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# Experimental study of kinematics of raw cotton roller of saw gin with shelling chamber

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**Abstract:** The article presents the results of an experimental study of the rotation frequency of the raw roller of the saw gin with huller roll box depending on the performance of the saw gin, the distance from the top of the grate to the horizontal axis of the saw cylinder and the position of the comb.

Setting the location of the bat in the video, determine the angle and time of recording the video frame. Knowing the time difference and the angle of motion of the bat, determine the angular velocity of the raw roller. To do this, use the program "Windows Movie Maker" for time-lapse recording of drawings in the format "*.png", and to determine the angle of finding the bat use the program "COMPASS".

To study the kinematics of the raw roller of saw gin with a peeling chamber, experimental studies were carried out using a full factorial experiment of type 23 depending on the performance of the gin (X1), the distance from the top of the grate to the horizontal axis of the saw cylinder (X2) and the position of the comb (X3), since these parameters affect the rotation frequency of the raw roller.

In the pilot study used a cotton variety With 6524 grade I, class 2, 8.19% humidity and 3.68% of the debris

according to the scheme: double-drum peg line feeder ⍰ the working chamber 30 of the saw gin mill chamber (working chamber Volume is reduced by 30% relative to the serial Gina 5DP-130).

As a result, it was found that with increasing angle of the comb and the distance from the top of the grate to the horizontal axis of the saw cylinder, the rotational speed of the raw roller increases, and decreases with increasing gin productivity.

**Keywords:** Cotton cleaning, machine, gin, working chamber, grate, saw cylinder, shaft, circular blade, gasket, seed comb, angle, raw cotton roller, rotation, kinematics, productivity.

**Introduction:** Cotton ginning plants widely use machines and units manufactured by engineering plants in Uzbekistan and the USA; under American patents, they are manufactured in India and China [1-8]. The practice of using US cotton ginning machines at domestic enterprises has shown their low efficiency, high cost of manufacture and operation since they have complex design units and mechanisms.

Research into the design of the working chambers of saw gins has shown that feeding raw cotton to the saw cylinder as the raw cotton roller increases the power consumption of the saw cylinder of the working chamber and leads to high wear of the ribs and saw blades [9-16].

The ginning process is hidden from direct observation due to specific conditions (the rapidity of the process, the design of the gin, etc.), therefore, recording devices must be used to study the rotation velocity of the raw roller.

The use of optical methods for recording movement, in particular photography, filming, multiple exposure methods (strobe photography, cyclography, chronophotography, etc.) significantly expanded the understanding of the movement pattern of the working parts of the saw gin. When filming the ginning process, it is possible to repeatedly view and analyze visual materials (photos and cinegrams).

To experimentally determine the position of the fiber slivers captured by the saw teeth in the grate zone (between the grate and baffle plate) and determine the air resistance force on the sliver of fibers, strobe photography was used with the ST-MEI strobotachometer and the Zenit-3M camera.

The advent of optical-electronic methods has resolved many questions and significantly improved the quality of information obtained. These methods are based on converting the light from a video image into an electrical signal. They utilize a physical phenomenon known as the photoelectric effect, which is the ability of a substance to emit electrons when exposed to electromagnetic radiation, such as light. Currently, optical-electronic methods are successfully employed in studying motion in mechanisms, as well as in analyzing and developing the most effective parameters.

## THEORETICAL RESEARCH

Figure 1 shows a laboratory stand for video recording of the ginning process, namely the rotation velocity of the raw cotton roller of a saw gin with a shelling chamber.

To study the kinematics of the raw cotton roller using a video camera, the laboratory stand shown in Fig. 1 was made. The entire ginning process (i.e., the rotation velocity of the raw cotton roller) was recorded by video camera 4, since the side parts of working chamber 2 are transparent.

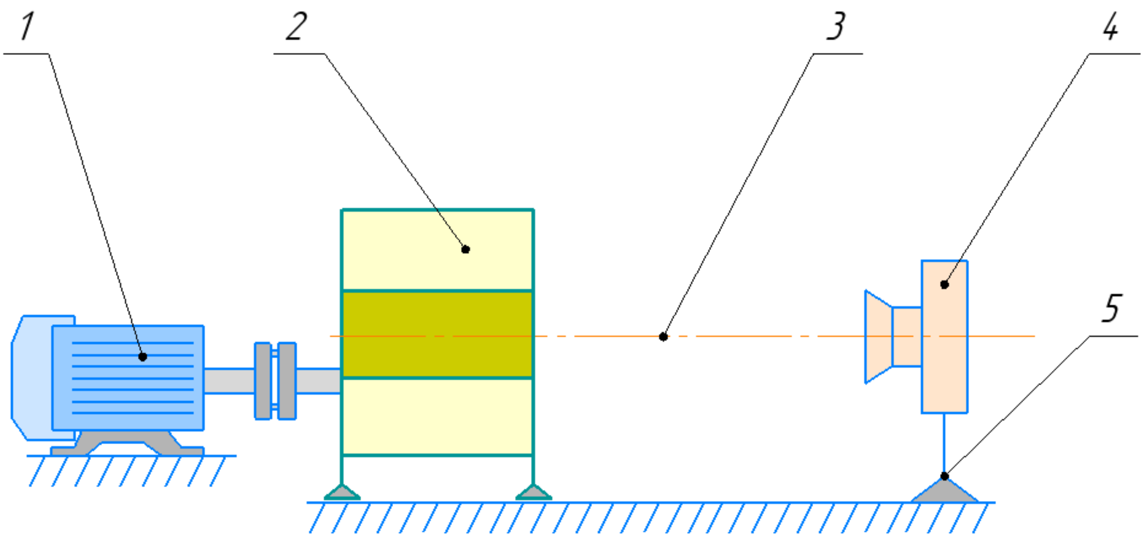


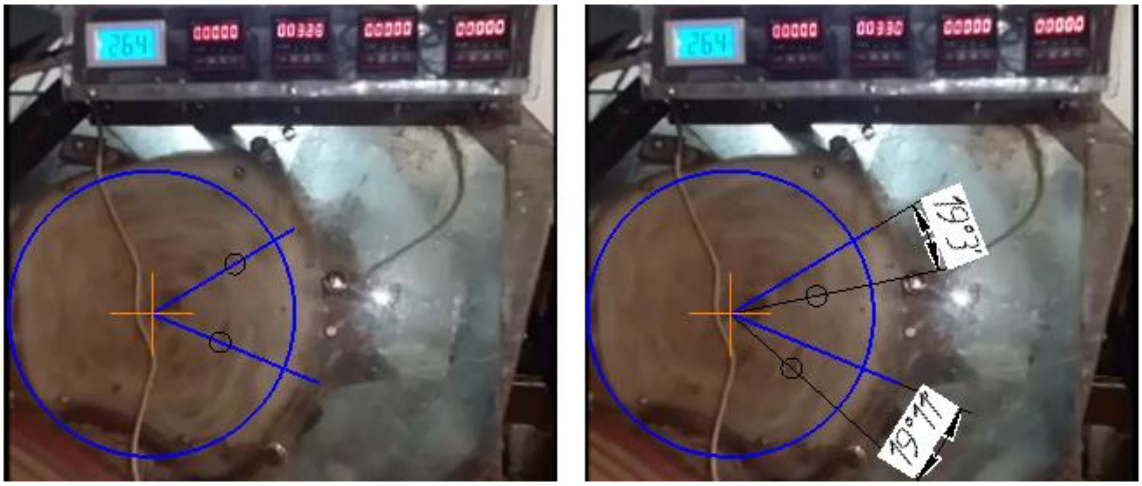

**Fig. 1. Scheme of the laboratory stand for video recording of the ginning process of the working chamber of a saw gin with a shelling chamber:**

1- electric motor; 2 - working chamber of a saw gin with a shelling chamber; 3 - horizontal axis of the center of the raw cotton roller; 4 - video camera; 5 - tripod.

The rotation velocity of the raw cotton roller, equal to the first derivative of the angle of rotation of pappus in time and directed along the axis of rotation 3 according to the right-hand screw rule is considered.

By stating the location of pappus in the video frames, we determine the angle and time of the video frame recording. Knowing the differences in time and angle of the pappus movements, we determine the angular velocity of the raw cotton roller. For this, we used the Windows Movie Maker program for frame-by-frame recording in the *.png format. To determine the angle of the pappus location, we used the KOMPAS program (Fig. 2).

**EXPERIMENTAL STUDY**




a) b)

**Fig. 2. Frames for measuring rotation angles over time by the *KOMPAS* program: a) start of point fixation; b) end of point fixation**

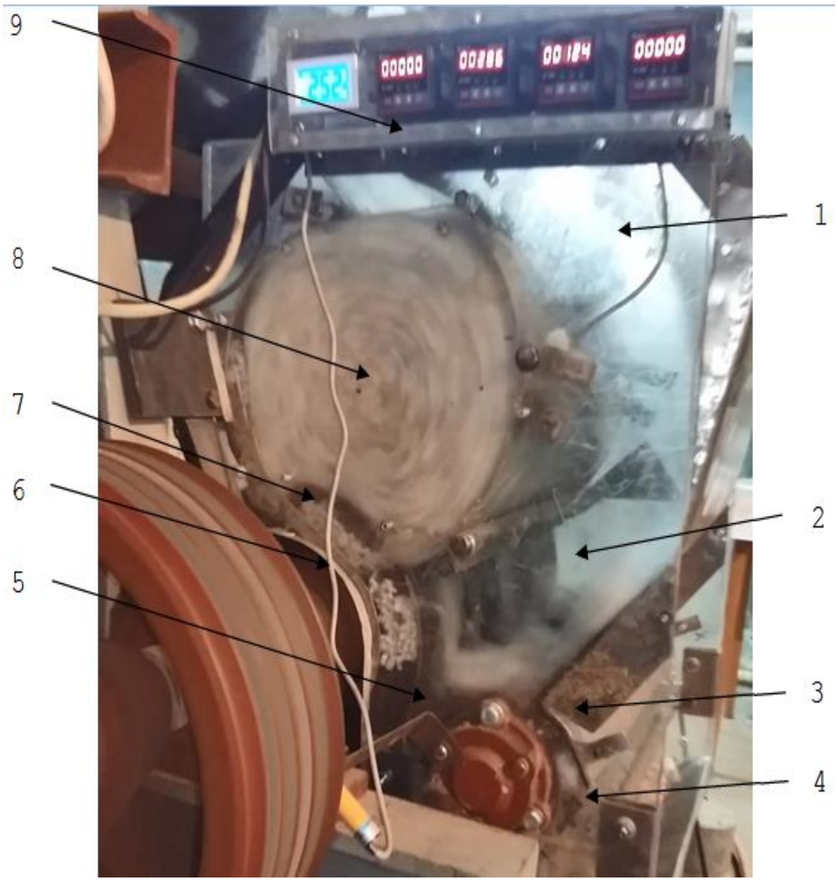



**Fig. 3. The working chamber of the saw gin with a shelling chamber:
1 - neck; 2 - shelling chamber; 3 - throwing drum; 4 - grate of the shelling chamber; 5 - ribs of the shelling chamber; 6 - saw cylinder; 7 – working chamber ribs; 8 – working chamber (raw cotton roller); 9 – sensor panel**

Figure 3 shows a saw gin with a shelling chamber. To reduce wear of grate ribs 7, saw blades (□320 mm), and power consumption of saw cylinder 6, raw cotton is fed directly to saw cylinder 6 through shelling chamber 2 using rotating throwing drum 3, under which grate lattice 4 is installed.

To investigate the kinematics of the raw cotton roller of the saw gin with a shelling chamber (Figures 2 - 3), experimental studies were conducted using a full factorial experiment of type 23 depending on the gin productivity (X1 = 430, 645 kg/h), the distance from the top of grate rib 5 to the horizontal axis of the saw cylinder 6 (X2 = 58; 78 mm), and the position of the comb (X3 = 35□; 50□) since these parameters affect the rotation frequency of the raw cotton roller y.

In the experimental study, cotton of the C 6524 I grade, class 2, 8.19% of moisture content and 3.68% of impurity was used according to the scheme: Double-drum peg feeder □ working chamber 30 of a saw gin with a shelling chamber (the volume of the working chamber is reduced by 30% relative to the serial gin 5DP-130).

The levels of factors, in this case, represent the boundaries of the study domain for the corresponding technological parameter (Table 1).

**Table 1. Factors, their levels and variation intervals**

| Factors | Lower level | Upper level | Basic level, $z^0$ | Variation interval, $\Delta z$ |
|---|---|---|---|---|
| $z_1$ | 430 | 645 | 537.5 | 107.5 |
| $z_2$ | 58 | 78 | 68 | 10 |
| $z_3$ | 35 | 50 | 42.5 | 7.5 |

Let us compile the design matrix of the PFE $2^3$ (Table 2), similar to the one given in [12].

**Table 2. Full factorial experiment for three factors with a dummy variable**

| Experi | Factors in natural scale | Rotation velocity of the raw cotton roller, $min^{-1}$ |
|---|---|---|

| ment number | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $z_1$ | $z_2$ | $z_3$ | $y_1$ | $y_2$ | $y_3$ | $y_4$ | $y_5$ | $\overline{y}_n$ |
| 1 | -1 | -1 | -1 | 79.87 | 79.07 | 81.49 | 83.10 | 79.87 | 80.68 |
| 2 | +1 | -1 | -1 | 76.38 | 75.62 | 77.14 | 77.91 | 74.85 | 76.38 |
| 3 | -1 | +1 | -1 | 69.85 | 70.56 | 71.27 | 71.97 | 69.15 | 70.56 |
| 4 | +1 | +1 | -1 | 74.42 | 72.93 | 76.65 | 74.42 | 73.68 | 74.42 |
| 5 | -1 | -1 | +1 | 74.98 | 75.20 | 76.06 | 76.28 | 75.63 | 75.63 |
| 6 | +1 | -1 | +1 | 80.15 | 80.85 | 81.31 | 81.55 | 80.39 | 80.85 |
| 7 | -1 | +1 | +1 | 85.17 | 84.68 | 85.66 | 85.90 | 84.44 | 85.17 |
| 8 | +1 | +1 | +1 | 76.36 | 76.58 | 77.46 | 77.68 | 77.02 | 77.02 |

The test showed that the experimental data are normally distributed and homogeneous.

We check the homogeneity of the variance by determining it using the Fisher criterion [18]. For $f$=5 for the maximum dispersion and $f$=5 for the minimum dispersion, the tabular value of the Fisher criterion is $F_{tab}$=5.05 [18].

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

$$F_{pac} = \frac{S_7^2}{S_3^2} = \frac{0,389}{0,267} = 1.45 < 5.05 .$$

Thus, all dispersions are homogeneous, and the experiment is reproducible (Table 3).

**Table 3. Experimental data processing results**

| Experiment number | $f_N$ | Empirical variance | | $\bar{y}$ | $\hat{y}$ | $R = \left\lvert \frac{\bar{y} - \hat{y}}{\bar{y}} \right\rvert \cdot 100\%$ |
|---|---|---|---|---|---|---|
| | | $S_n^2$ | $S_n$ | | | |
| 1 | 5 | 0.349 | 0.591 | 80.68 | 80.67 | 0.0093 |
| 2 | 5 | 0.313 | 0.560 | 76.38 | 76.38 | 0.0065 |
| 3 | 5 | 0.267 | 0.517 | 70.56 | 70.55 | 0.0213 |
| 4 | 5 | 0.297 | 0.545 | 74.42 | 74.41 | 0.0168 |
| 5 | 5 | 0.307 | 0.554 | 75.63 | 75.63 | 0.0066 |
| 6 | 5 | 0.351 | 0.592 | 80.85 | 80.85 | 0.0031 |
| 7 | 5 | 0.389 | 0.624 | 85.17 | 85.16 | 0.0147 |
| 8 | 5 | 0.318 | 0.564 | 77.02 | 77.01 | 0.0130 |
| Sum | 40 | 2.593 | 4.547 | 620.71 | 620.64 | 0.0913 |

Let us calculate the linear regression coefficients using formula given in [12]:

$$b_0 = \frac{1}{8}\sum_{i=1}^{8} y_i = 77.58 , \quad b_1 = \frac{1}{8}\sum_{i=1}^{8} y_i = -0.42 , \quad b_2 = \frac{1}{8}\sum_{i=1}^{8} y_i = -0.8 , \quad b_3 = \frac{1}{8}\sum_{i=1}^{8} y_i = 2.08.$$

We calculate the coefficients of pairwise interaction.

$$b_{12} = \frac{1}{8}\sum_{i=1}^{8} x_1 x_2 y_i = -0.65, \qquad b_{13} = \frac{1}{8}\sum_{i=1}^{8} x_1 x_3 y_i = -0.31,$$

$$b_{23} = \frac{1}{8}\sum_{i=1}^{8} x_2 x_3 y_i = 2.22, \qquad b_{123} = \frac{1}{8}\sum_{i=1}^{8} x_1 x_2 x_3 y_i = \text{-}2.7.$$

Substituting the coefficients, we obtain the regression equations for the rotation frequency of the raw cotton roller depending on the following input parameters:

$$y = 77.58 - 0.42 \cdot x_1 - 0.8 \cdot x_2 + 2.08 \cdot x_3 - 0.65 \cdot x_1 \cdot x_2 - 0.31 \cdot x_1 x_3 + 2.22 \cdot x_2 x_3 - 2.7 \cdot x_1 x_2 x_3 \quad (3)$$

Let us evaluate the significance of the coefficients of the regression equation (3). The reproducibility variance is defined as:

$$S^2_{восп} = \frac{S_1^2 \cdot f_1 + S_2^2 \cdot f_2 + ...... + S_8^2 \cdot f_8}{f_1 + f_2 + ...... + f_8}$$ = =5·(0.349+0.313+0.267+0.297+0.307+0.351+0.389+0.318) / 40=0.324.

Let us find the values of the coefficient error variances, considering the data from [18] for k=3:

$$S^2_{b_i} = \frac{S^2_{восп}}{\sum_1^N x^2_{iu}} ; \; S^2_{b_o} = S^2_{b_1} = S^2_{b_2} = S^2_{b_3} = S^2_{b_{12}} = S^2_{b_{13}} = S^2_{b_{23}} = S^2_{b_{123}}$$ =0.324/8=0.0405 .

We calculate the values of square errors:

$S_{b_o} = S_{b_1} = S_{b_2} = S_{b_3} = S_{b_{12}} = S_{b_{13}} = S_{b_{23}} = S_{b_{123}}$ =0.201

We determine the errors in estimating 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 the Student's criterion; *N* is the number of experiments for *N* = 8, *t* = 2.306 [18].

$$\Delta b_0 = \Delta b_1 = \Delta b_2 = \Delta b_3 = \Delta b_{12} = \Delta b_{13} = \Delta b_{23} = \Delta b_{123} = 2.306 \cdot 0.201 / 2.828 = 0.164.$$

A comparison of the absolute values of the coefficients with the corresponding confidence intervals showed that they are all significant. We will check the adequacy of equation (3) using the Fisher criterion [18].

$$F_{рас} = \frac{S^2_{ад}}{S^2_{восп}} = \frac{0.00018}{0.324} = 0.0023 \le F_{таб} = 2.25 \; ,$$

where the variance of adequacy is $S^2_{ад} = \frac{\sum_1^N n \cdot (\bar{y} - \hat{y})^2}{N - (k+1)}$ =0.00075/[8-(3+1)] = 0,00019.

The tabular value of the Fisher criterion for *f = (N-1) = 7* for the variance of adequacy and *f = (n-1) = 40* for the variance of reproducibility is [18] $F_{таб}$=2.25, where *N* is the number of series of experiments, *n* is the total number of experiments.

The adequacy conditions of the mathematical model (3) are met since $F_{рас}$=0.0023<$F_{таб}$=2.25.

As a result of implementing the regression equation (2) on the computer, graphs of the change in the rotation frequency of the raw cotton roller depending on the distance from the top of the grate to the horizontal axis of the saw cylinder ($x_2$ - Fig. 4), the productivity of the gin ($x_1$ - Fig. 5), and the angle of the comb position ($x_3$ - Fig. 6) were constructed.

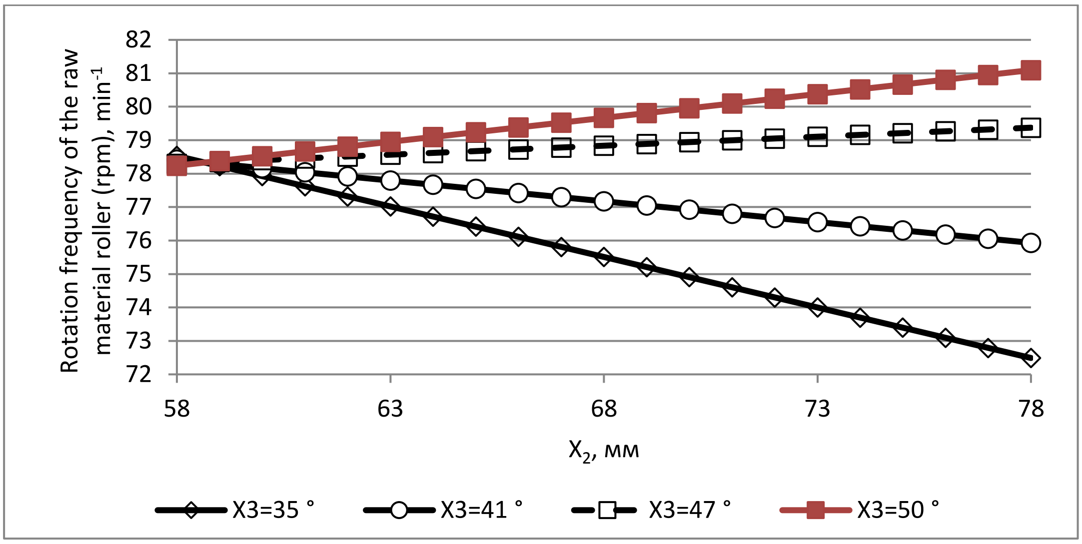



**Fig. 4. Changes in the rotation frequency of the raw cotton roller of the saw gin with a shelling chamber depending on the distance from the top of the grate to the horizontal axis of the saw cylinder ($X_2$) and the position of the comb ($X_3$) at the productivity of the gin ($X_1$ = 537.5 kg/hour).**

Analysis of the graphs plotted in Figures 4-6 shows that:

- with an increase in the distance from the top of the grate to the horizontal axis of the saw cylinder from $x_2$=68 mm to 78 mm and the angle of the comb position from $x_3$=42.5° to 50°, the rotation frequency of the raw cotton roller increases from $y$=72 min$^{-1}$ to 81 min$^{-1}$ with a saw gin productivity for cotton of $x_1$=430 kg/hour.

- with an increase in the productivity of the saw gin from $x_1$=430 kg/hour to 645 kg/hour with a comb position angle of $x_3$=47°, the rotation frequency of the raw cotton roller decreases to 1.2 min$^{-1}$ (79.4 – 78.2).

Analysis of the change in the raw cotton roller rotation frequency $y$ over time at the saw gin productivity for cotton $x_1$ = 430 kg/hour and the comb position angle $x_3$ = 35° and 50° allowed us to establish an increase in the raw cotton roller rotation frequency from $y$ = 68 min$^{-1}$ to 82 min$^{-1}$. Considering the average radius of the raw cotton roller 0.16 m, the linear velocity of the raw cotton roller is within 1.14-1.34 m/s.

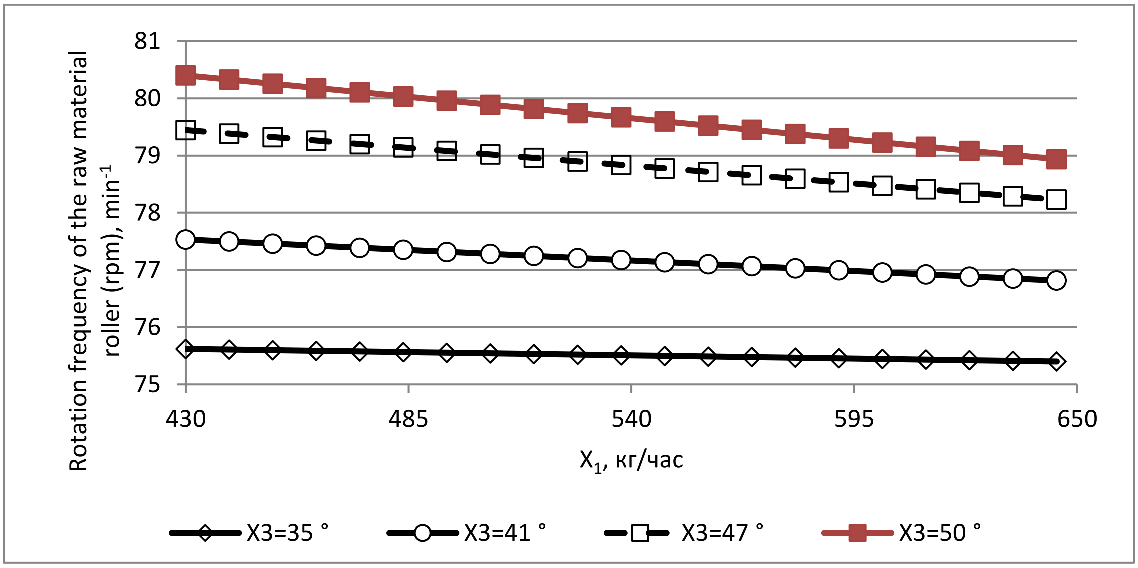



**Fig. 5. Changes in the rotation frequency of the raw cotton roller of the saw gin with a shelling chamber depending on the gin productivity ($X_1$) and the comb position ($X_3$) at the distance of the grate top to the horizontal axis of the saw cylinder ($X_2$ = 68 mm) for kg/hour).**

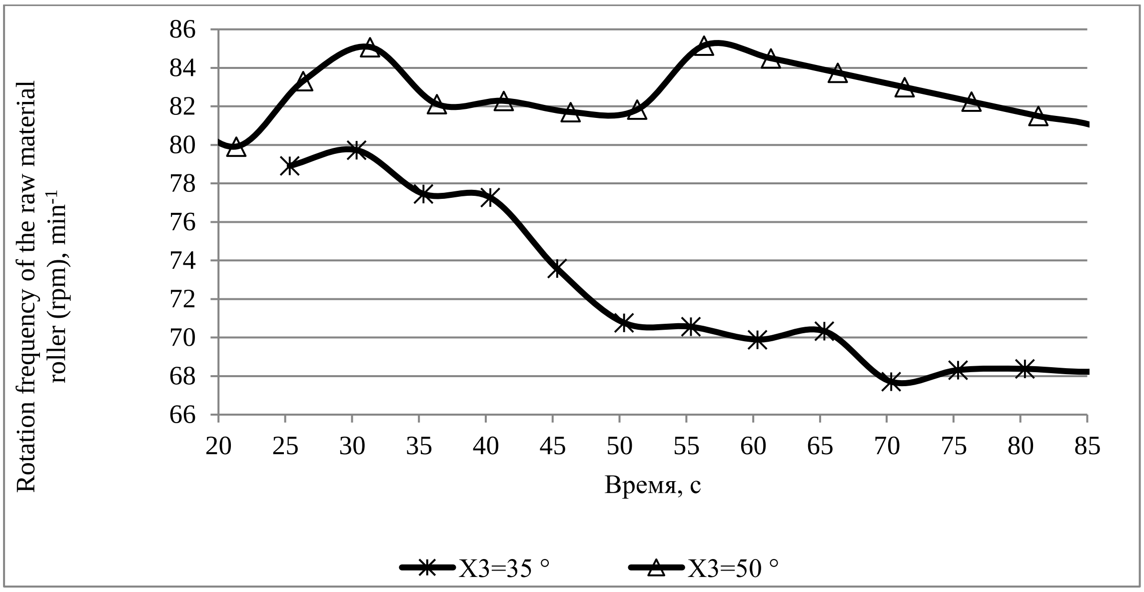



**Fig. 6. Changes in the rotation frequency of the raw cotton roller of the saw gin with a shelling chamber depending on time at a gin productivity of $X_1$ = 430 kg/hour.**

In general, the level of influence of the input parameters on the kinematics of the raw cotton roller was determined as:
- the angle of the comb position ($x_3$) - 12.5%;
- the distance from the top of the grate to the horizontal axis of the saw cylinder ($x_2$) - 3.8%;
- gin productivity ($x_1$) - 1.5%.

## ANALYSIS OF RESULTS

1. The kinematics of the raw cotton roller of the saw gin was studied using frame-by-frame analysis of video films of the ginning process using the software products "Windows Movie Maker" and "KOMPAS".

2. A regression equation was constructed for the rotation frequency of the raw cotton roller y depending on the productivity of the saw gin for cotton x1, the distance from the top of the grate to the horizontal axis of the saw cylinder x2, and the angle of the comb position x3.

3. An increase in the rotation frequency of the raw cotton roller was established with an increase in the angle of the comb position from x3=35⍰ to 50⍰ by 9 min-1 (12.5%) and the distance from the top of the grate to the horizontal axis of the saw cylinder from x2 = 68 mm to 78 mm by 3 min-1 (3.8%), and with an increase in the productivity of the gin from x1 = 430 kg/hour to 645 kg/hour, it decreased by 1.2 min-1 (1.5%).

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