Study of the 125 mm diameter seed-removing tube performance

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Abstract. The article presents the results of a study of the performance of a seed-removing (perforated) tube with a diameter of 125 mm. To study the practical performance of the seed-removing tube with a diameter of 125 mm, a 30-saw cotton gin with a cleaning section was developed. As a result of the study, a regression equation was derived to determine the productivity of the seed-removing tube, depending on the density of the raw cotton roller and the rotational velocity of the perforated tube. As a result of the research, a decrease in the productivity of the seed-removing tube (from 149.75 to 54.91 kg/h) was established with a decrease in the density of the raw cotton roller (from 227 to 219 kg/m3) and an increase in the rotational speed of the seed-removing tube (from 280 to 360 rpm).

1 Introduction

P.N. Tyutin, A.S. Ibragimov and others [1-3] developed original designs of saw gins with accelerators. Analytical expressions for determining the angular velocity of the raw cotton roller and the diameter of the accelerator were compiled.

In [1], Tyutin P.N. et al. considered the movement of a raw cotton roller inside the working chamber with pappus and seeds as a continuous medium under the impact of a saw cylinder and a perforated tube on it. The amount of fibers removed by saws from the seeds, the amount of clean seeds carried into the cylinder, and the pressure required to convey the clean seeds were determined.

The studies by P.N. Tyutin, M. Tillaev, N.K. Safarov and A.S. Ibragimov proved the fundamental possibility of installing an additional seed outlet from the central part of the raw cotton roller by means of a driven tubular seed-removing device, inside which a seed auger is installed, which makes it possible to increase the productivity of ginning [1-5].

In particular, N.K. Safarov proposed a saw gin with a seed-removing device with the following design parameters of the tube [4]: tube diameter ∅165mm, with a cross section of 9.5%; rotation frequency - 290 min^{-1}; hole orientation (oval 10x20) on the tube surface 44.5x43.1 mm with the optimum capacity of up to 12 kg per saw per hour and seed auger up to 380 kg/hour.

In [6], D.M. Mukhammadiev proposed a 156-saw gin with the optimal rotational speed of the seed-removing tube of 388.4 min^{-1} and a productivity of 14.1 kg per saw per hour and

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a seed auger up to 147.2 kg/hour. To save energy and simplify the design, the auger was installed permanently. However, the above studies were conducted in a single-chamber design of saw gins.

For energy and resource saving, a new design of saw gin with a cleaning section was proposed in [7], where the volume of the working chamber was reduced by 25% [8, 9].

Therefore, the purpose of the experimental study is to determine the optimal value of the productivity of the seed-removing device, depending on the density of the raw cotton roller and the rotational speed of the seed-removing (perforated) tube with a diameter of 125 mm.

The objective of the experimental research is to study the effect of the density of the raw cotton roller and the rotational speed of the seed-removing (perforated) tube with a diameter of 125 mm on the increase in the performance of the seed-removing device.

Planning an experimental study makes it possible to purposefully conduct it and choose the number of experiments and the conditions for their implementation, and solve the problem with the required accuracy [10].

2 Materials and methods

Preliminary studies have shown that the main control factors affecting the performance of the seed-removing device are X_1 - the density of the raw cotton roller and X_2 - the speed of the seed-removing (perforated) tube with a diameter of 125 mm. Their set values fluctuate within X_1=219-227 kg/m^3, and X_2 =280-360 rpm.

To determine the influence of the main factors X_1 and X_2 we use a second-order orthogonal planning matrix for a two-factor process. The choice of such a matrix is due to the fact that the linear mathematical model is inadequate for the process under study. The matrix of orthogonal planning of the second order for a two-factor process with the condition of conducting the experiment is presented in Table 1.

Table 1 shows the conditions for the experiment. The coding of the values of the levels of factors is performed according to the following formula

$$x_{Bi} = +1 = \frac{X_{Bi}^{H} - X_{Oi}^{H}}{\Im_i}, \qquad x_{Hi} = -1 = \frac{X_{Hi}^{H} - X_{Oi}^{H}}{\Im_i} \tag{1}$$

The experiment was conducted on a 30-saw cotton gin with the following densities of raw cotton roller ρ - 219; 223; 227 kg/m^3 and rotational speed of the perforated tube n_t - 280; 320; 360 mm.

Table 1. Experiment planning matrix.

№	X_o	X_1	X_2	$X_1 \cdot X_2$	$(X_1')^2$	$(X_2')^2$	Working matrix	
							ρ, kg/m^3	n_t, rpm
1	+	+	+	+	0.33	0.33	227	360
2	+	-	+	-	0.33	0.33	219	360
3	+	+	-	-	0.33	0.33	227	280
4	+	-	-	+	0.33	0.33	219	280
5	+	-	0	0	0.33	-0.67	219	320
6	+	+	0	0	0.33	-0.67	227	320
7	+	0	-	0	-0.67	0.33	223	280
8	+	0	+	0	-0.67	0.33	223	360
9	+	0	0	0	-0.67	-0.67	223	320

Before the experiment, the volume of the working chamber and the mass of the raw cotton roller were measured. The experiment was conducted in the following sequence: the required density of the raw cotton roller and the rotational speed of the perforated tube were provided in the process of the cotton gin. As a result of the experiments conducted, the values of the productivity of the seed-removing tube were obtained.

To obtain reliable results from the study, the experiment was conducted by processing the same batch, grade, and variety of cotton fiber (C-6524, II-grade, hand-picked).

The fiber before the cotton gin process was pre-dried and cleaned in accordance with the regulated technological process. The moisture content of raw cotton corresponded to the standard norms (7-8%). The experiment was conducted in the following sequence: preparation of the gin saw for operation, setting the saw cylinder, seed-removing tube in operation and idle work, and start-up of the gin saw feeder. Seed sampling for laboratory analysis was done according to the sampling procedure [10].

3 Results and discussion

According to the requirements of orthogonal planning of the experiment [10], by changing the interval of variation in the density of the raw cotton roller and the frequency of rotation of the seed-removing tube, repeated experiments were conducted to determine the pattern of change in the productivity of the seed-removing tube (see Table 2).

The mathematical processing of the experimental results is shown in Table 3.

Table 2. The results of the experiment on the performance of the seed-removing tube.

№	Values of factors		Repetitions for productivity of the seed-removing tube, seed, kg/h					
	ρ, kg/m^3	n_t, rpm	y_1	y_2	y_3	y_4	y_5	$\bar{y}^n$
1	227	360	119.51	118.31	121.93	124.34	119.51	120.72
2	219	360	56.27	55.71	56.83	57.40	55.14	56.27
3	227	280	148.57	150.07	151.57	153.07	147.07	150.07
4	219	280	78.90	77.32	81.27	78.90	78.11	78.90
5	219	320	68.65	68.85	69.65	69.85	69.25	69.25
6	227	320	138.98	140.19	141.00	141.40	139.38	140.19
7	223	280	110.75	110.11	111.39	111.70	109.80	110.75
8	223	360	84.02	84.26	85.24	85.48	84.75	84.75
9	223	320	98.62	99.48	100.05	100.34	98.91	99.48

Table 3. The results of experimental data processing of the seed-removing tube performance.

№ of test	f_N	S_N^2	$\bar{y}$	$\hat{y}$	$\bar{y}-\hat{y}$	$(\bar{y}-\hat{y})^2$
1	5	5.8293	120.72	120.4002	0.3198	0.1023
2	5	0.7916	56.27	54.9069	1.3631	1.8581
3	5	5.6303	150.07	149.7535	0.3165	0.1001
4	5	2.1788	78.90	77.5402	1.3598	1.8490
5	5	0.2574	69.25	70.4708	-1.2208	1.4905
6	5	1.0548	140.19	139.3242	0.8658	0.7496
7	5	0.6583	110.75	110.9242	-0.1742	0.0303
8	5	0.3855	84.75	84.9308	-0.1808	0.0327
9	5	0.5312	99.48	102.1748	-2.6948	7.2620
Total	45	17.3172	910.38	910.4257	-0.04574	13.4747

Assuming the level of reliability P=0.95 [10], we estimate the accuracy of measurements, for which we determine the variances of the experimental errors by the following formula

$$\sigma^2 = S^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(y_i - \overline{y}\right)^2 \qquad (2)$$

where $\overline{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$ is the arithmetic mean of the measurement results.

In a point estimate with an unknown measurement accuracy, the confidence estimate has the form

$$\left|a - \overline{y}\right| < \mathrm{t(P;k)}\frac{\mathrm{S}}{\sqrt{\mathrm{n}}}, \qquad (3)$$

where factor $t(P;k)$ depends not only on the confidence level, but also on the number of measurements n. Here a is the sought-for true value of the measured parameter. k is the number of degrees of freedom.

With a symmetric confidence estimate, we have

$$(\overline{y} - \varepsilon) < a < (\overline{y} + \varepsilon) \qquad (4)$$

where ε is the measurement error.

We check the homogeneity of the dispersion by determining it according to the Fisher criterion [10]. For f=5 for the maximum variance and f=5 for the minimum table value, the Fisher criterion is F_{tab}=5.05 [10].

Then, by the condition of homogeneity of variances, we obtain:

$$F_{ras} = \frac{S^2_{\max}}{S^2_{\min}} = \frac{S^2_1}{S^2_4} = \frac{5.829}{2.179} = 2.675 < F_{tab} = 5.05\ . \qquad (5)$$

Thus, all dispersions are homogeneous and the experiment conducted has the property of reproducibility.

Substituting certain coefficients, we obtain a regression equation of the following form:

$$y=102.175+34.427 \cdot x_1 - 12.997 \cdot x_2 - 1.68 \cdot x_1 \cdot x_2 +2.723 \cdot x_1^2-4.247 \cdot x_2^2\ . \qquad (6)$$

Let us estimate the coefficients of regression equation (6). Let us define the dispersions of reproducibility:

$$S^2_{vosp} = \frac{S^2_1 \cdot f_1 + S^2_2 \cdot f_2 + ... + S^2_9 \cdot f_9}{f_1 + f_2 + ... + f_9} = 517.3172/45 = 1.924\ . \qquad (7)$$

We determine the values of the error dispersion of the coefficients, taking into account the data given in [10] for k=0

$$S^2_{b_i} = \frac{S^2_{vosp}}{\sum_1^N x^2_{iu}}\ ; \qquad (8)$$

$$S^2_{b_o} = 1.924/9=0.2138; \qquad S^2_{b_1} = S^2_{b_2} = 1.924/6 = 0.3207;$$
$$S^2_{b_{12}} = 1.924/4 =0.481; \qquad S^2_{b_{11}} = S^2_{b_{22}} = 1.924/2 = 0.9621. \qquad (9)$$

We calculate the values of quadratic errors:

$$S_{b_o} = 0.4624 \qquad S_{b_1} = S_{b_2} = 0.5663$$
$$S_{b_{12}} =0.6936 \qquad S_{b_{11}} = S_{b_{22}} =0.9808 \qquad (10)$$

We determine the errors in the estimation of the coefficients by the following formula $\Delta b_i = \pm\frac{t \cdot S_{b_i}}{\sqrt{N}}$.

Here t is the tabular value of Student's criterion; N is the number of experiments for $N=9$, $t=2.262$ [10].

$$\Delta b_o=2.262 \cdot 0.4624/3=\pm0.3483 \qquad \Delta b_1 =\Delta b_2 =2.262 \cdot 0.5663/3=\pm0.4266$$
$$\Delta b_{12} =2.262 \cdot 0.6936/3=\pm0.5225 \qquad \Delta b_{11} =\Delta b_{22} =2.262 \cdot 0.9808/3=\pm0.7389 \qquad (11)$$

Then the confidence interval of the regression coefficients is:

$$\beta_o = 102.175 \pm 0.3483 \qquad \beta_{12} = -1.68 \pm 0.5225$$
$$\beta_1 = 34.427 \pm 0.4266 \qquad \beta_{11} = 2.723 \pm 0.7389 \tag{12}$$
$$\beta_2 = -12.997 \pm 0.4266 \qquad \beta_{22} = -4.247 \pm 0.7389$$

Tables 2-3 show the calculated values of $\hat{y}$ and $\bar{y}$ from the experimental data. Substituting the sum of standard deviations from Table 3, we determine the adequacy variance for equation (6) [10]:

$$S_{ad}^2 = \frac{\sum_1^N n \cdot (\bar{y} - \hat{y})^2}{N - (k+1)} = 13.4747/\ 8 = 1.684. \tag{13}$$

Let us check the adequacy of equation (6) according to the Fisher criterion [10].

$$F_{ras} = \frac{S_{ad}^2}{S_{vosp}^2} = \frac{1.684}{1.924} = 0.875 \leq F_{tab} = 2.16 \tag{14}$$

The tabular value of the Fisher criterion for $f=(N-1)=8$ for the variance of adequacy and $f=(n-1)=44$ for the variance of reproducibility is [10] F_{tab}=2.16, where N is the number of a series of experiments, n is the total number of experiments. The conditions for the adequacy of the mathematical model (6) are met since $F_{ras}=0.875<F_{tab}=2.16$.

Thus, equation (6) statically describes the pattern of change in the productivity of the seed-removing tube.

According to equation (6), a graph of change in the productivity of the seed-removing tube was plotted as a function of the density of the raw cotton roller - x_1 for various values of the rotational speed of the seed-removing tube - x_2 (Figure 1). In addition, a graph of the change in the productivity of the seed-removing tube was plotted as a function of the density of the raw cotton roller - x_1 and the frequency of rotation of the seed-removing tube - x_1 (Figure 2).

Analysis of the graphs in Figures 1 and 2 shows an increase in the productivity of the seed-removing tube (from 54.91 to 149.75 kg/ h) with an increase in the density of the raw cotton roller (from 219 to 227 kg/m^3) and a decrease in the rotational speed of the seed-removing tube (from 360 to 280 rpm).

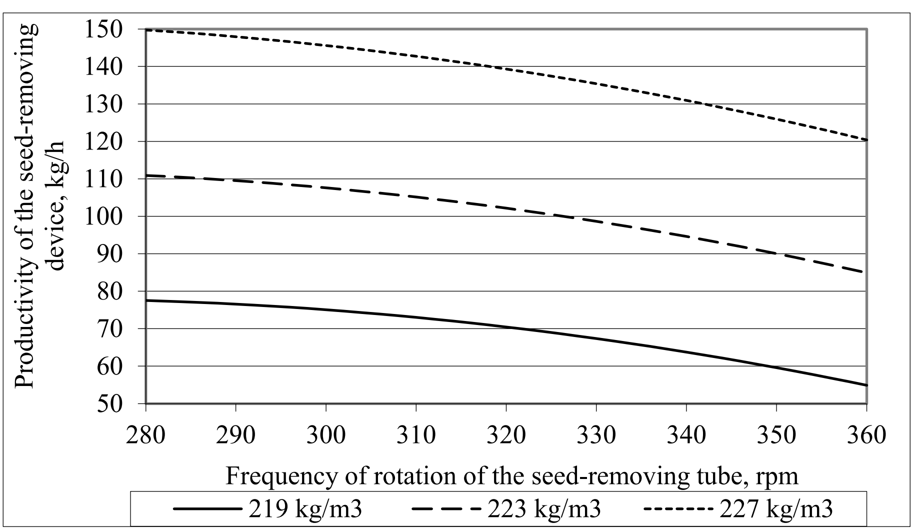

Fig. 1. Change in the productivity of the seed-removing tube depending on the frequency of rotation of the seed-removing tube x_2 at different values of the density of the raw cotton roller x_1.

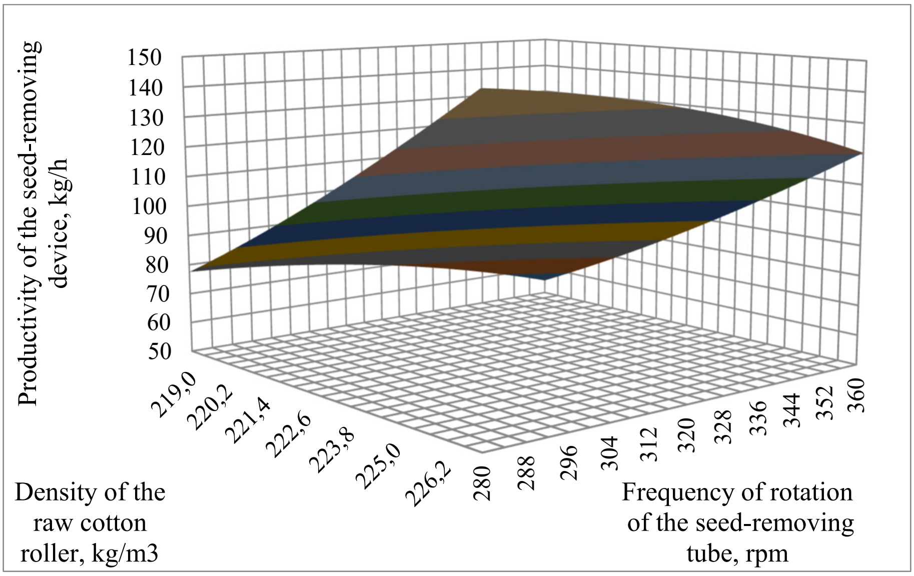

Fig. 2. Change in the productivity of the seed-removing tube depending on the density of the raw cotton roller x_1 and the frequency of rotation of the seed-removing tube x_2.

The use of a ginning machine with a seed-removing device at ginneries will increase the efficiency of the ginning process, which will undoubtedly improve the quality of the produced fiber.

4 Conclusions

It was established that the low productivity of the saw gin is due to the low rotational speed of the raw cotton roller; therefore, it is recommended to install a seed-removing tube in the working chamber, which will increase the speed of the raw cotton roller and additional removal of seeds from the working chamber. A regression equation to determine the productivity of the seed-removing tube was built depending on the density of the raw cotton roller and the rotational speed of the perforated seed-removing tube. The results of the experimental study (Figures 2) show a decrease in the productivity of the seed-removing tube (from 149.75 to 54.91 kg/h) with a decrease in the density of the raw cotton roller (from 227 to 219 kg/m^3) and an increase in the rotational speed of the seed-removing tube (from 280 to 360 rpm).

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