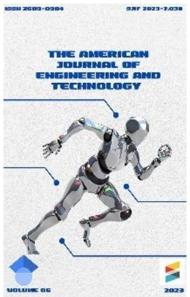
The American Journal of Engineering and Technology
(ISSN – 2689-0984)
VOLUME05 ISSUE10 Pages: 12-27
SJIF IMPACT FACTOR (2020: 5. 32)(2021: 5. 705)(2022: 6. 456) (2023: 7. 038)
OCLC– 1121105677
Crossref doi Google Scholar WorldCat MENDELEY
Publisher: The USA Journals



Journal Website: https://theamericanjournals.com/index.php/tajet

Research Article

INCREASING THE EFFICIENCY OF SAW GINNING TECHNOLOGY

Submission Date: October 20, 2023, **Accepted Date:** October 25, 2023,
Published Date: October 30, 2023|
Crossrefdoi: https://doi.org/10.37547/tajet/Volume05Issue10-03

Kamola Ortikova
Namangan Institute of Engineering and Technology, Namangan, Uzbekistan

Akmal Umarov
Namangan Institute of Engineering and Technology, Namangan, Uzbekistan

Maftuna Inamova
Namangan Institute of Engineering and Technology, Namangan, Uzbekistan

ABSTRACT

In the process of separating the fiber from the seed, the speed of the seed roll in the roll box of the saw gin varies depending on the diameter of the saw. As the blade diameter decreases, the peripheral speed does not change, but the linear speed does. This leads to a deterioration in the quality of the fiber and seed, and a decrease in the productivity of the machine. For this reason, the regulation of the linear speed of the saw is one of the important problems in the ginning process. To do this, the speed of rotation of the saw cylinder is changed following the change in the diameter of the saw. Thus, the speed of the seed roll is regulated.

KEYWORDS

Seed, fiber, dirt, experimental stand brand DP-30, saw teeth.

INTRODUCTION

In the world, the need for clothing made from the cotton fiber is increasing year by year. This is the reason for the increase in demand for cotton fiber and its consumption in the world market. Leading countries in the production of cotton fiber such as India, China, the USA, Pakistan, and Brazil, to maintain their position and prestige, conduct large-scale research in the field of improving the consumer properties of the produced cotton fiber and ensuring its compliance with market conditions.

In the world, as the main process of primary processing of cotton, special attention is paid to the process of separating the fiber from the seed (ginning), scientific and practical research aimed at developing its

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technique and technology. In this direction, in particular, the scientific foundations for increasing the efficiency of the cotton ginning process are being developed, and the issues of improving product quality and reducing costs through the strengthening of the widespread introduction of high-tech, automated, as well as resource-saving equipment and technology are of great importance. At the same time, as the main factors in the development of this area, it is of particular importance to create small-sized technologies with product quality management, maintaining the initial quality indicators of the fiber and seed, with the possibility of reducing the energy consumption of the process, there is a high need to create simple, non-material and energy-saving designs of devices for separating the fiber from the seed and feeding the process with cotton in the process of separating the fiber from the seed.

The republic pays great attention to the rapid development of the production of finished products with added value, improving the quality indicators of cotton products for the domestic and foreign markets, ensuring its competitiveness, based on the deep processing of cotton raw materials and the modernization of the cotton ginning industry.

The Action Strategy for the Further Development of the Republic of Uzbekistan for 2017-2021 provides for "...increasing the competitiveness of the national economy, ...reducing energy and material costs in the economy, and widespread introduction of energy-saving technologies into production" [1]. When meeting this requirement in the cotton ginning industry, one of the important tasks is the creation and implementation of effective technology for separating the fiber from the seed, based on the rational control of the speed of rotation of the working cylinder of the saw fiber separator.

The first gin created by the American engineer Eli Whitney in 1793 was the impetus for the formation of the cotton production industry. From the stages of development of the industry until today, the theoretical and practical foundations of the process have been developed, and the process of separating the fiber from the seed has been formed and developed into a whole technological chain of raw cotton processing. American inventors and scientists like Aslam S., Sumro N., Alberson D.M., Armijo S.V., Khugs S.E., as well as domestic scientists like Levkovich B.A., Boldinsky I.G., Miroshnichenko G.I., Tillyaev M., Bekmirzaev B.I., Kattakhodzhaev R.M., Tyutin P.N., Lugachev A.E., Burnashev R.Z., Korabelnikov R.V., Mavlyavieva F.M. ., Khafizov I.K., Tillaev M.T., Maksudov I.T., and Azizkhodzhaev A., Khozhiev M.T., Usmanov Kh.S., Akhmedkhodzhaev Kh.T., Muradov R.M., Maksudov I.T., Ergashev Zh., Bazarov B.B., Yunusov C., Agzamov M., Davlatov M., Safarov N.M., Sarimsakov A.U., Umarov A.A., Sharipov H.N., and others contributed not only to the development of the ginning process but also to the development of the technique and technology of the primary processing of cotton in general.

The research work carried out so far has been aimed at solving some problems of improving the processes and machines for separating the cotton fiber from the seed, in particular, improving the process of fiber separation in saw gins, determining the diameter of the saw, the rational profile of the working chamber, the optimal speed of the saw cylinder, as a result of them, to some extent, the technique and technology of primary processing of cotton have been developed, and the qualitative and quantitative indicators of the products obtained have been improved [2]. However, the problems of creating a resource-saving technology for controlling the speed of the saw cylinder, if necessary, in particular, following the change in the diameter of the saw in saw gins, while maintaining the natural properties of cotton, have not been studied sufficiently.

The study aims to increase the efficiency of the ginning machine by adjusting the circumferential speed of the saw cylinder.

The analysis of the considered studies on the topic led to the following conclusions: following the requirements of operation, saw blades are replaced when 10 teeth break along the perimeter or 4 in a row. In saw ginning, incomplete removal of the fiber from the saw teeth also significantly affects its performance. In this case, the fiber sticks to the teeth, and they do not engage other fibers, which negatively affects the overall yield of the fiber, causing a decrease in productivity with the number of saws of gin and a deterioration in fiber quality. Therefore, it is necessary to completely remove the fiber from the teeth of the saws, while productivity increases [3].

As the analysis of studies conducted to date shows, they do not disclose many aspects of the saw ginning process. With high productivity, the quality of the products produced is not at the level of requirements.

Despite the many studies carried out to improve the process of saw ginning, the problems of creating a resource-saving and enabling the preservation of the natural properties of cotton technology for controlling the speed of the saw cylinder in a saw gin, depending on the need, in particular following the change in saw diameter, have not been fully studied.

The performance of the saw gin depends on the change in the diameter of the saw, i.e. as the diameter of the saw decreases, its performance decreases.

To maintain productivity by maintaining the linear speed of the saw, a technical solution is proposed based on changing the corresponding circumferential speed through a frequency converter.

The geometric parameters of the saw teeth affecting the performance will be considered according to the scheme below (Fig. 1) [5].

Numerous formulas have been proposed in the studies to determine the performance of a saw gin, which show the main dependence of performance on the speed and performance of the saw.

The performance of the saw is proportional to the area ABC_1 – the triangle of fiber retention and the linear speed of the rotating saw (fig. 1).

The area of a triangle ABC_1 is determined by the following formula

$$S_\Delta = \frac{t^2 \sin^2 \gamma_1 \sin(\gamma - \varphi)}{2\cos(\gamma + \gamma_1)\cos(\varphi + \gamma_1)} \quad (1)$$

t – saw tooth pitch;

φ – the angle between the radial plane of the saw and the shear plane of the fiber;

ψ – fiber retention angle on saw teeth;

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γ – the anterior angle of the tooth.

If the number of saws N, then the productivity of saws on one gin is calculated by the following formula [6]:

$$\Pi = N \cdot \Pi_1 \quad (2)$$

On fig. 2 (a) shows a graph that characterizes the required amount of increase in the angular velocity with a change in the diameter of the saw. Here, the value of the linear velocity is taken $V_0 = 12.2$ as m/s. As can be seen from the graph, to maintain the traditional standard linear speed, it is necessary to increase the peripheral speed of the saw. For example, at $D = 272$ mm, $\omega = n = 860$ rpm ($\omega = n = \frac{60 \cdot V_0}{\pi D}$) is required.

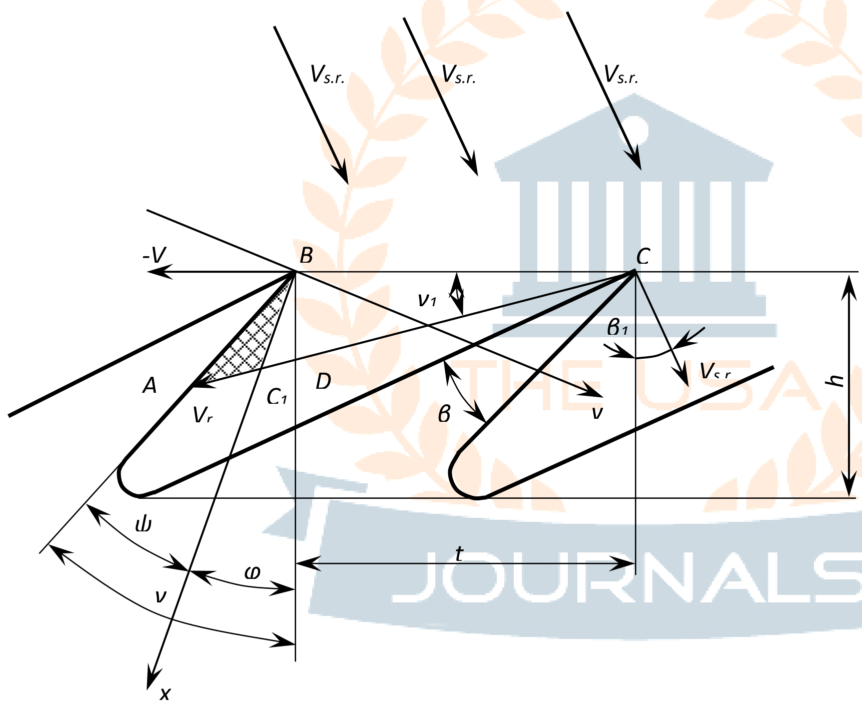

FIGURE 1. Scheme for determining the gripping ability of saw teeth

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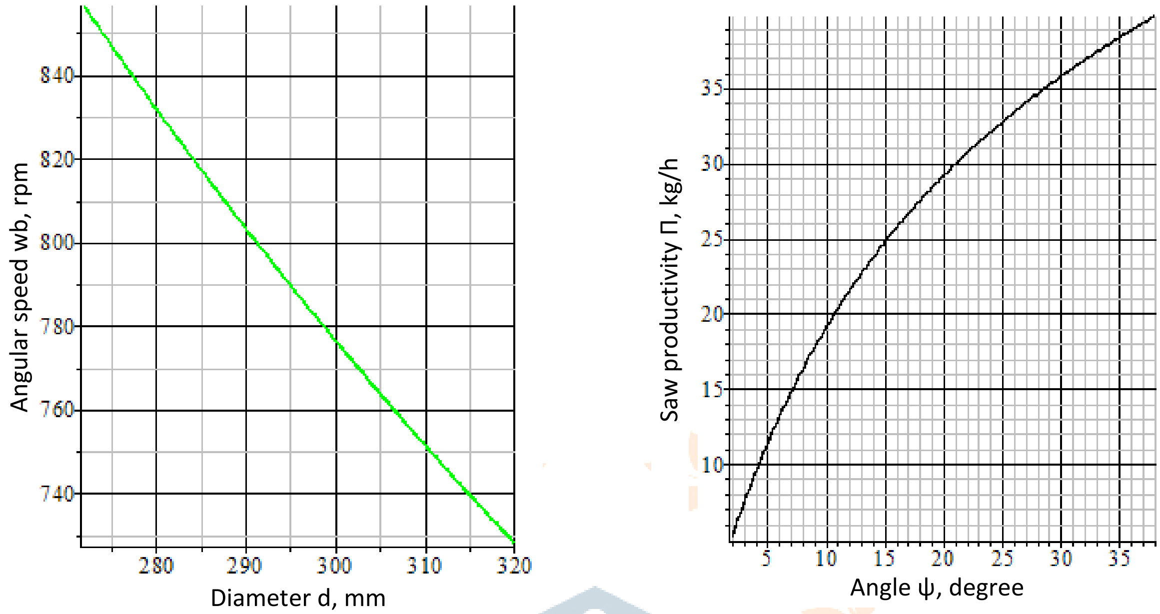

(a) (b)

FIGURE 2. Patterns of changes in the angular velocity (a) and the performance of the saw (b) depending on its diameter and various angles ψ

A graph of the change in the performance of one saw from an angle ψ or area $S_{\Delta ABC_1}$ is shown in fig. 2 (b). As can be seen from the graph, when $\psi = 5°$ the productivity is $\Pi_1(\psi = 5°) = 12$ kg/saw-hour, at $\psi = 10°$ – $\Pi_2(\psi = 10°) = 20$ kg/saw-hour. Here it is accepted $V_0 = 12.2$ m/s, $n = 730$ rpm. Performance is calculated by the following expression [7]

$$\Pi(\psi) = \frac{3600 \cdot k \cdot n_1 \cdot V_0}{t \cdot n_2} \cdot f(\psi), \qquad f(\psi) = \frac{\sin\psi}{\sin(\beta + \psi)} \tag{3}$$

On fig. 3, (a) shows a graph of the change in productivity at angles ψ equal to $15°\ 20°\ 25°\ 30°$, and saw diameter in the range of $D = 272 \div 320$ mm. From the graph, it can be seen that the value of the area $S_{\Delta ABC_1}$ on productivity is large.

The dependence of the coefficient of change in productivity on the diameter and angle ψ of the saw is shown in the graph in fig. 3 (b).

$$K = \frac{\Pi(\mathrm{D})}{\Pi(\mathrm{D}_0)} \tag{4}$$

here: $D_0 = 320$ mm; $D = 272 \div 320$ mm.

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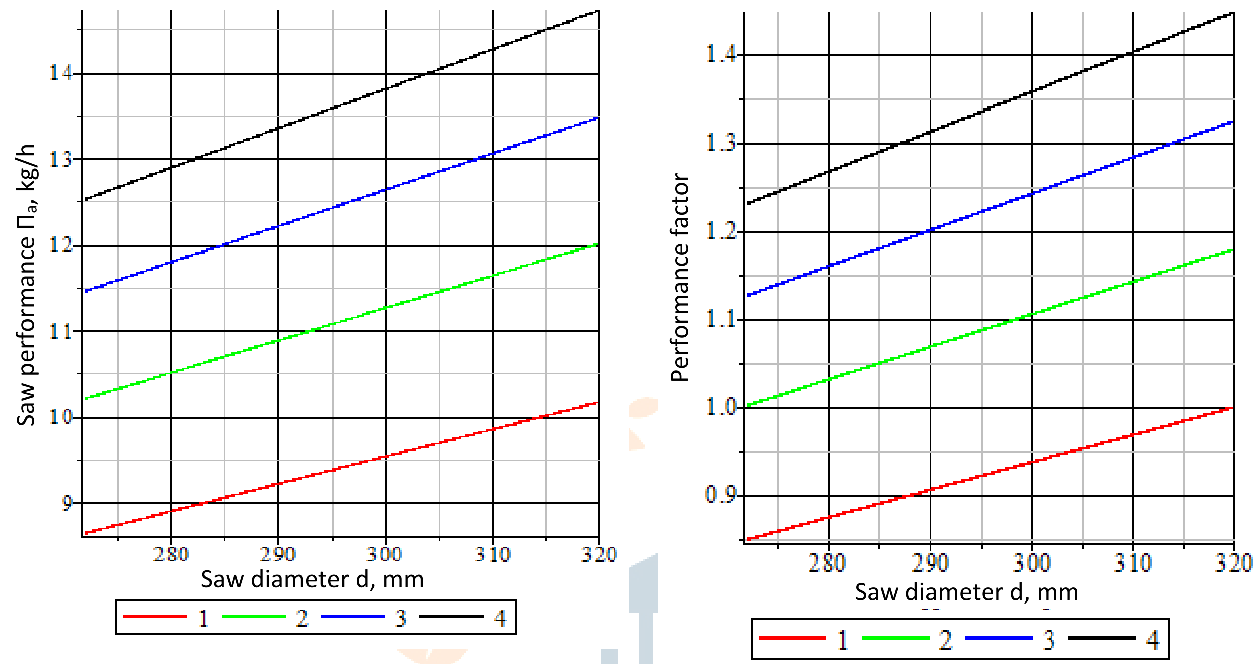

(a) (b)

FIGURE 3. Patterns of changes in the performance of one saw (a) and the performance coefficient (b) depending on different values of the saw diameter

1 $-\psi=15°$; 2 $-\psi=20°$; 3 $-\psi=25°$; 4 $-\psi=30°$

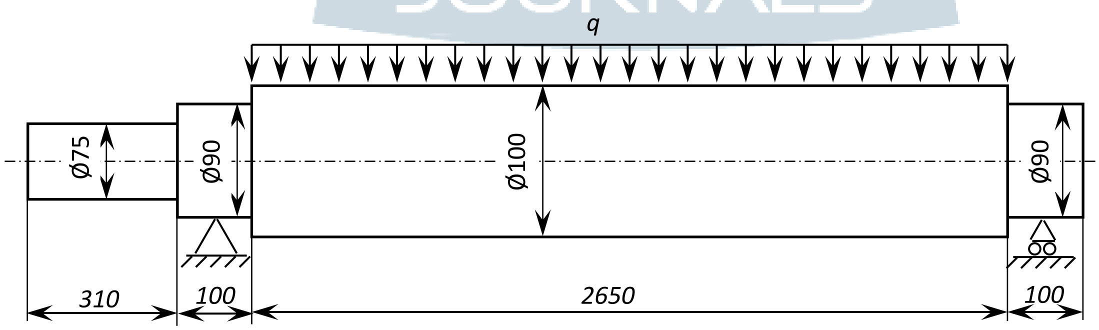

FIGURE 4. Scheme for determining the critical speed of the saw cylinder

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To maintain productivity, it was proposed to maintain 12.2 m/s of the linear speed of the saw. That is, with a saw blade diameter of Ø310 mm, it is necessary to provide a peripheral speed of 752 rpm, and with a Ø300 mm – 777 rpm. When determining the critical speed of the saw cylinder, the Simulation package of the modern SolidWorks computer program was used [8].

So, in our case, the first critical frequency was 18.565 Hz. To convert it to the number of revolutions, apply $1\ Hz = 60\ rpm$. As a result, the first critical speed was $18.565\ Hz = 60 \cdot 18.565 = 1113.9\ \ rpm$.

From the condition $n_{1cr} \geq 1.3 n_w$, we find n_w: $n_{1cr}/1.3 \geq n_w$; $1113.9/1.3 \geq n_w$, $856.85\ rpm \geq n_w$.

In our case, the maximum speed of rotation of the shaft will be $n_w = 777\ rpm$ with a saw diameter of Ø300 mm, i.e. the condition $856.85\ rpm \geq 777\ rpm$ is met.

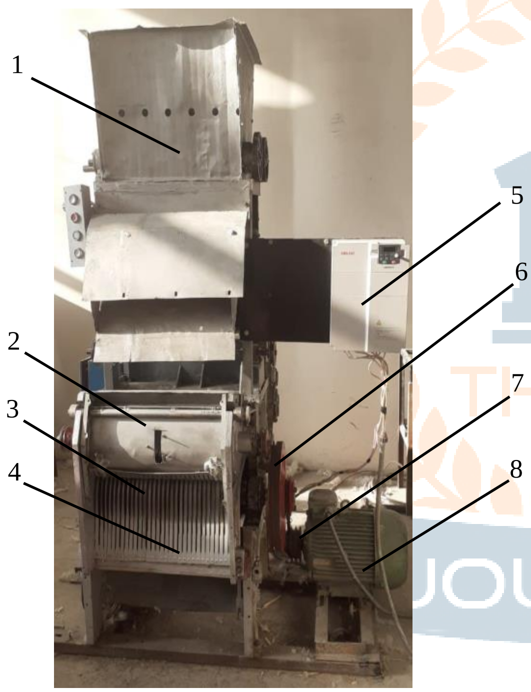

FIGURE 5. Experimental stand brand DP-30

1 - feeder,

2 – roll box,

3 - saw cylinder,

4 - grate,

5 - frequency converter,

6 - driven pulley,

7 - drive pulley,

8 - an electric motor

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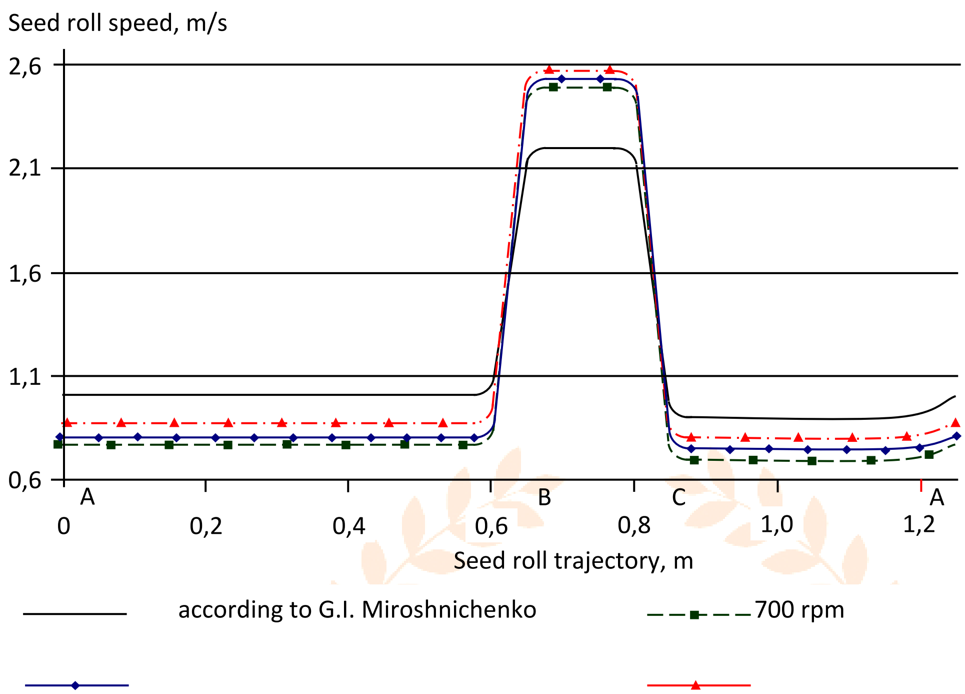

FIGURE 6. Distribution of raw roller speed along with the profile of the roll box

Based on the research on the speed of the saw cylinder gins, using new devices and process control systems, a rational direction was chosen to improve the process of regulating the speed of the saw cylinder with a change in the diameter of the saw, the dependence of the machine's performance and quality indicators of the fiber on the diameter of the saw and the speed of the saw cylinder was determined.

TABLE 1. Experiment plan

Factors	**I-experience**			
	X_{min}	X_{max}	Δ	X_0
Saw diameter, mm	310	320	5	315
Circumferential saw speed, rpm	700	780	40	740
x_1, x_2	-1	1		0

The formation of a seed roll during the separation of the fiber from the seed in gin depends on many factors. The main ones are the density of the seed roll, the number of seeds separated from the fibers, and others. To determine the

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influence of these factors on the productivity of gin and the quality of the fiber, experiments were carried out in the laboratory of the Department of Technology for the Primary Processing of Natural Fibers at NamIET on a laboratory bench of the DP-30 brand (Fig. 5). The experiments were carried out on hand-picked cotton of the selection variety C65-24, III-industrial grade, with a moisture content of 7.5% and a weediness of 2.8% [9].

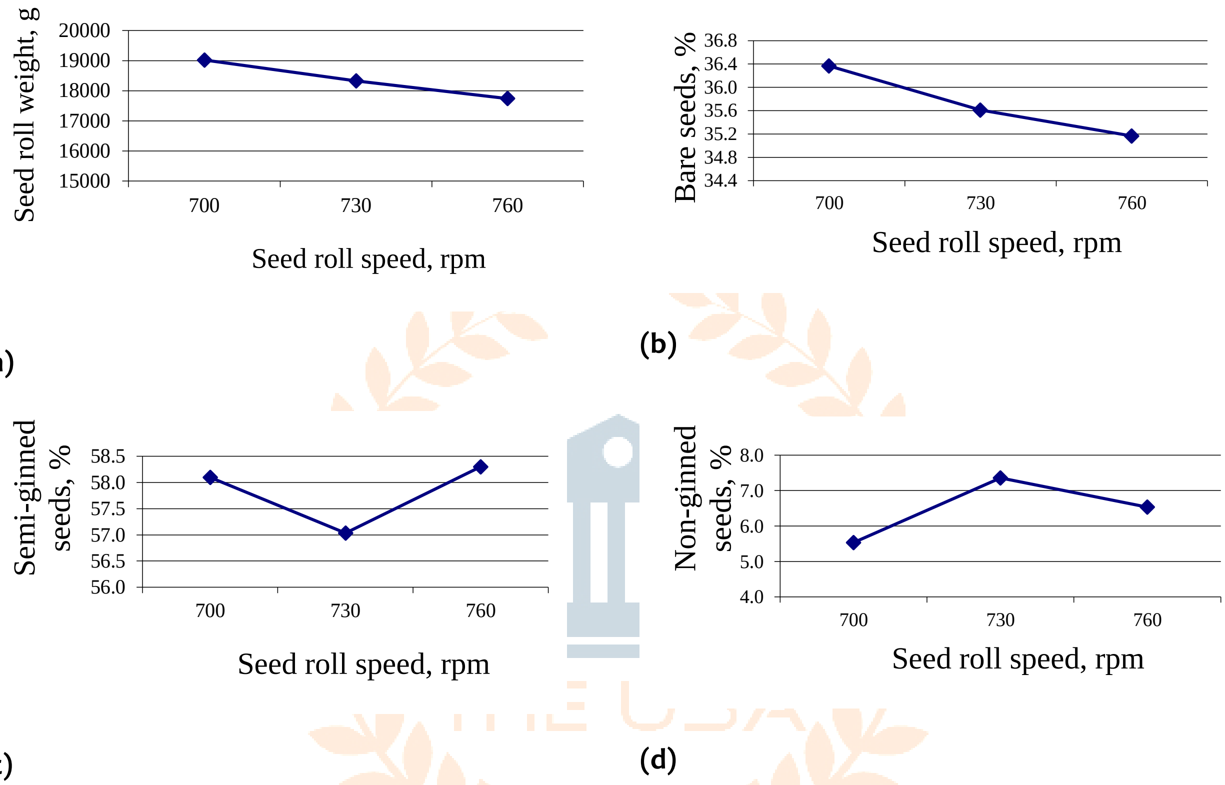

FIGURE 7. Graphs of the influence of the speed of the saw cylinder on the composition of the seed roll

When comparing with the results of experiments obtained by "Pakhtasanoat ilmiy Markazi" JSC, we can see the coincidence of the patterns of change in the speed of the seed roll and the difference between the current speed of the seed roll from that given in the literature, i.e. speed on arcs AB CA and less, and the arc BC more. In addition, as the speed of the saw cylinder increases, the speed of the seed roll also increases.

Based on the experiments, a straight-line regression dependence of the machine productivity Y_1 (kg/saw-hour) and the staple length of the fiber Y_2 (mm) on the influencing factors – saw diameter x_1 and speed x_2 was determined. Based on the above, after conducting experiments based on the matrix 2^2 of the full factorial experiment (FFE) for experiments, a regression mathematical model was obtained [10].

Using a computer program, regression equations for the dependence of the performance of the genie on the diameter and speed of the saw are obtained, tested according to the Cochran, Student, and Fisher criteria, and are reduced to the following form:

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$$y_1 = 2 + 0.6x_1 + 0.3x_2 \quad (5)$$

$$y_2 = 29.1 - 0.4x_1 - 0.3x_2 \quad (6)$$

From the above graphs, it can be seen that in the ginning process, to maintain the staple length of the fiber L (mm) and the productivity of the machine Π (kg/saw-hour) to the required extent, with such external factors as the diameter D (mm) and peripheral speed n (rpm) of the saw, it is necessary to ensure the preservation of the linear speed V (m/s) with a change in the diameter of the saw.

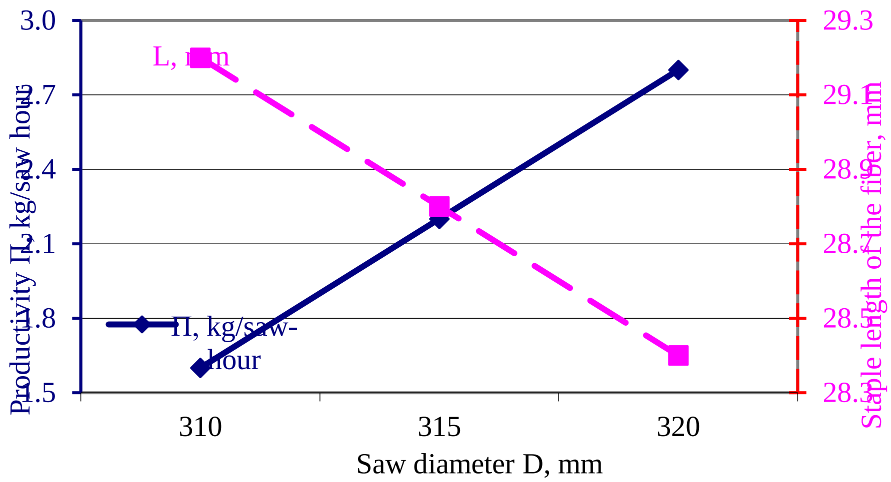

FIGURE 8. Graph of machine performance Π and staple fiber length L versus saw blade diameter D

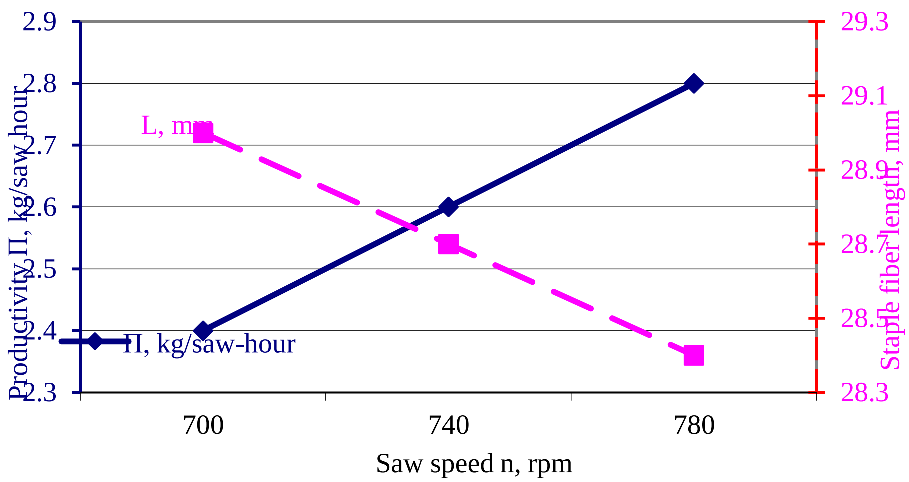

FIGURE 9. Graph of machine performance Π and staple fiber length L versus saw speed n

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Based on the experiments, the presence of a rectilinear regression dependence of the productivity of the machine and the staple length of the fiber on the influencing factors – the diameter and speed of the saw was determined.

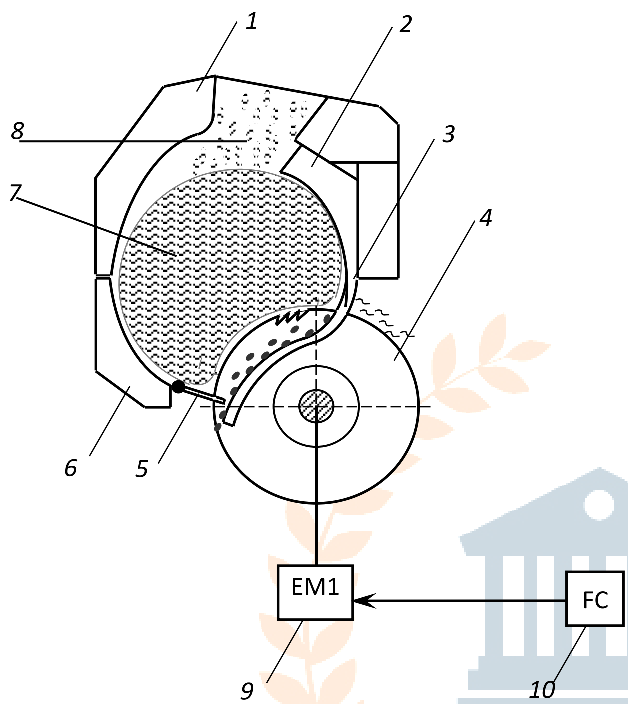

FIGURE 10. Saw gin with saw cylinder speed control

1 - front apron,

2 - front bar,

3 - grate,

4 - saw cylinder,

5 - seed comb,

6 - bottom apron,

7 - seed roll,

8 - cotton,

9 – saw cylinder electric motor,

10 - frequency converter

The diameter of the new saw blades on the saw cylinder is 320 mm, with a saw blade peripheral speed of 730 rpm, the line speed for optimum machine performance and product quality is 12.2 m/s. When the saw diameter is reduced to 310 mm, 300 mm, its circumferential speed of 730 rpm cannot be changed. As a result, the linear speed of the saw will be 11.8 m/s and 11.5 m/s, respectively. And at the same time, the productivity of the machine decreases, and the quality of the products is deteriorating. Therefore, the development of a saw gin with a speed control of the saw cylinder is of great importance.

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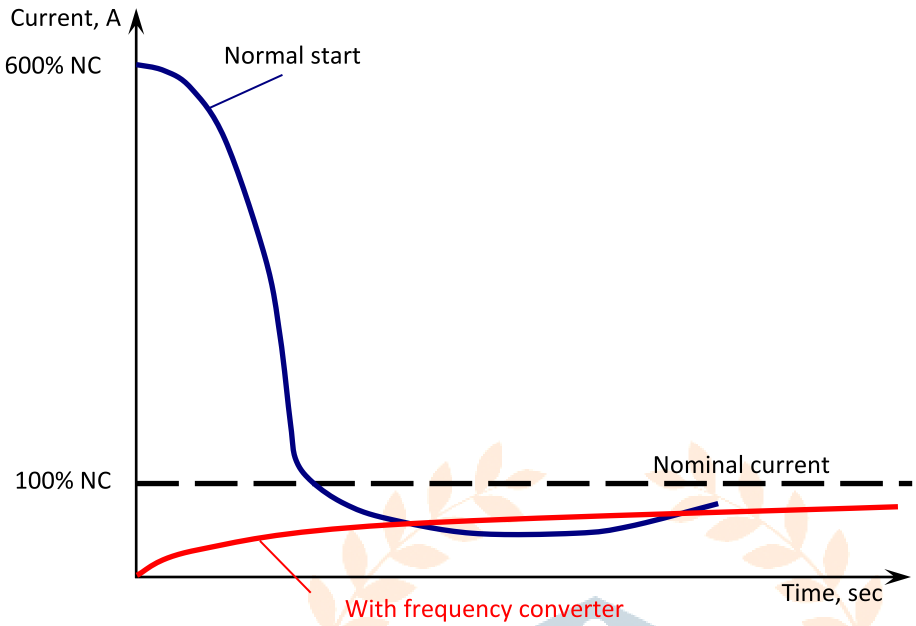

FIGURE 11. Diagram of the soft start of asynchronous electric motor

The main goal of the work is to create a saw gin with the regulation of the speed of the saw cylinder depending on the diameter of the saw. The problem is solved in the following way. A saw gin with saw cylinder speed control consists of a front apron 1, a front bar 2, a grate 3 installed on it, a saw cylinder 4, a seed comb 5, and a bottom apron 6. The saw cylinder shaft is connected to the shaft of the gin motor 9. The electric motor 9 of the saw cylinder is provided with a frequency converter 10. Using the frequency converter of the electric motor of the saw cylinder, its speed is changed following the diameter of the saw blade (Fig. 10) [11].

Equipping the saw gin with a frequency converter makes it possible to change the speed of the saw cylinder, as well as increase the productivity of the machine and maintain product quality.

When replacing the saw blades 4 of the saw cylinder with smaller diameter saws, the frequency converter 10, by appropriate regulation of the speed of rotation of the saw cylinder electric motor 9, ensures its constant linear speed of 12 m/s.

To test the saw gin with the speed control of the saw cylinder under production conditions, experiments were carried out at the Chust cotton gin in the Namangan region, Uzbekistan (Fig. 12). The tests were carried out on cotton of the selection variety C65-24, I-grade with a moisture content of 7.9% and contamination of 0.8%, as well as III-grade with a moisture content of 9.3% and contamination of 2.9%. Based on the results of the initial experiments, we chose the circumferential speed of the saw cylinder to select the control method. A saw gin with a saw blade diameter of 310 mm was chosen for the experiments [12, 13].

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(a) (b)

FIGURE 12. Gin with a new system (a) and frequency converter (b)

1 - saw gin 5DP-130, 2 - control panel

TABLE 2. Comparative results of experiments carried out on two types of saw gins on cotton of the S65-24 selection of I- and IV-grades

#	Qualitative indicators	I-grade cotton		IV-grade cotton	
		5DP-130	5DP-130 with a new system	5DP-130	5DP-130 with a new system
1	Productivity, kg/saw-hour	12.3	12.0	8.1	8.5
2	Mass fraction of defects and weeds after cleaning, %	2.2	1.7	5.7	6.1
3	Staple length, mm	33.3	33.4	31.6	31.5

The speed of rotation of the saw cylinder for grades I and IV was 700 rpm and 741 rpm, i.e. linear speed – 11.5 m/s and 12.2 m/s, respectively. Several positive results have been obtained through the use of a saw gin with a speed control of the saw cylinder. The quality indicators of the fiber obtained as a result of tests on the existing gin 5DP-130 and the gin 5DP-130 with a new device are shown in Table 2.

The calculation of economic efficiency from the introduction of the proposed saw gin with the speed control of the saw cylinder was calculated according to the method for determining the economic effect of the introduction of new technology in the cotton processing industry [14]. The economic effect of the introduction of saw gin with saw cylinder speed control was determined to equal 22.728 thousand sums (Uzb) for each ton of produced fiber.

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CONCLUSION

As a result of the research, the following conclusions were obtained:

1. As a result of modeling the static and dynamic parameters of the seed roll under the influence of the saw cylinder, the equation for the balance of forces acting on the saw cylinder, the equation for immersing the saw cylinder into an arbitrary point of the seed roll, the formula for the intensity of the process of separation of the fibrous mass (ginning) were obtained.

2. The effect of changing the diameter of the saw gin on the performance of the machine was theoretically investigated, and the dependence of the diameter of the saw and the speed of the saw cylinder on the performance of the machine and the quality of the fiber were determined. It was found that to maintain the optimal linear speed of 12.2 m/s of the saw cylinder with saw diameters of 320 mm, 310 mm and 300 mm, it is necessary to provide circumferential speeds of 730 rpm, 752 rpm, and 777 rpm, respectively.

3. From the analysis of the regression equations for the dependence of machine performance and fiber quality indicators on the diameter and speed of the saw, it was determined that with a saw diameter of 310 mm for I- and IV grades of cotton, the circumferential speed of the saw cylinder was 708 rpm and 770 rpm, with saw diameter 320 mm – 686 rpm and 746 rpm, respectively.

4. Based on the available research on the speed of the gin saw cylinder, using new devices and process control systems, a rational direction was chosen to improve the process of regulating the speed of the saw cylinder with a change in the diameter of the saw.

5. A resource-saving technology for regulating the speed of the saw cylinder with a change in the diameter of the gin saw has been developed based on the analysis of the existing systems for regulating the speed of the saw cylinder of technological machines, and a device for monitoring and controlling the speed of the gin saw cylinder has been created.

6. As a result of the introduction of saw gin with saw cylinder speed control into production, it was possible to reduce the mass fraction of defects and weeds by 0.5%, increase the staple mass length by 0.1 mm, reduce mechanical damage to seeds by 0.4%, seed pubescence by 0.2% when processing I-grade cotton, and increase the productivity of the machine by 4.7% when processing IV-grade cotton.

7. The economic effect of the introduction of a saw gin with saw cylinder speed control was determined to equal 22.728 thousand sums (Uzb) for each ton of produced fiber.

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