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Exploring the Efficiency of Experimental Construction of Sorting Ginned Cotton Seed Machine

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Abstract

In this paper, research has been conducted to increase the quantity of fiber produced in the enterprise by creating a sorting device for spun seeds, dividing them into fractions by geometric dimensions, and by re-ginning, separating those with long fibers. A new model was developed for geometric sorting of cotton seeds in the harvest, and experiments determined its effectiveness and the optimal values of the factors affecting the efficiency using mathematical modeling. Based on the results of the study, graphs of the influence of factors on device performance and on device efficiency were constructed.

Keywords

Cotton Seeds, Cotton Fiber, Fractions, Sorting Machine, Short Fiber, Air Flow, Vibration Machine, Vibration Frequency

1. Introduction

In the global market in recent years, consumers have demanded a certain assortment and quality indicators of cotton products. From this point of view, the supply of consumer goods with specified qualitative and quantitative indicators, the development of "smart" technologies that control the quality and quantity of cotton products, the identification and elimination of processes and factors that negatively affect the quality and quantity of products at each stage of production. The development of technical solutions, all technological processes, it should be noted that topical issues of the industry, including the separation of cotton fiber and improving the processing of ginned seeds, are on the agenda [1] [2] [3].

After the ginning process of cotton, the cotton fiber is subjected to various impurities and pressed. Dirty seeds are sent to processes such as sintering and delamination and fibers such as fluff is produced. Of great importance is the sintering and delamination of cotton seeds, that is, the separation of the remaining cotton fiber and short fiber after ginning. As a result of primary processing of cotton seeds at processing plants, fibers, short fibers, seeds and technical seeds, feathers and bark products were obtained [4] [5].

The main focus of the study is to improve the quality of the pile and prevent damage to the seeds of the genus, as well as increasing the production of spinning fibers.

In fact, the technological process of cleaning and regeneration is based on the principle of transferring seeds to the process one or more times or until the material is removed from the regenerating machine. This method increases the cost of labor, cleaning or regeneration. In this process, the quality of cleaning and regeneration will depend on the number of passes through this machine, which will depend on how well the separation of the impurity mixture is selected and on the operation of mechanical devices and working bodies for its separation.

As is known, the following methods are used for separation [6] [7]:

- Separation by air flow;
- Separation by mechanical means;
- Separation of material surface by difference;
- Combined method.

The aim of the study is to ensure the required quality of fibers and fluff by developing and implementing effective technology for the processing of cotton seeds, ginning as a result of comprehensive studies. This fiber processing technology involves eliminating an undesired transition to each other by cleaning and sorting the seeds of the genus, reducing the process by re-mixing the fractions and leveling the remaining fractions in accordance with the degree of blur and, therefore, improving the quality and quantity of the product.

Currently, the industry uses a more mechanical approach to catch poorly harvested cotton seeds and loose fibers, using this method to study the frequency of occurrence of fibers and seeds during cotton processing [8] [9].

2. Method

To study the movement of cotton seeds, S-6524 sort cotton was selected for experiments. At a ginnery, the total number of cotton seeds is 3% - 4% of cotton seeds, dirty impurities, 1.5% - 2.5% of cotton seeds, 45% - 60% of disposable linear seeds, 25% - 35% of double flax seeds, from 5% to 6% of long and free fibers [10].

One of the main advantages of the vibratory sorter in poor fibers and free processing of fibers is the absence of negative effects on the material. In the "Primary processing of cotton" laboratory at the Namangan Institute of Engineering and Technology, a vibrating device for selecting insect seeds was developed and prepared.

The experimental vibration device (**Figure 1**) consists of a frame 1, an eccentric shaft 2, a rod 3, an elastic column 4, a vibrating trolley 5, a rod 6 for

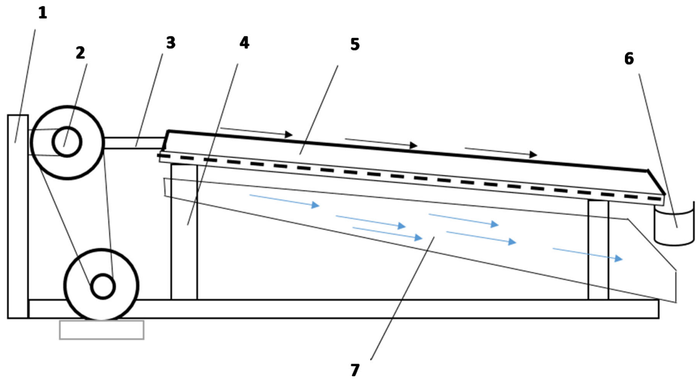

Figure 1. Scheme of a vibrating device.

transporting insulated pieces of cotton and a groove 7 for transferring residual cotton seeds.

The test unit operates in the following order: through the feed fractions of the ginned seeds, an oscillating device mounted on elastic columns gets onto a clean surface of the carriage, and the device receives vibrational motion from a centrifugal shaft. Deformation waves propagate due to vibration of the seed mixture on the surface of the mesh.

2.1. Determination of Technological Parameters

Experimental studies were conducted to determine the amplitude-frequency characteristics of the generator. The experiments were carried out at the following amplitude-frequency values:

The amplitude of the oscillations: $A = 7; 12; 17; 22; 27$ mm;

Vibration frequency: $p = 3; 4; 5; 6; 7$ Hz.

The transfer of material was carried out in a single layer by the feeder and was regulated using a variator. The results of the study are presented in Table 1.

Vibration of poorly ginned cotton seeds and free fibers was carried out at different tilt angles ($\alpha = 10^\circ$ - 20°), and a further increase in the tilt angle to increase fertility was impossible due to the possibility of proper orientation of cultivated seeds.

A graph of changes in the retention efficiency for various vibration amplitudes was built on the basis of Table 1 (Figure 2).

Analysis of the obtained graph shows that the separation of normally treated seeds from experimental results occurs at high vibration frequencies ($p = 5$ - 6 Hz) with an efficiency of 80% - 85%. A further increase in frequency to 7 Hz led to a decrease in the separation of normally treated seeds. After processing the experimental results, a regression equation was obtained that describes the relationship between retention efficiency and vibration frequency.

In addition to factors affecting screening efficiency in the above example, one factor must be taken into account—the thickness of the treated seeds on the screening surface. Therefore, further studies were carried out taking into account this factor.

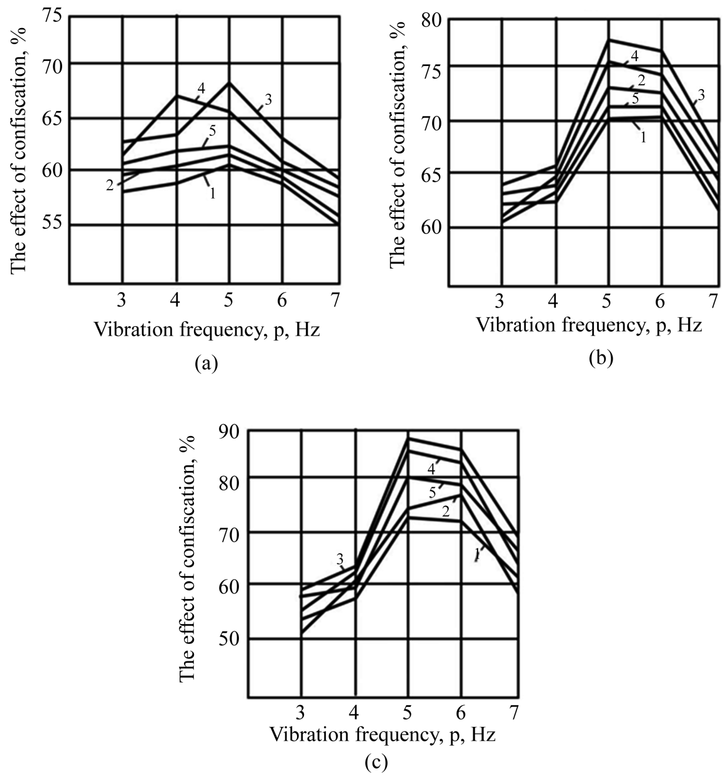

Figure 2. Graphs of the effectiveness of the retention of the vibrator on the slope: (a) a = 10˚; (b) a = 20˚; (c) a = 15˚: 1—A = 7 mm; 2—A = 12 mm; 3—A = 17 mm; 4—A = 22 mm; 5—A = 27 mm.

Table 1. The efficiency of seed conservation during operation of the vibrating device in different modes (%).

Angle of vibrating camera, α	Vibration frequency Hz (speed·min^{-1}), p	Amplitude, *mm*, A				
		7	12	17	22	27
10	3 (180)	61.5	63	64.2	61.4	60.6
	4 (240)	64.2	61.1	66.4	65.8	64.6
	5 (300)	70.2	71.1	74.2	76.7	71.3
	6 (360)	70.6	73.4	76.1	74.6	72.1
	7 (420)	64.1	66.7	67.7	66.1	63.8
15	3 (180)	58.7	63.1	63.7	62.7	61.5
	4 (240)	62.8	64.3	64.5	65.2	63.1
	5 (300)	71.2	74.0	77.7	76.4	72.3
	6 (360)	82.5	84.5	84.6	87.9	74.5
	7 (420)	72.6	75.2	77.2	81.0	78.9
20	3 (180)	68.0	71.2	72.4	72.1	69.8
	4 (240)	68.6	71.8	73.7	72.1	69.7
	5 (300)	60.5	72.1	68.6	66.4	62.3
	6 (360)	59.1	60.0	62.4	61.8	60.8
	7 (420)	56.4	58.5	59.7	58.4	55.3

During the operation of the vibrating device, the upper and lower layers of the material vibrate differently, the lower layer with normal seeds vibrates with A_1 and frequency p_1 with the same amplitude as the working fluid, and the upper layer with unprocessed cotton seeds, with amplitudes A_2 and p_2. Inequality $p_2 \neq p_1$; $A_2 \neq A_1$ preserves.

Seeds are flexible bending material that is deformed by its physical and mechanical properties, with a partial change in the upwelling p_1 and A_1.

The aim of the experiment was to study the dependence of the retention efficiency on the thickness of the processed layer on the device.

Prior to the experiment, factors that may affect the characteristics of the device, such as the frequency and amplitude of the vibration, including the speed of the eccentric shaft, the tilt of the carriage, the initial weight of the selected seeds, the operating time of the device and the weight of the pulp extracted from poorly welded seeds.

The formula used in [11] can determine whether the performance of a device depends on the speed of movement of cotton seeds. Various vibrations are performed by adjusting the amplitude of the device and frequency r. In addition, the slope of the rectangular surface a and the angle of the directed vibration β influence the speed of the material.

The main criteria for evaluating the vibration process are amplitude-frequency characteristics. As the amplitude-frequency characteristics change, the efficiency of the vibration process changes. Based on this, it was necessary to determine the optimal amplitude-frequency characteristics of the seed sorting unit in order to keep the seeds more productive.

Experimental studies of the following amplitude-frequency characteristics were carried out in the horizontal direction of vibration:

- Amplitude of vibrations, mm;
- Oscillation frequency, Hz.

An analysis of these lines depending on the thickness of the material and the vibration frequency of the slicer showed that the efficiency of the process decreases with increasing layer thickness. If the minimum thickness of the processed layer with an amplitude of 17 mm Hz is 20 - 25 mm, this gives an efficiency of 62% - 63%, with h = 45 - 50 mm this value is 5% - 10% lower. Changes in the intensity of vibration with the same thickness of the seed layer affect the retention efficiency. For example, the most effective layer has a thickness of 20 mm and is 82% - 83% in Hz, and this is 77% in Hz.

Analyzing the graph in **Figure 3**, we can see how changes in process efficiency depend on the amplitude, frequency, and thickness of the processed layer.

According to the results of the study, the optimal thickness of the treated layer is selected at h = 20 - 30 mm, where conventional treated seeds are quickly separated through the mesh latch and provide a minimum number of seeds in the fiber mass.

Mathematical processing of the results of the above studies was performed using modern computer technology with three factors (2^3) based on full-scale

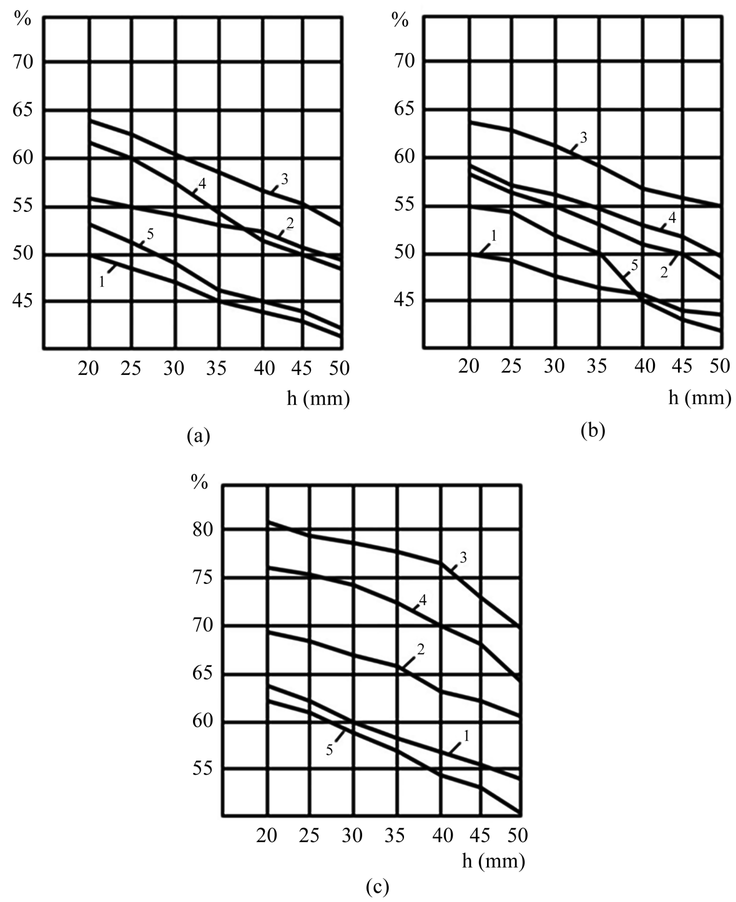

Figure 3. Effect of seed layer thickness on vibrator efficiency: (a) $A = 10$ mm; (b) $A = 15$ mm; (c) $A = 20$ mm. 1—3 Hz; 2—4 Hz; 3—6 Hz; 4—7 Hz; 5—8 Hz.

experiments (Table 2 and Table 3).

Impact factors: X_1—vibration frequency; X_2 is the amplitude of the oscillations; X_3—layer thickness.

Efficiency of the device: Y_1—for sorting small impurities (5.5 mm with the surface of the gap), Y_2—for clean isolated seeds (surface 7 mm), Y_3—for seeds of residual fiber (surface 10 mm), %.

The selection of input factors has been taken into account to ensure the power of the device when selecting crazy seeds and efficient operation.

The following models were used to create mathematical models:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + \beta_{123} X_1 X_2 X_3$$

Here: $\beta_0, \beta_1, \beta_2, \beta_3, \beta_{12}, \beta_{13}, \beta_{23}, \beta_{123}$

Regression coefficients:

$$\beta_0 = \frac{1}{8}\sum_{j=1}^{8} \bar{Y}_j ; \beta_i = \frac{1}{8}\sum_{j=1}^{8} X_{ij} \bar{Y}_j ; \beta_{i2} = \frac{1}{8}\sum_{j=1}^{8} X_{ij} X_{2j} \bar{Y}_j ; \beta_{i,2,3} = \frac{1}{8}\sum_{j=1}^{8} X_{ij} X_{2j} X_{3j} \bar{Y}_j \quad (1)$$

Here: X_{ij}, X_{2j}, X_{3j} encoded layer values; *j* is the number of experience;

We calculate the regression coefficients:

Table 2. Factors affecting the process and their limits.

Humidity	Stages of change factors		
	X_1 (Hz)	X_2 (mm)	X_3 (mm)
Top	7	20	50
Bottom	3	10	20
Main	5	15	35
Change range	2	5	15

Table 3. TOT 2^3 matrix.

N°	Coded value of factors				Values of output parameters (output parameters)		
	X_0	X_1	X_2	X_3	$\bar{Y}_1$	$\bar{Y}_2$	$\bar{Y}_3$
1	+	−	−	−	62.4	60.5	61.2
2	+	+	−	−	65.4	64.1	63.1
3	+	−	+	−	71.8	68.3	67.8
4	+	+	+	−	79.2	78.4	77.8
5	+	−	−	+	59.1	57.8	60.4
6	+	+	−	+	60.1	61.7	58.5
7	+	−	+	+	59.6	58.1	57.8
8	+	+	+	+	61.1	61.8	60.2

$$Y_{R1} = 64.8 + 1.6X_1 + 3.08X_2 - 4.68X_3 + 0.68X_1X_2 - 0.88X_1X_3 - 2.71X_2X_3 - 0.05X_1X_2X_3$$

$$Y_{R2} = 63.8 + 2.66X_1 + 2.81X_2 - 3.38X_3 + 0.78X_1X_2 - 0.76X_1X_3 - 2.71X_2X_3 - 0.08X_1X_2X_3$$

$$Y_{R3} = 63.3 + 1.55X_1 + 2.55X_2 - 4.12X_3 + 1.55X_1X_2 - 1.42X_1X_3 - 0.77X_2X_3 - 0.052X_1X_2X_3$$

We study the values of the coefficients in the regression equation obtained by the Student criterion [8], and write a model taking into account the significant regression coefficients:

$$\begin{aligned} Y_{R1} &= 64.8 + 1.6X_1 + 3.08X_2 - 4.68X_3 \\ Y_{R2} &= 63.8 + 2.66X_1 + 2.81X_2 - 3.38X_3 \\ Y_{R3} &= 63.3 + 1.55X_1 + 2.55X_2 - 4.12X_3 + 1.55X_1X_2 - 1.42X_1X_3 \end{aligned} \quad (2)$$

We check the adequacy of the model obtained using the Fisher criterion:

$$F_p = \frac{S_{a\partial}^2}{S^2(Y)} \quad (3)$$

In here: $S_{a\partial}^2$ —the variance depends on the suitability of the model (This variance is often called residual dispersion).

If we calculate the regression coefficients in numbers, S_{ad}^2 —can be calculated in the following formula:

$$S_{a\partial}^2 = \frac{m}{N-M}\sum_{j=1}^{N}\left(\bar{Y}_j - Y_j\right) \tag{4}$$

For our case, $m = 3$, $N = 8$, $M = 3$. In this case:

$$S_{a\partial}^2 = \frac{3}{8-3}\times 5.3465 = \frac{3}{5}\times 5.3465 = 3.2079 \tag{5}$$

$$F_p = \frac{S_{ad}^2}{S^2(Y)} = \frac{3.2079}{1.43} = 2.2433 \tag{6}$$

Define the values of the Fisher criteria table:

$$F_{\text{т}}\left\{P_\alpha = 0.95^0;\ f_1 = N - M = 8 - 3 = 5;\ f_2 = N(m-1) = 8(3-1) = 16\right\} = 2.85$$

Based on the Fisher criteria, the model is adequate [12]. For our case, the models obtained in this way represent a sufficient volume of the research process.

The retention efficiency was determined by changing the frequency and amplitude of vibration depending on the thickness of the processed material (**Figure 3**).

Thus, the analysis of the regression equations once again showed that the vibration apparatus increased with increasing r thickness with increasing r frequency (6 Hz) and amplitude A (20 - 22 mm), decreasing with increasing layer thickness.

Production tests were carried out on a new device according to the results of theoretical studies.

2.2. Experiment

Tests of the new device under production conditions were carried out in accordance with applicable law. Industrial studies were carried out in the industrial class S-6524 of the first and second grades with a moisture content of 6% - 12%, dirt of 1.9% - 4.8% and a blur of 7% to 12%. Sampling after the device was carried out in accordance with the available methods [13] [14] [15].

This experiment shows that at 6 Hz the best efficiency is ensured by an oscillation amplitude of 20 mm and an inclination angle of 13˚ (**Table 4**). We will also consider this conclusion in a graphical representation (**Figure 4**).

Now we get the same experiment by changing the frequency of oscillation and the angle of inclination of 13˚ and 20 mm with the amplitude of the oscillations, which gave good results in the experiment. The results of the experiment are presented in **Table 5**.

Based on this experience, the oscillation is 20 mm and the tilt angle is 13˚ degrees, providing the best efficiency at 6 Hz. Graphs were built for this condition (**Figure 5**).

In addition, machine performance was monitored for each case. Productivity changes were between 1580 and 3650 kg/h. The maximum efficiency was at 22 mm, the angle of vibration of 18˚ and 7 Hz, but the sampling efficiency was only

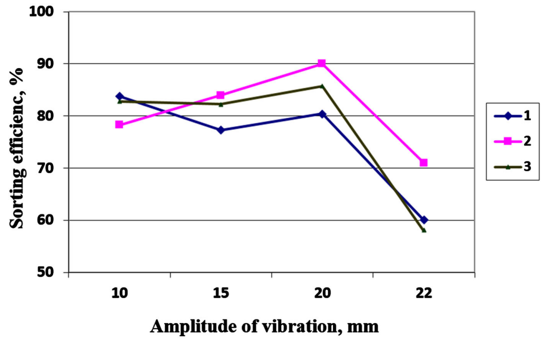

Figure 4. Experimental results depending on factors. 1—$\alpha = 10˚$; 2—$\alpha = 13˚$; 3—$\alpha = 18˚$.

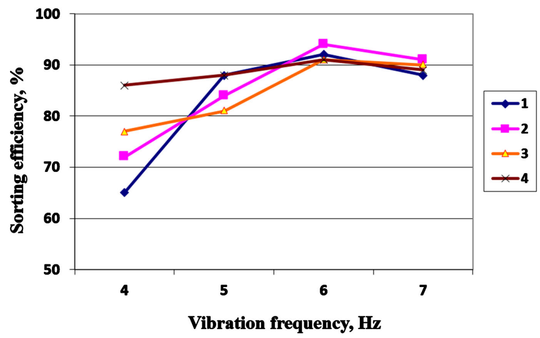

Figure 5. Depending on factors, section efficiency. 1—pollution; 2—pure seeds; 3—the seeds of a linter; 4—fibrous seeds.

Table 4. The results of experiments on the effectiveness of key factors.

Amplitude of vibration, mm	Vibration frequency, Hz	Slope surface sorting	Efficiency, %			
			1-section	2-section	3-section	Separation drum
20	7	10	78	82	75	87
		13	88	92	90	90
		18	80	90	83	90
15		10	74	72	75	88
		13	75	88	85	88
		18	71	87	81	90
10		10	80	82	85	88
		13	85	70	71	87
		18	82	79	81	89

Table 5. The experimental results of determining the effectiveness at different vibration frequencies.

Amplitude of vibration, mm	Vibration frequency, Hz	Slope surface sorting	Efficiency, %			
			1-section	2-section	3-section	Separation drum
20	4	13	65	72	77	86
	5		88	84	81	88
	6		92	94	91	91
	7		88	91	90	89

81%. With the values of the factors providing the highest efficiency (93%), rational productivity was achieved on average 3500 kg/h.

The results of the above experiments show that the overall efficiency was 90% - 93% with an amplitude of mm, an angle of inclination, and an oscillation frequency of Hz.

Theoretically, if the layer of seeds of a madman is treated on a working surface 30 mm thick, he will be able to achieve maximum productivity at 3500 kg/h. When the device will work with such power, the plant will be able to work off the seeds of the demon. Therefore, further studies were devoted to studying the possibility of high throughput at a thickness of 30 mm from the feeder.

The experimental results are presented in Table 6.

As can be seen from the Table 6, when a layer with a thickness of 30 mm provides higher productivity, high efficiency is achieved with values of sufficient amplitude and frequency of oscillations. Therefore, the rational value of the thickness is 30 mm, and if the thickness exceeds this value, case studies have shown a significant decrease in efficiency.

Subsequent studies conducted tests to compare existing technology and the technology used in the new classifier. During the tests, the number of fibers secreted by reindeer fibers, pile contamination and seed damage were studied.

3. Results

The results of production experiments are shown in Table 7.

Table 6. Seed thickness experiment results.

Layer thickness, mm	Productivity, kg/h	The moisture content of the seeds, %	Efficiency, %			
			1-section	2-section	3-section	Separation drum
10	2800		88	90	92	90
20	3100	13	87	91	92	91
30	3500		86	92	91	90

Table 7. Production test results.

N˚	Pointer name	Units	Amount	
			When an existing device works	When the new presented device is working
1.	Fiber output	%	32.0	32.52
	Dirty pile			
2.	After 1st pass	%	4.3	2.1
	After the 2nd pass		6.4	3.2
	Seed Injury			
3.	Primary	%	3.9	3.9
	After Qualification		4.7	4.1
4.	Lint Energy Consumption	kVt	86,292	82,012

The data presented in Table 7 shows that the amount of fiber increased as a result of the introduction of new insect seeds, as well as improved cotton and seed quality. Fiber excretion increased by 0.52% due to sorting and re-ginning of fibrous seeds with bulk material. The ability to sort granular mass into a fractional separation unit significantly reduced pile contamination due to the separation of crushed seeds and other impurities.

The spinning ability of fibers obtained by insulting ginned cotton seeds is based on further research.

The results of the theoretical study in this study were fully confirmed by the results of tests in the factory. Checking the operation of the new sorting plant at the ginnery, it was proved that it is recommended to use this machine for the cotton seed selection process in cotton processing technology.

4. Conclusions

1) During the study, an experimental device for the selection of ginned seeds was developed. In this device, the efficiency of seed selection depends on the frequency, amplitude and thickness of the seed mass. Based on the results of studies, it was found that the separation of seeds of normal seeds was effectively carried out with a frequency of 6 Hz with an efficiency of 80% - 85%.

2) The effect of layer thickness on seed selection efficiency was also investigated. Based on the results of the study, it was found that the optimal thickness of the treated layer was chosen at h = 20 - 30 mm. It was found that normal cotton seed production was carried out through a net, and that the seeds remained in the fiber mass to a minimum.

The obtained regression equations once again prove that the retention efficiency of the vibrating device decreases with increasing layer thickness due to an increase in r vibration frequency (maximum 6 Hz) and amplitude (average 20 - 22 mm).

3) For production tests, a device was developed and introduced into the technological process with the ability to efficiently sort insulated fur of a new design.

The efficiency of sorting seeds by fractions according to the results of tests carried out when introducing a new device was 90% - 93%, seed damage decreased by 0.6%, and fiber yield increased by 0.52%.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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