d*=110 mm, height *l*=5 cm, fiber and seed density respectively ρ=1.51 g/cm^3, ρ_C=1.0 g/cm^3, seed cotton sample weight m=150 g and index fiber density $B_в$=0.43 we obtain the bulk density of the fiber in the sample of seed cotton in the measuring chamber δ =0.17 g/cm^3, which is obtained from the following relationship:

$$\delta = \frac{m \cdot B_в}{V - V_C} = \frac{m \cdot B_в}{\frac{\pi d^2 l}{4} - \frac{m(1 - B_в)}{\rho_C}} =$$

$$\frac{150 \cdot 0{,}43}{\frac{3{,}14 \cdot 11^2 \cdot 5}{4} - 150 \cdot (1 - 0{,}43)} = 0{,}17 \text{ g/cm}^3 .$$

With the selected bulk density of the fiber, the bulk density of the measured sample of raw cotton is:

$$\delta_{xc} = \frac{m}{\frac{\pi d^2}{4} l} = \frac{150}{\frac{3{,}14 \cdot 11^2 \cdot 5}{4}} = 0{,}316 \text{ g/cm}^3 .$$

This bulk density of the measured sample was chosen as optimal on the mock-up of an acoustic device for monitoring the seed cotton variety according to the maturity coefficient of the PAN-1 fiber. A further increase in density leads to a sharp increase in the sample compression force and cumbersome design of the sample compression mechanism, which is not advisable [2].

Methodology for conducting experimental research. Experimental research on the model of the PAN-1 acoustic device were carried out on samples of seed cotton breeding varieties C-6524, Bukhara 8, Andijan 35, Namangan 77 different industrial varieties selected from different regions of the republic, and had different values of the maturity coefficient.

Samples of raw cotton were previously kept at room temperature and had a moisture content of about 8%. Samples of raw cotton of each selection belonged to different regions of the republic and had different maturity coefficients. The samples were cleaned of weed impurities on the LKM device. Four samples (150 ± 0.02) g each were weighed from peeled seed cotton and placed in turn into the measuring chamber of the PAN-1 model. Then the frequency of sound vibrations was set on the sound generator (150 ± 2) Hz, while controlling the frequency setting accuracy with the help of a frequency meter, the voltage on the speaker was set to (4 ± 0.01) V, and the voltage at the output of the microphone amplifier in volts was measured using a millivoltmeter. Then, without removing the sample from the measuring chamber, measurements were carried out in a similar manner at a frequency of 200 Hz. Measurements were carried out in the same order on the remaining three samples. Next, the tested samples of raw cotton were prepared to determine the maturity of the fiber on the LPS-4 device in the following order. Each sample of raw cotton was ginned on a laboratory gin DL-10, then passed through a Shirley Analyzer. Before testing, the samples were kept for at least 4 hours in climatic conditions according to ISO 139 at a temperature of (20±2) °C and relative humidity (65±4)%. Tests on the LPS-4 device were carried out according to the method of the national standard of the Republic of Uzbekistan "O'z DSt 593:2008 Raw cotton. Methods for determining the characteristics of cotton fiber".

Research results. Using the average results of measurements of the output signal of the PAN-1 device model and the maturity coefficient on the LPS-4 device, the regression analysis method approximated the results of the experiment using the analytical dependence (9), which are presented graphically in Figures 3–12 and the equations for breeding varieties:

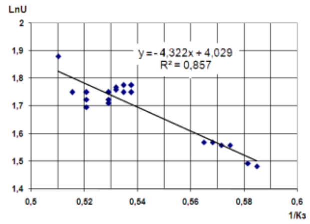


Figure 2 - Calibration dependence of the PAN-1 device for selection S-6524 with a sample weight of 150 g and a frequency of 150 Hz.

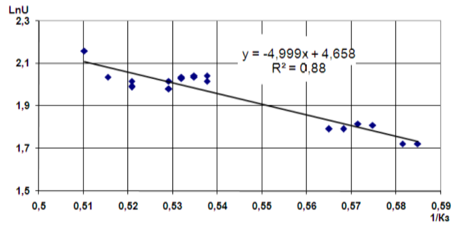


Figure 3 - Calibration dependence of the PAN-1 device for selection S-6524 with a sample weight of 150 g and a frequency of 200 Hz.

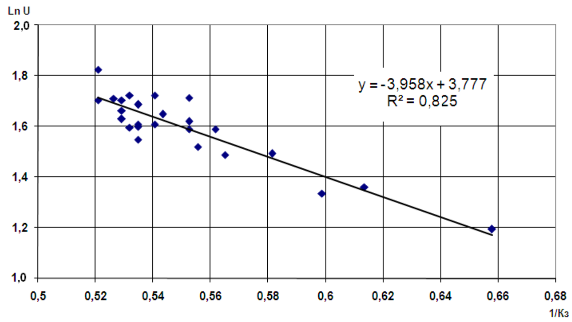


Figure 4 - Calibration dependence of the PAN-1 instrument for Bukhara 8 selection with a sample weight of 150 g and a frequency of 150 Hz

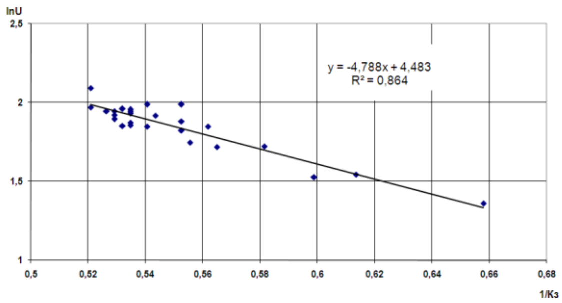


Figure 5 - Calibration dependence of the PAN-1 instrument for selection Bukhara 8 with a sample weight of 150 g and a frequency of 200 Hz

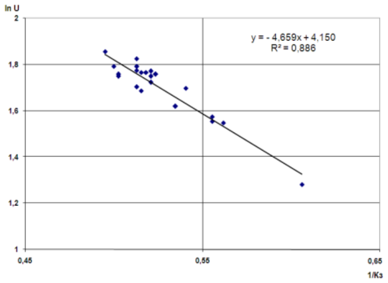


Figure 6 - Calibration dependence of the PAN-1 device for selection Andijan 35 with a sample weight of 150 g and a frequency of 150 Hz.

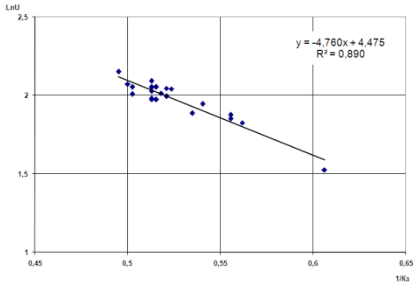


Figure 7 - Calibration dependence of the PAN-1 device for selection Andijan 35 with a sample weight of 150 g and a frequency of 200 Hz.

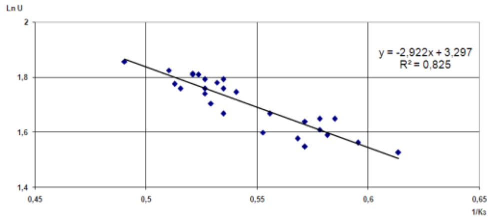


Figure 8 - Calibration dependence of the PAN-1 instrument for Namangan 77 selection with a sample weight of 150 g and a frequency of 150 Hz

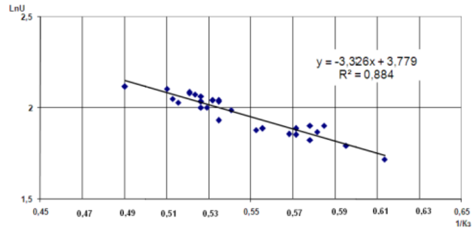


Figure 9 - Calibration dependence of the PAN-1 instrument for Namangan 77 selection with a sample weight of 150 g and a frequency of 200 Hz.

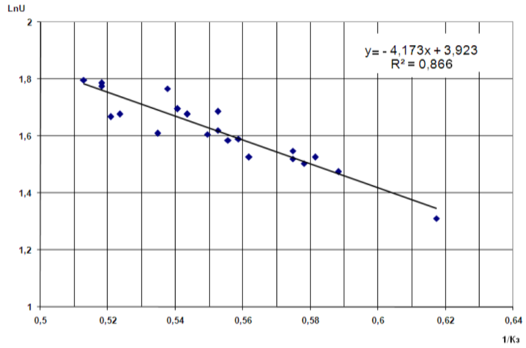


Figure 10 - Calibration dependence of the PAN-1 device for Sultan selection with a sample weight of 150 g and a frequency of 150 Hz.

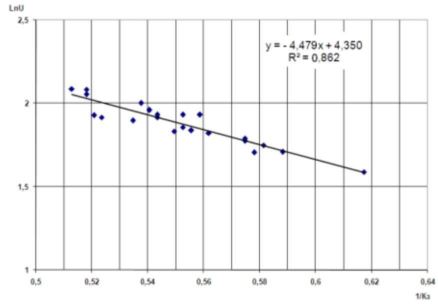


Figure 11 - Calibration dependence of the PAN-1 instrument for Sultan selection with a sample weight of 150 g and a frequency of 200 Hz.

The solid lines on the graphs show the following equations, constructed by approximating the experimental data:

breeding variety S-6524

$\ln U_{150} = - 4,3222/ \boldsymbol{К_з} + 4,0293,$ $R^2 = 0,857$

$\ln U_{200} = - 4,9999/ \boldsymbol{К_з} + 4,658,$ $R^2 = 0,88$

breeding variety Bukhara 8

$\ln U_{150} = - 3,9585/ \boldsymbol{К_з} + 3,777$ $R^2 = 0,825$

$\ln U_{200} = - 4,7884/ \boldsymbol{К_з} + 4,4834,$ $R^2 = 0,864$ (10)

breeding variety Andijan 35

$\ln U_{150} = -4{,}659 / K_з + 4{,}1504 \qquad R^2 = 0{,}886$

$\ln U_{200} = -4{,}706 / K_з + 4{,}458, \qquad R^2 = 0{,}89$

breeding variety Namangan 77

$\ln U_{150} = -2{,}922 / K_з + 3{,}298 \qquad R^2 = 0{,}826$

$\ln U_{200} = -3{,}326 / K_з + 3{,}779 \qquad R^2 = 0{,}885$

breeding variety Sultan

$\ln U_{150} = -4{,}1734 / K_з + 3{,}222 \qquad R^2 = 0{,}867$

$\ln U_{200} = -4{,}4792 / K_з + 4{,}3503 \qquad R^2 = 0{,}885$

Analysis of results. From equations (10) and graphs in the figures, it follows that between the logarithm of the output signal lnU and the reciprocal of the maturity coefficient 1/Kз there is a linear relationship with an approximation coefficient R^2=0.825-0.886 at a frequency of 150 Hz and R^2=0.864-0.89 at a frequency 200 Hz. This confirms the consistency of theoretical calculations in formula (9) with experimental results. At the same time, for all breeding varieties, the approximation coefficient was obtained higher at a frequency of 200 Hz, which indicates the need to choose this frequency as a working one when choosing a measurement mode.

From the above research results, it follows that as an algorithm for calculating the maturity coefficient from the measured value of the output signal from formula (9), we obtain the following expression:

$$K_з = \frac{A_1}{A_0 - LnU} \qquad (11)$$

Here A_0 and A_1 are constant coefficients set for each selection separately when calibrating the device.

Conclusion. As a result of the conducted research, a new method and device for express analysis of a variety without ginning samples of seed cotton on large samples has been developed. Sample weight is 150 g, measurement time of one sample is 1 min.

When using a new device at procurement points, the time spent in determining the grade from 20-25 minutes to 1-2 minutes, which allows the introduction of instrumental acceptance of seed cotton for each delivered batch. This makes it possible to complete batches of seed cotton with a uniform grade characteristic and, during processing, obtain a more uniform yarn and increase its competitiveness in the world market. Farmers better pay for seed cotton delivered and reduce the downtime of their transport.

Reference

1. Yudin E.Ya., Osipov G.Ya. etc. Sound-absorbing materials, - M .: Stroyizdat, 1966, 247 p.
2. A. Ahmedov. Research on the creation of an acoustic laboratory device for determining the grade of raw cotton and cotton fiber. Dissertation for the degree of candidate of technical sciences, Tashkent, 1980, 187 p.
3. A.Akhmedov, Yu.D. Yakubov. Acoustic method for assessing the quality of cotton fiber. Scientific and technical magazine of the Uzstandart agency "STANDART", No. 2/2007, p.27.
4. A. Ahmedov. Acoustic method for non-destructive testing of the micronaire index of cotton fiber. // "STANDARD". - 2012. - No. 2. – S.36–37.
5. A. Akhmedov. On the issue of choosing modes for measuring the micronaire

index of cotton fiber on an acoustic device. // "STANDARD". - 2012. - No. 2. – pp. 42–44.

6. A. Ahmedov. On the influence of the mass of the sample on the convergence of the results of measurements of the microneure index on an acoustic device. Scientific and technical magazine of the Uzstandart agency "STANDART", No. 3/2012.
7. A. Ahmedov. On the acoustic method of non-destructive testing of the micronaire index of cotton fiber. Scientific and technical journal of the Uzstandart agency "STANDART", No. 2/2012, p.36.
8. A. Akhmedov, Yu.D. Yakubova "Study of the influence of state parameters of samples on the modes of measuring the micronaire index on an acoustic device", Collection of works "Technical sciences - from theory to practice": materials of the XVII international scientific and practical conference (Part II) (Novosibirsk, 2013), p.105 -112.
9. Development of an acoustic device for determining the variety of raw cotton by the coefficient of maturity PAN-1 by the express method with the issuance of technical requirements for R & D, research report (final) of Pakhtasanoat ilmiy markazi JSC, leader A. Akhmedov - topic 1614. Tashkent, 2017, 79 p.
10. A. Akhmedov Acoustik and device for measurement micronaire index of cotton fiber. China Science & Technology Overvise. 2012 № 12. p.37-38
11. Akhmedov A. "Density influence of a measured cotton fiber sample on repealabilitiy of measurememts of a micronaire index on an acoustic device" "2nd international scientific Conference "European Applied Sciences: modern approaches in scientific researches" Confernce papers (Vol. 3), Stuttgart, Germany/02.2013. p. 18-19.
12. A. Axmedov, Y.D. Yakubova/ Issledovanie vliyaniya parametrov sostoyaniya obrazsov na rejimi izmereniya pokazatelya Mikroneyr na akusticheskom pribore. Cbornik trudov "Texnicheskie nauki- ot teorii k praktike": Materiali XVII Mejdunarodnoy nauchno-prakticheckoy konferensiya (Chast II) Novosibirsk ,2013 g.
13. A. Axmedov, Y.D. Yakubova. Ob attestasii metodiki vipolneniya izmereniy lineynoy plotnosti xlopkovogo volokna na akusticheskom pribore. // "STANDARD[1]. - 2012. - №4. - s.26-28.
14. A. Axmedov, Y.D. Yakubova. Ob ispitanii po proverke metrologicheskix xarakteristic akusticheskom pribora Mikroneyr// "STANDARD[1]. - 2013. - №2. - s.45-47.
15. Prof. G.N. Kukin, phof. A.N. Soloveov. Tekstilnoe materialovedenie, chast II, Mqskva, 1981, 318 s.
16. ISO 2403:2014 Textiles - Cotton fibres - Determination of micronaire value. International standard, www.iso.org.
17. ISO 139:2005 Textiles- Standard atmospheres for conditioning and testing. International standard, www.iso.org.