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Improvement of the Process of Separation of Cotton Fiber from Seeds

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Abstract

The differential equation, obtained as a result of the theoretical study of the movement of the bare seed on the surface of the grate of the saw gin, made it possible to determine the trajectory of the movement of the seed. The rib is one of the main working bodies of the saw gin. It serves for the free passage of the saw blades through it into the working chamber, for the withdrawal of the fiber caught on the saw teeth after separating it from the seed. A number of studies have been carried out to improve the working elements of the saw gin. The purpose of the research is to create the possibility of timely withdrawal of bare seeds from the working chamber of the saw gin by creating a concavity on the working surface of the grate. The use of the Euler equation for the movement of bare cotton seed along the grate contour, taking into account its speed V, density ρ, pressure P, made it possible to obtain a graph of seed distribution along the grate contour. An experimental 30-saw gin was developed and manufactured, the research carried out on it allowed to determine the rational parameters of new grates, which are recommended for introduction into production. The dependence of the location of the rectilinear part of the general contour on the shape of its convexity and concavity is determined. Based on the above equations, using separate functions, we present the view of the grate profile in the coordinate system modeled on the MAPLE-17 program.

Keywords

Cotton, Saw Gin, Grates, Ginning, Fiber, Seeds, Concave Surface, Seed Cotton, Ginning of Cotton, Roll Box, Seed Roll, Profile of the Roll Box, Speed of the Feed Rolls, Density of the Seed Roll

1. Introduction

According to the International Cotton Advisory Committee (ICAC), "…23 - 24 million tons are produced every year in the world. Cotton fiber, its annual consumption amounted to 24 - 25 million tons". Due to the increase in the consumption of cotton fiber, the requirements for its specific type and grade, quality indicators have changed. In this regard, on a global scale, its ensuring the efficiency of cotton fiber production, improving quality, reducing costs, identifying and preventing factors that adversely affect product quality at all stages of production, including in the process of separating fiber from seed, creating resource-saving technologies that reduce the cost of production remains the most important task for the industry.

In the world, scientific research is being carried out aimed at improving the process, technique and technology of primary processing of cotton, in particular, the separation of fiber from seed.

In our republic, much attention is paid to the rapid development of the production of finished products with added value based on deep processing of cotton raw materials, providing competitive cotton products in the domestic and foreign markets based on the modernization of cotton ginning plants.

Therefore, the improvement of the working bodies of the saw gin (saw cylinder, raw roller accelerator, working chamber) and the issues of improving the intensive withdrawal of bare seeds from the working chamber of the saw gin are currently an urgent problem.

Currently, much attention is paid to increasing the output of value-added finished products, improving the cotton industry system based on the deep processing of cotton raw materials, lowering production costs and improving the quality of cotton products based on the re-equipment of cotton primary processing technology.

When solving these problems, increasing the efficiency of the ginning process by improving the working chamber of the gin is one of the important tasks.

Also, the main way to increase the efficiency of the saw gin is to increase the fiber content of the raw roller, accelerate the yield of bare seeds and a uniform decrease in its density [1] [2] [3] [4].

The grate is one of the main parts of the working chamber of the saw gin. It serves as an obstacle to the braking of seeds and the free passage of saw cylinders with trapped fibers on the saw teeth. Grid-irons are made by casting from SCH-15-32 cast iron.

The working surfaces of the grate are processed on special machines, brought to a certain purity. The surface of the grille is hardened to give a certain hardness to ensure reliable operation. The working surface of the grate should be smooth and not rough. The distance between the grates in the working area should be 3 ± 0.2 mm, and in the lower part 4.5 - 5 mm [5] [6] [7] [8].

The number of grates in the grate is one more than the number of saws on the shaft. Two narrow grates are installed on both sides of the grate, as extreme ones, and the rest with a normal width are intermediate. At cotton ginning plants, when the saw gin DP-130 is operating, the teeth of the saw cylinder, grabbing the fibers from the raw roll, pass through the gap between the grates, and the seeds stop on the grate due to their large size relative to the gap. Further, the saw teeth strongly attract the fibers and tear them away from the seeds. The fibers hooked onto the saw teeth are separated by an air stream exiting the nozzle.

The surface of the grate of this gin is flat, the interaction of the raw roller and the saw cylinder is constant, the machine performance is low, energy consumption and damage are high.

Taking into account the above, we have proposed a grate with a concave profile for the rapid removal of bare seeds from the working chamber.

This rib-grate makes it possible to reduce friction with a saw cylinder and a raw roller, as a result of reducing damage to the fiber and seeds, as well as reducing energy consumption, accelerating the exit of bare seeds from the working chamber [9] [10] [11] [12].

2. Research Methods

Research methods.

In contrast to the existing grates, grates with a concave surface are offered. The goal is to accelerate the removal of bare seeds from the raw roller. Such methods are also used in other works of the authors [13] [14] [15] [16]. The law of movement of bare seeds along the grate was studied theoretically (**Figure 1**).

Mathematical model of the problem.

Let us study the movement of the bare seed along the arcuate part of the grate from top to bottom under the force of its gravity, taking the mass of the seed as a material point, in relation to the natural coordinate system (**Figure 2**).

Let us assume that the exposed seed moves in an arc with a radius and a center.

Then *M*—the forces influencing the seed.

Gravity: $G = mg$

The reaction of the grate to the seed—*N*.

The friction force between the seed and the grate surface is $F_{\text{ишк}} = f \cdot N$.

f—the coefficient of friction.

Let's compose the equation of movement of the seed on the surface of the rib

$$\begin{cases} m\dfrac{\mathrm{d}v}{\mathrm{d}t} = F_r \\ m\dfrac{v^2}{R} = F_n \end{cases}$$

Here—*R* is the radius of the seed trajectory rounding;

v—is the modulus of its speed.

The rate of seed falling depends on the depth of the grate concavity; small seeds lead to an increase in the coefficient of friction between them. At the transition from the arcuate part of the grate to the rectilinear part, the speed of the seeds has the maximum speed.

Theoretical study of the movement of a single seed and the flow of seeds along a grate with a concave surface on a saw gin.

Let the transitions of a grate with a concave surface AB, BC, CD, and EF be expressed by circular arcs (**Figure 3**).

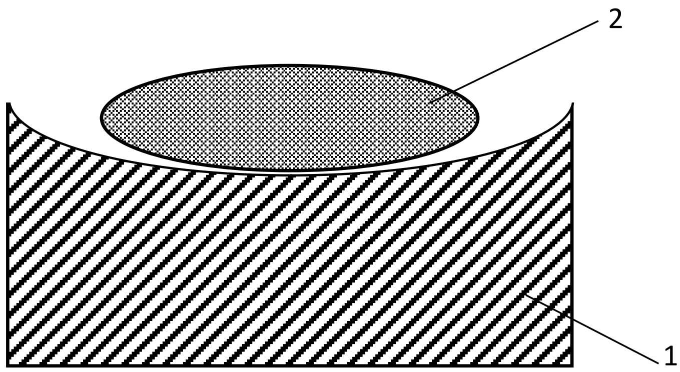

Figure 1. A grate with a concave surface. 1—grate with a concave surface, 2—bare seed.

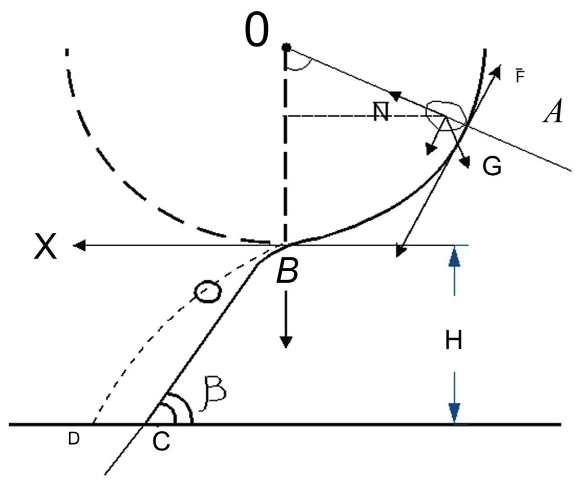

Figure 2. Movement of the bare seed.

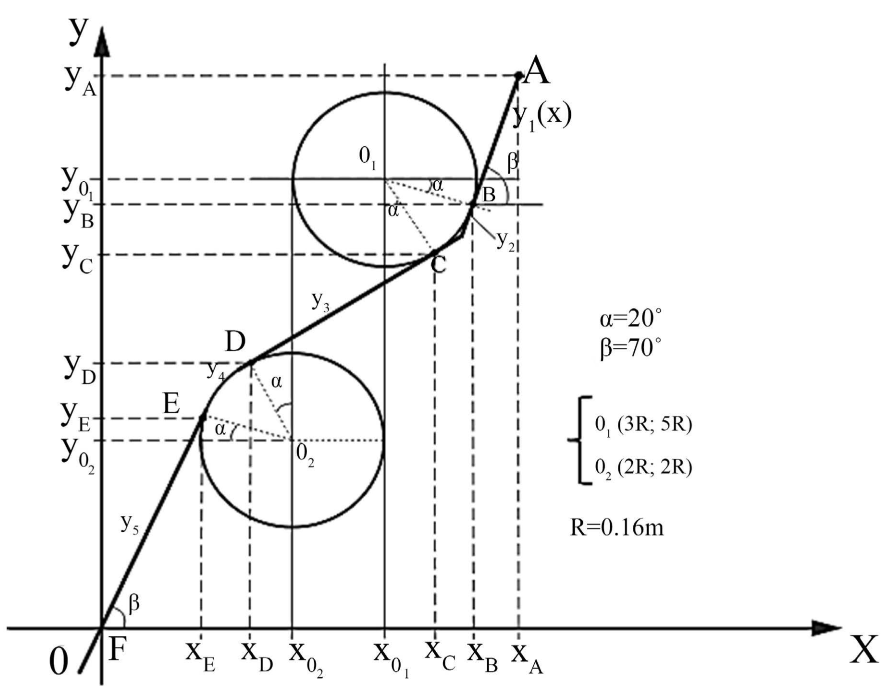

Figure 3. Design diagram of a grate with a concave profile.

We write the equations of the circles in the following form:

$$\left.\begin{aligned}(x-x_1)^2+(y-y_1)^2=R_1^2\\(x-x_2)^2+(y-y_2)^2=R_2^2\end{aligned}\right\}\tag{1}$$

where: x_i, y_i —coordinates of the centers of the circles, R_i their radii.

Equations of lines AB, BC, CD

$$\left.\begin{aligned}y_1=k_1(x-x_{11})+y_{11}\\y_2=k_2(x-x_{12})+y_{12}\\y_3=k_3(x-x_{13})+y_{13}\end{aligned}\right\}\tag{2}$$

The points x_{11}, y_{11} lie on the arc therefore

$$(x_{11}-x_1)^2+(y_{11}-y_1)^2=R_1^2\tag{3}$$

In addition, the slope of the straight line AB

$$k_1=\frac{x_{11}-x_1}{\sqrt{(x_{11}-x_1)^2+(y_{11}-y_1)^2}}=tga_1\tag{4}$$

If the slope is given K_1, the coordinates x_{11}, y_{11} are determined from equations (2) and (4).

The coordinates are determined in the same way x_{12}, y_{12}

$$(x_{12}-x_1)^2+(y_{12}-y_1)^2=R_1^2\tag{5}$$

$$k_2=\frac{x_{12}-x_1}{\sqrt{(x_{12}-x_1)^2+(y_{12}-y_1)}}=tga_2\tag{6}$$

$$(x_{21}-x_2)^2+(y_{21}-y_2)^2=R_2^2\tag{7}$$

$$k_3=\frac{x_{21}-x_2}{\sqrt{(x_{21}-x_2)^2+(y_{21}-y_2)}}=tga_3\tag{8}$$

$$k_3=\frac{x_{21}-x_2}{\sqrt{(x_{21}-x_2)^2+(y_{21}-y_2)}}=tga_3\tag{9}$$

From each Equation (3)-(8) unknown coordinates were determined, $x_{11}y_{11}$; $x_{12}y_{12}$, $x_{21}y_{21}$; $x_{22}y_{22}$. We write the concavity equation for the grate in the following form

$$\begin{aligned}&y=k_1(x-x_{11})+y_{11},\ x_0<x<x_{11}\\&y=y_1-\sqrt{R_1^2-(x-x_1)^2},\ x_{11}<x<x_{12}\\&y=k_2(x-x_{21})+y_{21},\ x_{12}<x<x_{22}\\&y=y_2-\sqrt{R_2^2-(x-x_2)^2},\ x_{21}<x<x_{22}\\&y=k_3(x-x_{22})+y_{22},\ x_{22}<x<x_{12}\end{aligned}\tag{10}$$

Based on the above equations, using separate functions, we present the view of the grate profile in the coordinate xoy system modeled on the MAPLE-17 program shown in **Figure 4**.

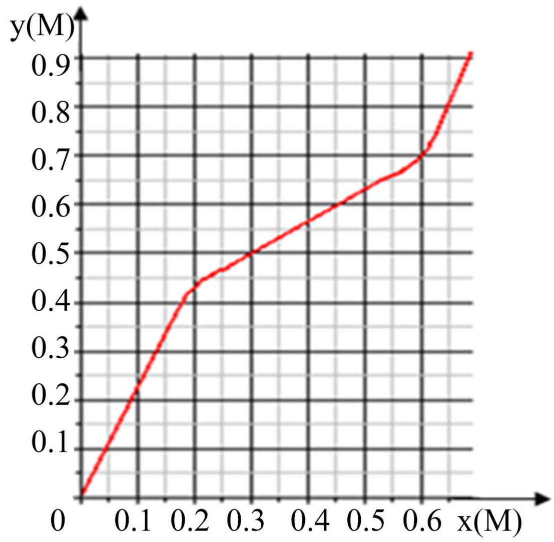

Figure 4. View of the grate profile in the coordinate system.

The results of experimental studies carried out on a 30-saw gin made in the laboratory of the department of "Primary processing of natural fibers" of the institute are presented (**Figure 5**).

When operating 30 of the experimental gin sawing device, cotton from hopper 1 is fed by feed rollers 2 to the peg drum 3. By the peep drum 3 the cotton is loosened, hitting the mesh surface and cleaned of fine debris, then enters the working chamber.

In the working chamber, raw cotton at the seed comb 7 is captured by the teeth of the rotating saws 13, and moves to the workstation of the grate 8.

The cotton flaps captured by the saw teeth are connected with other flaps and impart to them the movement received from the saw teeth; As a result, the entire mass of cotton in the working chamber rotates in the opposite direction to the direction of rotation of the saw blades. This forms a rotating raw roller, which ensures a continuous supply of cotton to the saw teeth, and, consequently, continuous operation of the gin.

The strands of fibers captured by the saw teeth are pulled in the workplace by the grate, are torn off the seeds and transported to a removable device, where they are removed from the saw teeth by an air flow and transported through the neck to the general fiber outlet.

After all the fibers are separated, the seeds lose their connection with the mass of raw fiber and are sent from the gin down the grate.

It is known that 50% of the raw fiber mass consists of seeds completely freed from fibers and collected in the central part of the raw roller, therefore it is possible to increase the productivity of saw gins by reducing the average residence time of seeds in the chamber.

Our studies are aimed at improving the design of grates by cutting grooves on their concave part, which allows intensive extraction of bare seeds from the working chamber of the gin (**Figure 6**).

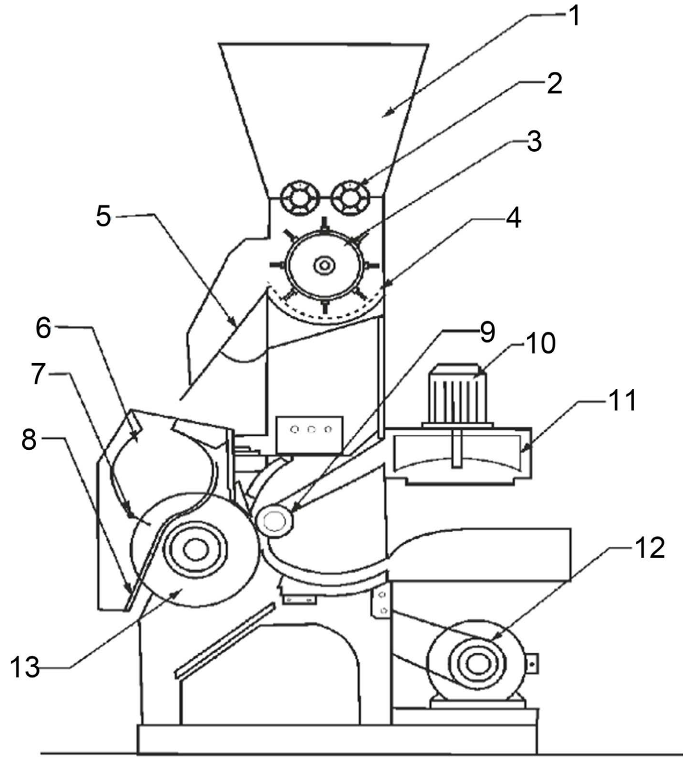

Figure 5. Diagram of 30 saw gin. 1—hopper, 2—feed rollers, 3—head drum, 4—mesh surface, 5—tray, 6—working chamber, 7—seed comb, 8—grates, 9—air nozzle, 10, 12—electric motors, 11—fan, 13—saw cylinder.

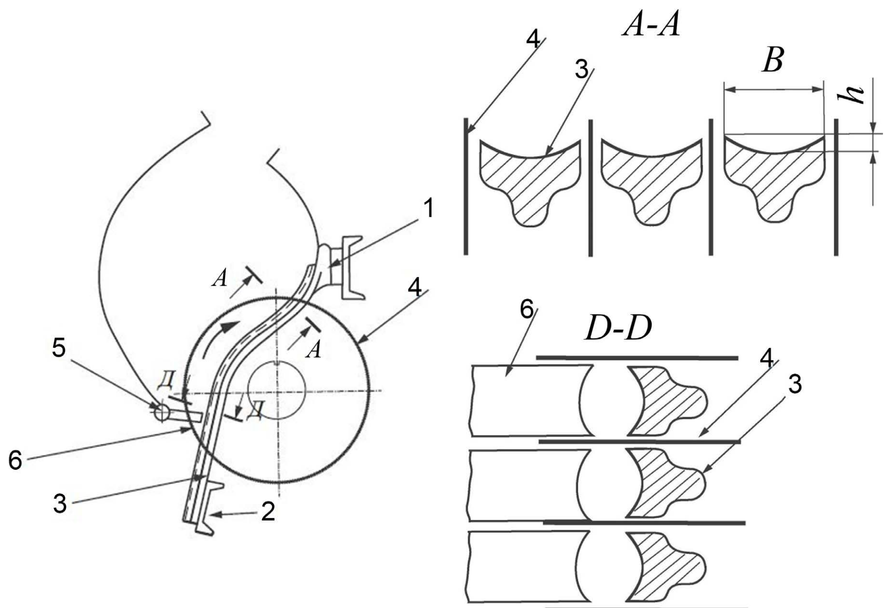

Figure 6. Schemes of the working chamber with new grates and sections of the grate surface. 1—the upper bar of the grate; 2—the lower bar of the grate; 3—grates; 4—saw cylinder; 5—steel bar; 6—seed comb.

As a result, a uniform density of the raw roll is achieved, which leads to the preservation of fiber quality and a decrease in damage to cotton seeds.

Production tests were carried out to study the efficiency and performance of the grate of the new design.

The grates of three forms were installed on gins in the production workshop of the joint-stock company "Kosonsoy paxta tozalash".

For comparison of seeds dropped from different grates, 20 grates with a usual shape without grooves were also installed (**Figure 7**).

The number of bare seeds per unit time, falling from grates with different sizes of concavity, has been determined.

When comparing the number of bare seeds, the grates with form A gave the maximum value (**Table 1**).

The analysis showed that the release rate of bare seeds increased by 18%. This provides increased productivity of the gin while maintaining fiber quality and reducing seed damage.

The width of the concavity of the grate, mm X1, is taken in the range of 8 - 12 mm.

The use of existing grates leads to a decrease in seed yield (**Table 2**). Taking into account the limitations of possibilities in laboratory conditions, the productivity was estimated by the number of seeds per minute (kg/min) and converted to a standard form (ton/hour) during analysis.

The depth of concavity of the grate surface is one of the main factors and affects the movement of seeds. Based on the initial experiments, the concavity depth of the grate surface is taken in the range of 2 - 4 mm.

After statistical processing of the experimental results, the following regression equation was obtained:

$$y = 10.55 + 0.45x_1 + 0.75x_2$$

As can be seen from the graph (**Figure 8**), for different values of the width of the concavity, there is a linear relationship between the depth of concavity and the amount of seed output.

Saw gin grates with rational parameters of the concavity of the working profile have been introduced in the joint-stock company "Kosonsoy paxta tozalash".

As a result of the introduction of grates with concave surfaces when processing cotton of I-, II- and III-grades, a decrease in the mass fraction of vices and trash

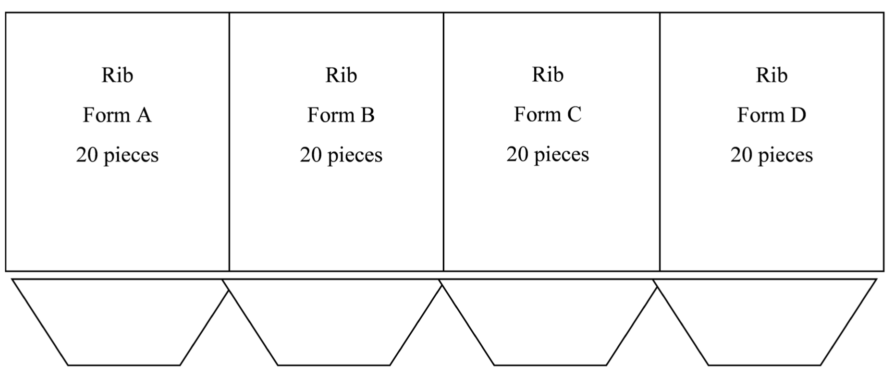

Figure 7. Diagram of the installation of grates in gins.

Table 1. Experiment input factors.

Rib shape	Concavity on the rib surface	
	Concavity width, mm	Concavity depth, mm
Form A	12	4
Form B	10	3
Form C	8	2
Form D	0	0

Table 2. Step of the investigated factors.

Factors	x_{max}	x_{min}	Δ	x_0
Concavity width of the rib, mm	12	8	2	10
The depth of the rib concavity, mm	4	2	1	3

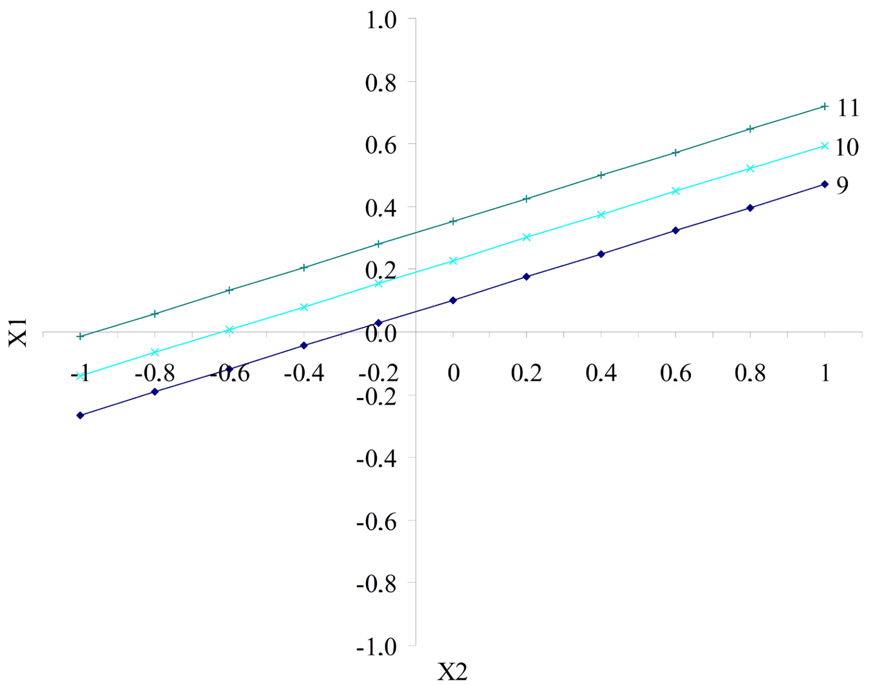

Figure 8. Dependence of the amount of seed yield on the width and depth of the concavity. 1—$Q = 9$ kg/min, $a_1 = 8$ mm, $b_1 = 2.0$ mm; 2—$Q = 10$ kg/min, $a_1 = 10$ mm, $b_1 = 3.0$ mm; 3—$Q = 11$ kg/min, $a_1 = 12$ mm, $b_1 = 4.0$ mm.

impurities by 0.2% - 0.5%, an increase in staple mass-length by 0.1 - 0.2 mm, reduction of mechanical damage to seeds by 0.5% - 0.8%, seed fibrillation by 0.3% - 0.5%.

As a result of the installation of grates with concave surfaces in the working chamber of the saw gin and their introduction into production, the economic effect amounted to 37,800 thousand soums per year.

3. Conclusions

The differential equation, obtained as a result of the theoretical study of the movement of the bare seed on the surface of the grate of the saw gin, made it possible to determine the trajectory of the movement of the seed.

The Euler equation for the movement of bare cotton seed along the grate contour was compiled, taking into account its speed V, density ρ, pressure P, the solution of which made it possible to obtain a graph of the seed distribution along the grate contour.

An experimental 30-saw gin was developed and manufactured, the research carried out on it allowed to determine the rational parameters of new grates, which are recommended for introduction into production.

The studies carried out using the method of mathematical planning made it possible to determine the optimal parameters of the grooves of the new grates (width a_1 = 12 mm, depth b_2 = 4 mm), at which the best effect of removing bare seeds from the working chamber of the gin is achieved.

Conflicts of Interest

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

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