STUDY OF THE INFLUENCE OF GRATES ON FIBER FLOW IN THE CLEANING ZONE

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Abstract. *During the initial processing of cotton, the cleaning efficiency of the unit of the cotton cleaning chamber — which removes fine and coarse impurities — is relatively low, and due to insufficient removal of foreign mixtures from cotton, it is necessary to clean the fiber more effectively in the saw gin to improve fiber quality. To accelerate the removal of coarse and fine impurities from the fiber in the gin, theoretical studies were conducted on an improved grate with grating bars, and the optimal parameters of the grates were determined. The impurity separation process from the fiber was studied at inter-grate distances of* $l_1 = 44$ *mm,* $l_2 = 46$ *mm, and* $l_3 = 48$ *mm, and at different fiber flow coverage angles. The research found that when the coverage angle of the grates is* $\varphi = 60°$*, the interaction between the fiber and the grate bars under the action of the rotating saw teeth intensifies the separation of coarse and fine impurities from the fiber. The most effective interaction between the fiber and the grate bars was observed when the inter-grate distance was* $l_2 = 46$ *mm and the angle at the ends of the grate bars had an optimal value, leading to high cleaning efficiency of the improved grate system.*

Keywords: *Saw gin, grate system, saw cylinder, centrifugal force, resistance force, density, pressure, velocity, fiber, cleaning efficiency.*

Introduction.

The quality of cotton fiber depends on several factors, among which the mass proportion of defective fibers and foreign impurities in the fiber is one of the most significant. This mass proportion is itself influenced by a variety of factors, including the maturity of the cotton, the readiness of the field for harvesting, the moisture and impurity levels of high- and low-grade cotton varieties delivered to ginning plants, as well as practices related to cotton storage, preventive maintenance, and the initial processing of cotton. These processes must take into account cotton moisture and impurity levels to ensure that the technological system and equipment operate in accordance with the technological regulations [1, 2].

Therefore, at cotton ginning plants, particular attention is paid to the mass proportion of defective fibers and impurities in the fiber produced during the initial processing of cotton. Variations in the amount of impurities in the fiber are closely related to the drying process, which must consider cotton moisture, and to the cleaning processes for both cotton and fiber. Currently, the unit of the cotton cleaning chamber unit is primarily used for removing fine and coarse impurities from cotton. According to its technical specifications, the unit of the cotton cleaning chamber unit has an average cleaning efficiency of 80–90%. However, research conducted in production environments shows that its actual efficiency when cleaning both high- and low-grade cottons averages around 70–80%. It has been found that the unit of the cotton cleaning chamber unit lacks the capability for multi-stage and deep cleaning of cotton [3].

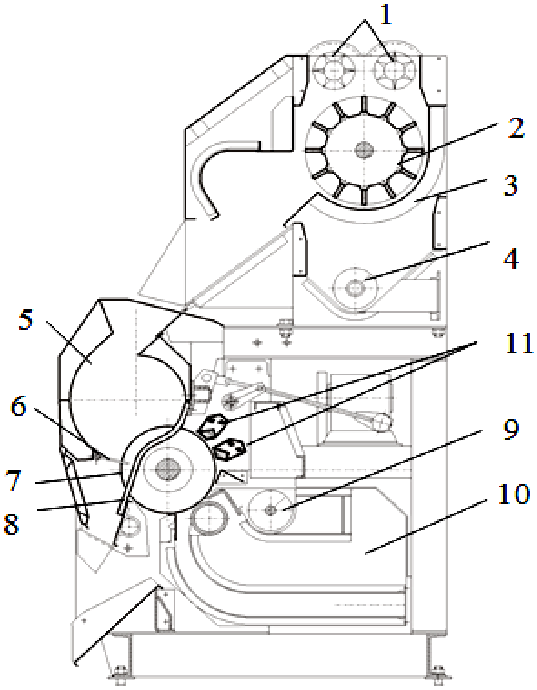
Adding additional cotton-cleaning equipment to the unit of the cotton cleaning chamber unit to increase efficiency results in higher electricity consumption and operational costs. It also increases the likelihood of random clogging, leading to specific operational challenges. Furthermore, the number of rotating working elements in the cleaning process increases, and the interaction of cotton with multiple rotating elements significantly raises the risk of fiber damage [4].

During the saw ginning process, this leads to an excessive amount of defective fiber and impurities, negatively impacting fiber quality. For this reason, in foreign countries, deep cleaning of cotton is avoided to prevent such negative effects on fiber quality. Instead, these countries focus on implementing efficient fiber cleaning processes to improve fiber quality.

Because coarse fibers, fibers with seed coats, and entangled fibers mainly appear during the gin processing of cotton, they are primarily located in the upper layer of the fiber and do not adhere strongly to the fiber. For this reason, cleaning the fiber of coarse impurities and foreign matter directly in the gin is easier than cleaning it later in the fiber cleaner [5]. Therefore, cleaning the cotton in the unit of the cotton cleaning chamber unit and directing the fiber to be effectively cleaned within the gin itself positively affects the natural properties of the fiber and improves its quality.

Taking these factors into account, in the mid-1980s, modifications were made to the design of the working chamber of the 4DP-130 gin to enable preliminary cleaning of the fiber directly in the saw gin [6]. Two trapezoidal grates were installed at the rear part of the chamber, and this design was industrially introduced in the 5DP-130 gin (see Figure 1). The trapezoidal separating grates cover 450 degrees of the radius of the saw cylinder; the grate pitch is 60 mm, and the spacing between the saw teeth on the saw cylinder and the grates ranges from 1.5 to 2.0 mm [7, 8].

In the 5DP-130 gin, the use of two grates allows the fiber produced by the gin to be cleaned by impacting these grates, which partially separates coarse fibers and foreign impurities from the fiber. As a result, the quality of the produced fiber is improved.



1 - Feed rollers, 2 - Spiked drum, 3 - Mesh surface, 4 - Waste auger, 5 - Working chamber, 6 - Seed brush, 7 - Saw cylinder, 8 - Grate, 9 - Coarse fiber auger, 10 - Air chamber, 11 - Separating grates.

Figure 1. Diagram of the cross-section of the 5DP-130 model saw gin

Research Methods and the Received Results

However, since the separating grates (kolosniks) are individually fastened to the gin side wall, during the operation of the gin, the grates may become loose. This leads to inconsistent spacing between the grates and irregular variation in the deviation angle of the grates relative to the radius of the saw cylinder, rather than maintaining the required constant values. As a result, during the cleaning process, the separation of trash and other impurities from the fiber decreases, reducing the cleaning efficiency of the grates.

Additionally, the loosening of the grates leads to an increase in the gap between them, and during fiber cleaning by striking against the grates, the amount of fiber lost to waste increases. Consequently, the fiber content in the waste becomes high, with waste accounting for an average of 25–35% of the total mass, depending on the type of fiber being cleaned [9].

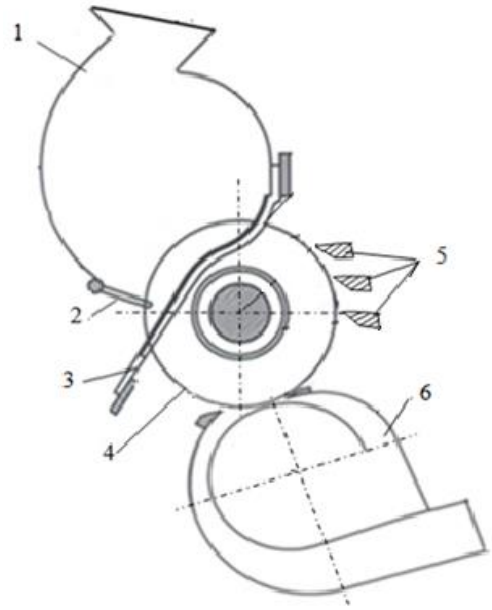
The cultivation of hard-to-clean selective varieties and the mechanized harvesting of cotton — introduced to reduce manual labor and additional costs — create problems in separating impurities from cotton and fiber.

As a result, the production volume of fibers classified as "Premium" and "Good" grades from both high- and low-quality cotton decreases.

To enable effective fiber cleaning within the gin itself, research efforts led to the improvement of the fiber cleaning system by 2016. The system was enhanced with a kolosnik grate featuring three trapezoidal-shaped kolosniks, and it was implemented in the 8DP-90 model gin and introduced into production (Figure 2).

This improvement in the fiber cleaning section led to an average increase in fiber quality by 0.21 (abs)% and 0.32 (abs)% when cleaning high- and low-quality cotton, respectively, compared to the fiber quality produced by gins equipped with only two individual kolosniks [10, 11].

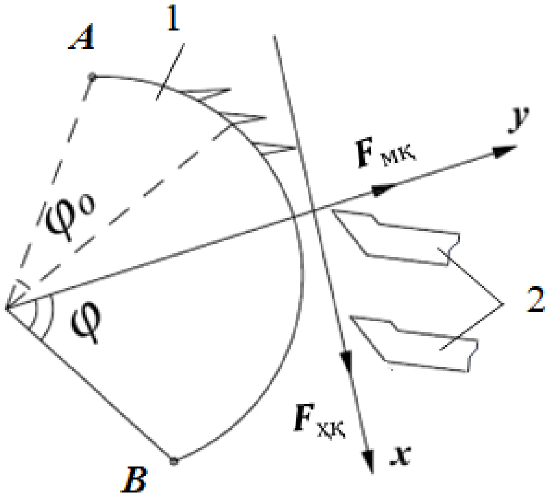
However, despite these advancements, due to the high adhesiveness of impurities to the fiber, both hand-picked and machine-harvested cotton still retain a significant amount of trash and small impurities. The excessive presence of these contaminants in the fiber reduces the overall quality of the final product.



1 – Working chamber, 2 – Seed brush, 3 – Grate, 4 – Saw cylinder, 5 – Separating grates, 6 – Air chamber.

Figure 2. Diagram of a saw gin with trapezoidal grates featuring fiber cleaning working parts

As a result of research aimed at accelerating the separation of coarse and fine impurities from the fiber and improving fiber quality during cleaning in the saw gin, a schematic of a grate system with improved design grates was developed. Based on the developed schematic, the effect of the grates on the separation of fine impurities from the fiber flow transmitted from the saw cylinder during cleaning directly in the gin was theoretically studied. We analyze the external forces generated by the interaction of the fiber flow moving with the saw cylinder on the grates, as well as the dependency of the arrangement and geometric parameters of the improved grates.



1 – Saw cylinder, 2 – Grates.

Figure 3. Diagram of the effect of fiber flow on the improved grates

are subjected to external forces, such as centrifugal force $F_{cq} = \frac{mv^2}{r}$and drag force (Figure 3).$F_{x*q} = mv^2k$

here$m$ - fiber mass , v- fiber speed, k - constant coefficient.

$AB = \ddot{S}$we express the movement of fibers along the arc as follows [12]:

$$I\ddot{\varphi} = \left(F_{x*q} + F_{mq}sin\alpha\right)r \qquad (1)$$

here $I = mr^2$is equal to .

Substituting this expression into equation (1), we calculate the differential equation:

$$mr^2\ddot{\varphi} = kv^2r + \frac{mv^2}{r}sin\alpha \cdot r$$

From now on

$$\ddot{\varphi} = \frac{kv^2}{mr} + \frac{v^2}{r^2}sin\alpha \qquad (2)$$

we assume that $F_{хк}$the fiber flow is the separation of impurities from the fiber by the interaction of the improved sieves, taking into account the distance between the sieves . As a result, we express equation (2) in the following form:$sin\alpha = \alpha$

$$\ddot{\varphi} = \frac{v^2}{r^2}\varphi = \frac{kv^2}{mr} \qquad (3)$$

(3) we determine the homogeneous and particular solutions of the differential equation. To do this, $\frac{v}{r} = z$we introduce a notation and calculate the homogeneous part of equation (3) [13].

$$\ddot{\varphi} - z^2\varphi = 0 \qquad (4)$$

(4) the homogeneous part of the differential equation

$\varphi = e^{\mu t}$, $\dot{\varphi} = \mu e^{\mu t}$, $\ddot{\varphi} = \mu^2 e^{\mu t}$ defining it, we get the following expression:

$$\varphi_1 = c_1\, e^{\mu_1 t} + c_2\, e^{\mu_2 t} \qquad (5)$$

In this case $\mu^2 - z^2 = 0$, we take into account and $\mu_1 = z$ ва $\mu_2 = -z$define (5) into equality

$$\varphi_1 = c_1\, e^{z\,t} + c_2\, e^{-z\,t}$$

(4) the solution of the differential equation $\varphi_2 = A$ look for it. As a result

$$-\frac{v^2}{r^2}A = \frac{kv^2}{mr} \text{from this} A = -\frac{kr}{m}$$

(4) by determining the general solution of the equation $AB = \vec{S}$ we determine the equation of motion of fibers along the arc:

$$\varphi = \varphi_1 + \varphi_2 = C_1\, e^{zt} + C_2\, e^{-zt} - \frac{kr}{m} \qquad (6)$$

From equality (6) C_1 and C_2 we determine the integral constants using free and boundary conditions : $t = 0$, $\varphi = 0$, $\dot{\varphi} = \varphi_0$

$$\begin{cases} C_1 + C_2 - \dfrac{kr}{m} = 0 \\ C_1 + C_2 = \dfrac{\varphi_0}{z} \end{cases} \Rightarrow 2C_1 = \frac{kr}{m} + \frac{\varphi_0}{z}$$

$$C_1 = \frac{krz+\varphi_0 m}{2mz}, C_2 = \frac{krz-\varphi_0 m}{2mz}$$

determined integral constants C 1 and C 2 into equation (6) and obtain the following expression [14, 15]:

$$\varphi = \frac{krt + \varphi_0 m}{2mz} e^{zt} + \frac{krz - \varphi_0 m}{2mz} e^{-zt} - \frac{kr}{m} \qquad (7)$$

Equation (7) determines the effective separation of coarse and fine impurities from the fiber as a result of the transfer of the fiber flow from the saw cylinder to the grates and their interaction. The solution to this equation was determined using the Maple program, and the analysis of the results is presented in the form of graphs in Figures 4 and 5. The following parameters were used in the calculations: $\varphi_0 = 25^0$; $r = 240$ мм; $k = 0.5$ $m = 1.4 \cdot 10^{-2}$ гр; $\varphi = 60^0$.

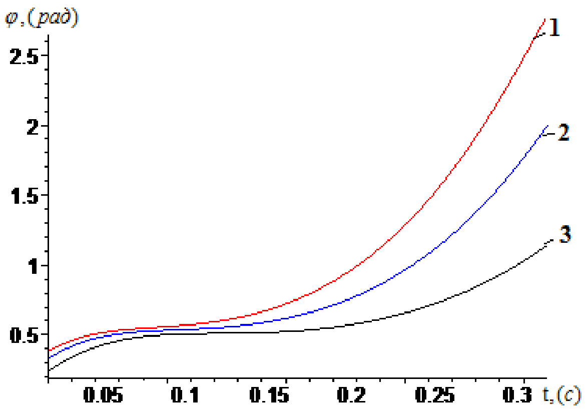


Figure 4. The distances between the columns are different when transmitting the fiber flow according to the angle of

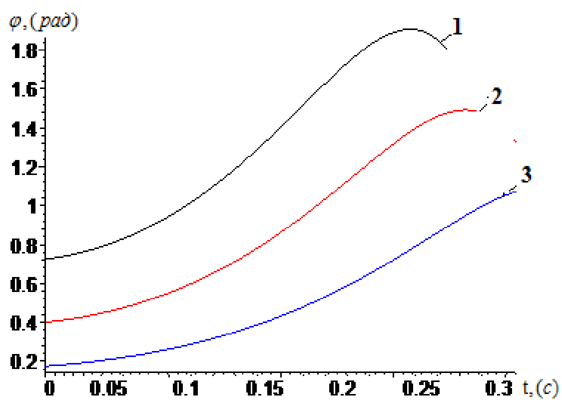


Figure 5. When transmitting the fiber flow according to the angle of coverage, the angle at the end of the columns is different

coverage$l_1 = 50$ мм , $l_3 = 46$ мм Time-dependent graph of values $l_2 = 48$ мм , $\alpha_1 = 50^0$,$\alpha_2 = 45^0$, $\alpha_3 = 40^0$ Time-dependent graph of values

The graphs above show the movement trajectories of fibers and impurities at different values of the distances between the columns. In this case, the distances between columns$l_1 = 44$ мм, $l_2 = 46$ мм, $l_3 = 48$ мм The process of separating large and small impurities from fibers is analyzed $\varphi = 60^0$when the fiber flow angle is $\alpha_1 = 50^0$, , $\alpha_2 = 45^0$ and $\alpha_3 = 40^0$ the fiber flow $l_2 = 46$ ммangle is , , . It is found that when the fiber flow is transmitted and the fiber flow is cleaned of large and small impurities due to the angle of the grates, $\alpha_3 = 40^0$ the fibers effectively interact with the grates and achieve high cleaning efficiency.

Conclusion.

Theoretical studies were conducted on the grates in the improved grate grid to improve the quality of the fiber by accelerating the separation of large and small impurities from the fiber composition during fiber cleaning in a sawtooth comb. The process of separation of large and small impurities from the fiber stream by the interaction of the fiber stream moving with the grates with the teeth of the sawtooth cylinder was observed. In this case, the distances between the grates$l_1 = 44$ мм, $l_2 = 46$ мм, $l_3 = 48$ мм when and fiber current coverage angle$\alpha_1 = 50^0$, $\alpha_2 = 45^0$, $\alpha_3 = 40^0$ The process of separating large and small impurities from fibers was studied at values . As a result of the studies, it was found $\varphi = 60^0$that when the angle of the bars is , the interaction of the fibers in the flow, which is cut by the teeth of the sawtooth cylinder, with the bars, the separation of large and small impurities from the fiber structure occurs, and when the distance between the bars is , and the angle at $l_2 = 46$ ммthe ends of the bars $\alpha_3 = 40^0$ is , the fibers interact effectively with the bars, and the cleaning of the bar screen works with high efficiency.

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