Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 46 No.04 (2025)

Modeling the Interaction of Fiber Bundles with Airflow and Aerodynamic Correlations in Fiber Cleaners

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Abstract. The modernization of process control methods, the development of automated methods for designing equipment and technologies, and the development of automated control systems for the cotton processing process. Currently, due to the improvement of machines for cleaning cotton fiber, which are developed according to the technology of primary processing of cotton, one of the urgent issues is to ensure the production of high-quality fiber. Taking this into account, it is necessary to conduct a constructive analysis of the fiber cleaning equipment and develop an effective design. In view of this, this study was aimed at improving the aerodynamic parameters of a fiber cleaner on the basis of theoretical and applied research by creating and experimenting new saw blade construction. In process of the research, methods are used optimization by theoretical statistics, evaluation and target electronic programs, theoretical and applied mechanics, higher mathematics and vibration theory. Aerodynamic equilibrium of a freely rotating saw cylinder due to the presence of friction forces arising between the saw blades and air and atmospheric pressure cannot be overcome by centrifugal forces acting on the air mass during rotation. This justification makes it possible to explain the reason for the industry's refusal of the cleaning rate at 1000 min^{-1} and its transition to 1500 min^{-1}. For the normal operation of the fiber cleaning machine, it is necessary that the saw cylinder, taking air on the cleaning arc. The conducted studies show that the dependence of the reduced velocity of air particles depends on the polar angle practically depends on a linear law, and an increase in air velocity in the initial arc of entry in the zone of the inter-core space also leads to an increase in the velocity when particles exit space, as well as the absolute velocity of air particles in the inter-core space non-linearly depends on the polar angle.

Key words: fiber cleaner, saw cylinder, saw blade, fire grate, air flow, aerodynamic parameters

Introduction. In developed countries, the modernization of process control methods, the development of automated methods for designing equipment and technologies, and the development of automated control systems for the cotton processing process [1-9]. Currently, due to the improvement of machines for cleaning cotton fiber, which are developed according to the technology of primary processing of cotton, one of the urgent issues is to ensure the production of high-quality fiber. Taking this into account, it is necessary to conduct a constructive analysis of the fiber cleaning equipment and develop an effective design [10-16].

To maintain the quality of fiber and seeds produced by researchers, cotton is repeatedly cleaned from small impurities up to 32 times [17], although in fact that cotton can be cleaned from large impurities up to four times and from small impurities up to 20 times [18]. Moreover, the cleaning efficiency of the demand level is below 90-95%, and the amount of residual impurities in the fiber is not cleaned at the required level. The complexity of the problem lies in the fact that now the maximum number of cotton cleaners in the equipment for cleaning from small and large impurities in cotton factories largely requires the installation of additional filters that increase the cleaning efficiency, leading to a sharp increase in the number of impurities with fiber defects. Therefore, the efficiency of cotton cleaning should be carried out without additional mechanical impact on it [19, 20].

In one of the scientific studies to improve the efficiency of cleaning cotton, which are on the assembly machine, a special structural guide device is installed on the equipment in order to improve the equipment for cleaning fibers used in cotton-cleaning mill. Recommendations were given for the introduction of a directional device in a special design into production [21-24].

Other study presented the results of a fiber cleaner developed and implemented at the Buz cotton-cleaning mill to determine the technological performance indicators depending on the rotation speed of the saw cylinders and the aerodynamic mode of operation [25].

In addition, fiber cleaning in direct-flow cleaners takes place in aerodynamic flows; the technological parameters of the machine depend on the aerodynamic mode of operation. The saw cylinders of the fiber cleaner not only clean the fiber, but also perform a number of aerodynamic functions associated with the interaction of several different air flows. Therefore, the scheme of movement of air masses inside the fiber cleaner is a rather complex phenomenon and has not been fully studied [26]. In view of this, this study was aimed at improving the aerodynamic parameters of a fiber cleaner on the basis of theoretical and applied research by creating and experimenting new saw blade construction [27, 28].

Fiber cleaners had low productivity, low cleaning efficiency, large dimensions, and complex design and operation. In the research work on the development and recommendations of scientists, as well as in the design concepts, the main focus has been on increasing the cleaning effect and selecting the main kinematic parameters of cleaning machines, particularly fiber cleaners.

Fiber cleaners had low productivity, low cleaning efficiency, large overall dimensions, and complex design and operation. In research work, the developments and recommendations of scientists, as well as engineering thought, were mainly aimed at increasing the cleaning effect and selecting the main kinematic parameters of cleaning machines, particularly fiber cleaners.

Researcher D.A. Kotov proposed two methods for constructing fiber cleaners: centrifugal, based on the aeromechanical cleaning method, and saw-based, relying on the mechanical cleaning method of fibers. As a result of laboratory tests, the author concluded that the centrifugal fiber cleaner is acceptable for cotton ginning plants [29; pp. 34-35].

After ginning raw cotton with contamination and moisture levels above the standard norms, the processed cotton fiber also contains impurities such as "uluk," the amount of which in some cases exceeds the norms established by the standard. If the fiber is pressed into bales in this state, the impurities, uluk, and other defects embedded in the fiber strands will create problems for the operation of textile industry equipment.

Additionally, ginned cotton fiber contains a significant amount of twists (strands), which degrade the marketable appearance of the fiber. Although not a malicious defect, twists can increase waste output after fiber pressing and further processing in textile mills.

In the fiber cleaning system, there are three methods of fiber cleaning [30; pp. 46-47]: the first method is the aerodynamic cleaning method (Fig. 1, a), based on changing the trajectory of the cotton-air flow in the cleaning zone, where mass forces act on the bends, resulting in intensive fiber cleaning (Fig. 1, a); the second method is the mechanical cleaning method, where cleaning is achieved by feeding the fiber through a feed table 2 to the cylinder's garniture 3, where the fiber beard is teased, and the fiber clumps captured by the cylinder 3 are cleaned of trash on the grid 4 (Fig. 1, b); the third method is the aeromechanical cleaning method, where cleaning is achieved by feeding a layer of fiber mixed with air onto the teeth of the saw cylinder, where the fiber clumps captured by the saw teeth are cleaned of trash and uluk due to impact actions against the grid (Fig. 1, c). Fiber cleaners are divided into single-stage and multi-stage based on the number of cleaning repetitions in the machine.

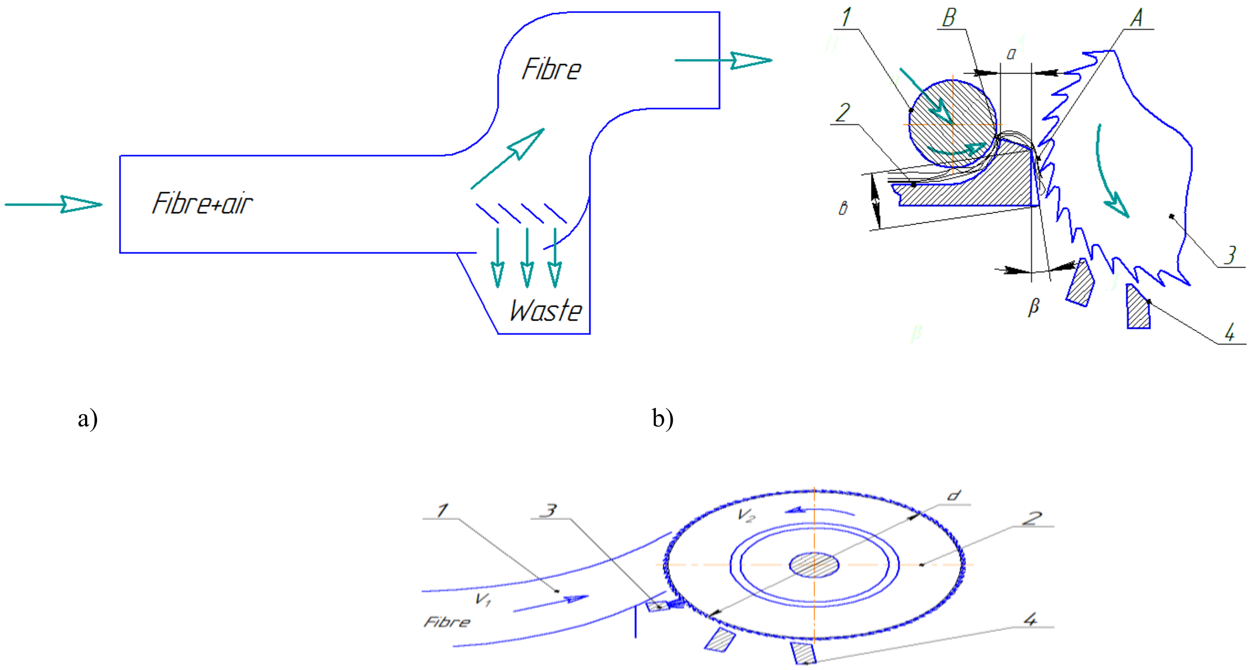
The following technological requirements are imposed on fiber cleaners: the impact of the working organs of the fiber cleaning machine on the fiber should not lead to the formation of fiber defects or deterioration of its natural physical and mechanical properties; the machines should remove the maximum amount of trash and uluk from the fiber, ensuring its release within standard norms; fiber cleaning should improve the marketable appearance of the fiber; the waste should contain a minimal amount of fiber; the machine design should include devices and mechanisms for controlling and regulating the cleaning effect and fiber content in the waste.

Devices based on the aerodynamic (pneumatic) principle are less effective as cleaners. Aerodynamic fiber cleaners have no moving working organs, and this quality, despite the relatively low cleaning efficiency (8÷15% per cleaning stage), is the reason for their application (especially in the USA). To this day, American firms Platt-Lummus and Continental Moss-Gordin produce such fiber cleaners. The absence of mechanical impact by aerodynamic fiber cleaners on the fiber preserves its physical and mechanical properties, which is very important for the textile industry. Fiber cleaning in such cleaners occurs due to a sharp change in the direction of the transporting air flow. At the bend of the fiber conduit, under the action of centrifugal forces, trash impurities, being heavier, are separated from the fiber mass and fall into the hopper. In the USA, several schemes of two-stage aerodynamic fiber cleaners have been patented, representing a two-column section of the fiber conduit with a trash removal system and transport means for removing foreign impurities [30; p. 48].

Fiber cleaning machines with the aerodynamic cleaning method cannot provide high cleaning efficiency, as uluk and trash are mainly separated by centrifugal forces, which can only remove weakly attached impurities.

According to experimental data from CRIindustry, the adhesion force of uluk to the fiber reaches 0.98-1.47 N, while the centrifugal force acting on the uluk is only 0.09-0.11 N. Therefore, without delving into technical and aerodynamic qualities, it can be said that the cleaning efficiency of such a device will be around 15÷20%, which is even lower than that of single-stage saw-type fiber cleaners of the straight-through type [30; p. 49].

Aerodynamic fiber cleaners mainly remove large impurities, the weight of which significantly differs from the weight of the fiber strands. The cleaning efficiency (no more than 20%) cannot meet the needs of cotton ginning plants. Additionally, their high aerodynamic resistance (around 140÷160 N/m² for one cleaning stage) presents certain difficulties for inclusion after air chambers of gins, as significant backpressure causes the air chambers to "fluff."



c)a – diagram of the aerodynamic fiber cleaning method; b – diagram of the mechanical fiber cleaning method; c – diagram of the aeromechanical fiber cleaning method

Fig. 1. Diagrams of fiber cleaning methods.

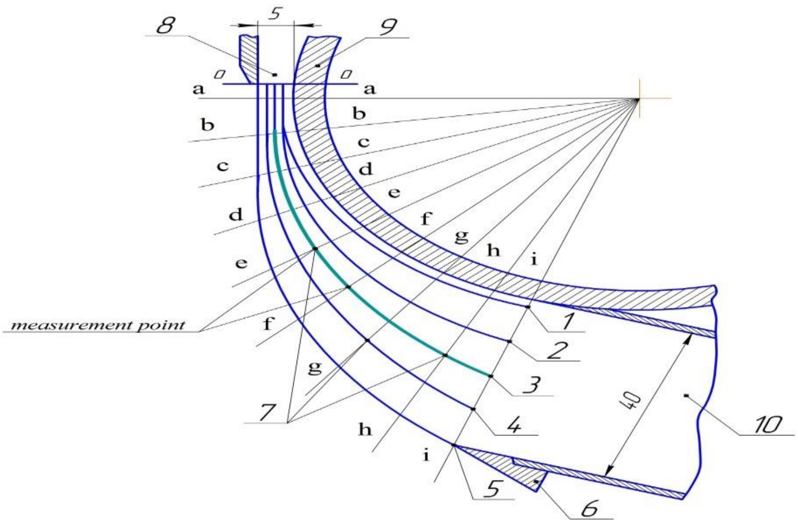
For these reasons, aerodynamic fiber cleaners have not found application in domestic cotton ginning plants. Among all fiber cleaning devices, saw-type fiber cleaners are the most effective. At the same time, their dimensions are smaller than those of knife-type machines, making them more preferable for cotton ginning plants. The best results are shown by the saw cylinder when working with a grid. The issue of the number of grids and their spacing on each machine is resolved independently, depending on the design and technological features of the particular fiber cleaner. Consequently, in practice, machines with a wide variety of grid numbers are encountered. All saw-type fiber cleaners are divided into four types: straight-through, inertial, with clamping rollers, and with a feed table. The straight-through principle is the simplest among them, as the fiber is fed to the saw cylinder without the participation of any auxiliary devices [30; p. 50].

In the work of F.A. Saadi [31; pp. 23-24], materials from experimental studies were analyzed (Fig. 2). The air jet, exiting the nozzle, in the fiber removal zone, ejects a certain amount of air and becomes mixed. The jet exiting the nozzle is called active, and the mixed jet, which was studied, is called working. The highest speed of the jet of the first flow line is at a distance of 30-35 mm from the nozzle, the second – at 20-25 mm, the third – at 10-15 mm, the fourth – at 5-7 mm. From the first to the fifth mode, the jet speed increases along the first flow line by 11-28%, the second – by 8-14%, the third – by 5-2%. On the fourth and fifth lines, the speed decreases. Upon entering the receiving pipe, the jet speed near the guide wall is the highest, near the uluk deflector – the lowest. Here, the ratio of air speeds between the first and fifth flow lines is within 20-23. The greatest rarefaction is between the first and third flow lines. In the transverse direction, rarefaction sharply increases in sections b-b, c-c, d-d, e-e, i.e., the fiber removal zone from the saw teeth.

Significant transverse pressure drop persists even when the jet enters the receiving pipe.

When the saw cylinder is operating on the third flow line, velocity and pressure profiles were obtained, shown in
Fig. 3. Under the action of the saw cylinder, at all operating modes of the doffer, the maximum velocities of the flow lines increase, and the pressure decreases compared to when the cylinder is removed. At the point where atmospheric pressure was, a slight rarefaction is formed [31; pp. 26-31].

In a freely rotating saw cylinder, a field of centrifugal forces arises on the side surfaces of the saw disks. Therefore, air particles directly adjacent to the disk, when rubbing against the surface, are drawn into circular motion and thrown away by centrifugal force along a curvilinear trajectory beyond the disk edge (Fig. 4). In place of the thrown air mass, through the middle strip between the saw disks, i.e., between two boundary layers, air is sucked in by the disks and ejected outward. On both sides of the saw disks, air particles move from the center to the periphery, while in the middle strip between them, they move from the periphery to the center, thus circulating air in the rotating medium. The air movement regime in the inter-saw space depends on the rotation speed of the saw disks. With an increase in the peripheral speed and roughness of the saws, air exchange in the



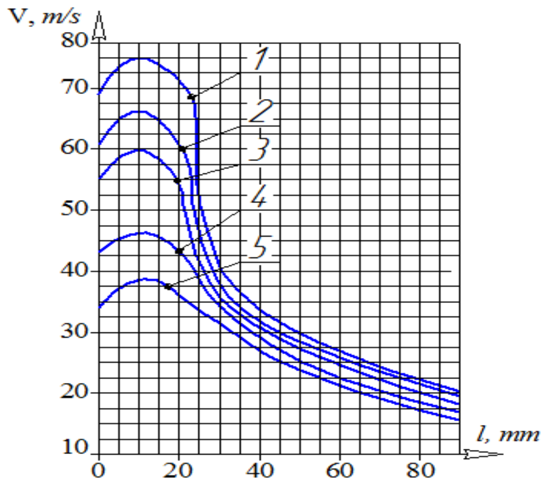
saw cylinder intensifies, while with some increase in the distance between the saws, this process weakens. Thus, rotating saw disks, acting as fan blades, continuously suck in and eject a certain amount of air through their side surfaces. When the saw cylinder rotates in a chamber concentric with the cylinder (Fig. 4, b), the air mass drawn into circular motion along the chamber wall flows back to the center of the disks through the rarefied area in the middle strip between them [31; pp. 126-128].

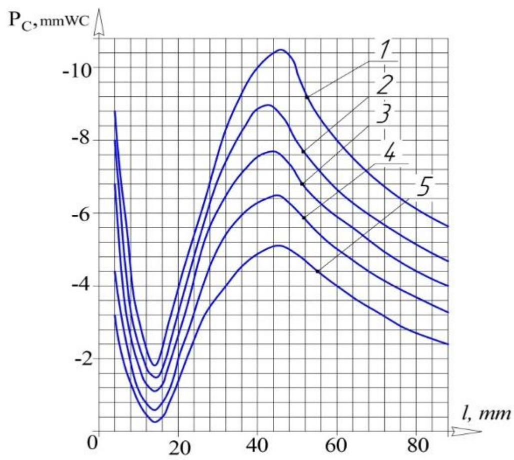
1-5 – Flow lines; 6 – Guiding visor; 7 – Measurement points; 8 – Nozzle;

9 – Guiding cylinder; 10 – Receiving pipe;

a-i – Cross-sections

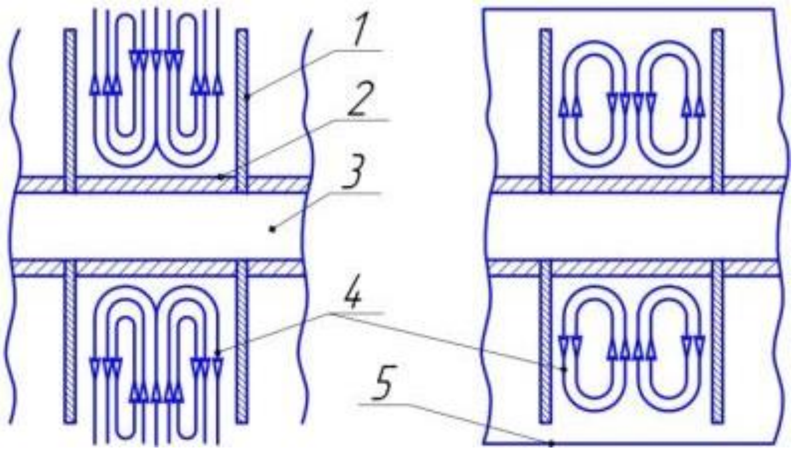
Fig. 2. Diagram of flow lines and cross-sections of the air jet in the fiber removal zone.





1-5 – Modes in the fiber removal zone

Fig. 3. Velocity and static pressure profiles of the working jet along the third flow line with an operating saw cylinder.



a) b)

Fig. 4. Airflow pattern between saw blades during saw cylinder rotation:**

a – in free space; b – in a concentric chamber;

1 – saw blade; 2 – inter-blade spacer; 3 – saw shaft; 4 – airflow between saw blades; 5 – chamber wall concentric with the saw cylinder.

The air flow entering from the gin penetrates the fiber cleaner, picks up the cleaned fiber at the exit, and transports it through the fiber conduit to the common battery condenser in the pressing shop. Thus, in straight-through fiber cleaners, cleaned and uncleaned fibers are transported by the same air flow, as is the case in pneumatic fiber cleaners. Inertial fiber cleaners are somewhat more complex, including, in addition to the saw cylinder, a condenser drum. Then comes the subgroup of machines with clamping working organs. This subgroup is the most complex. Even single-stage fiber cleaners with clamping rollers have a large number of rotating working organs, and fiber cleaners with a feed table are even more complex.

The presence of clamping working organs is driven by the desire to improve fiber carding during the cleaning process. This creates favorable conditions for separating trash impurities.

However, increasing the cleaning efficiency is not without negative consequences. The saw disk of the saw cylinder of the fiber cleaner, when interacting with the compression working organs, partially damages the fiber and breaks its ends. This leads to fiber shortening and a decrease in its strength.

Materials and methods. The object of research is cotton cleaning mills, fiber cleaner (fig.5), aerodynamic parameters. The properties of fibers in the composition of cotton fibers and semi-finished products are determined using the laboratory equipment of AFIS PRO 2 of the company "Oster". At the same time in the laboratory equipment it is possible to determine the length L(n), endings (Neps/g), the amount of thick fibers (SFC n, SFC w), linear density (Fineness), the amount of mature (ripened) fiber (Muturity), the amount of dead fiber (IFC), the amount of dust (Duct Cnt), pollution (Trash Cnt), visible large impurities (VFM). With the help of the above laboratory equipment, the quality indicators of the cotton obtained from the existing and improved fibers are studied [32].

The effect of the fiber on aerodynamic parameters of the working bodies in t cleaning process is calculated based on the values contained in the tables below [33]. (Table 1 and 2)

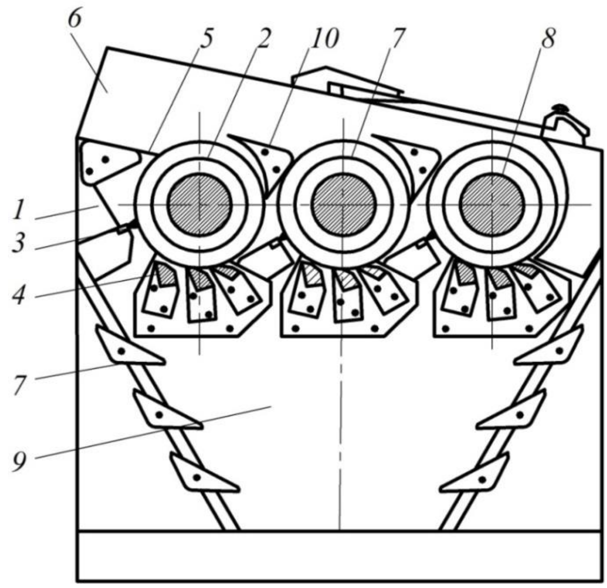
Table 1Air density depending at different temperatures

t, °C	-30	-20	-15	-10	-5	0	10	15	20	30
ρ, kg/m³	1,453	1,395	1,369	1,342	1,318	1,293	1,247	1,226	1,205	1,165

Table 2 Kinematic viscosity of air at different temperatures

t, °C	-30	-20	-15	-10	-5	0	10	15	20	30
$\nu \cdot 10^6$, m²/s	10,8	11,61	12,02	12,43	12,86	13,28	14,16	14,61	15,06	16

In process of the research, methods are used optimization by theoretical statistics, evaluation and target electronic programs, theoretical and applied mechanics, higher mathematics and vibration theory, theory of mechanisms and machines, mathematical modeling of working processes of technological machines,

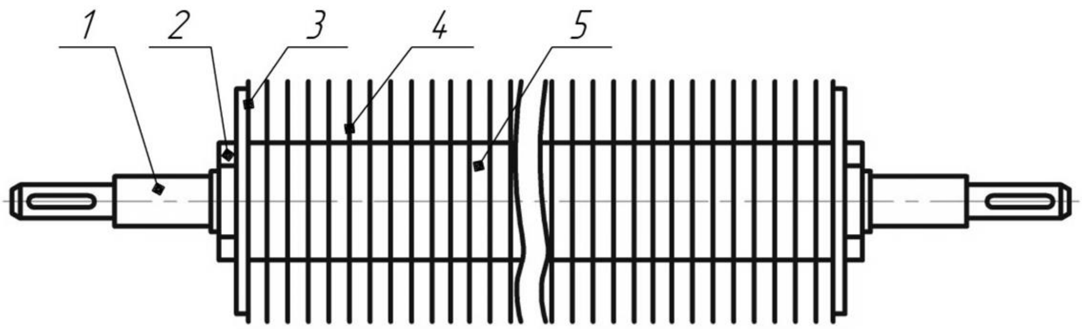


mathematical statistics and mathematical calculations [34-37].

Fig.5. Technological process scheme of 1ВП fiber cleaner

1-inlet pipe of fiber; 2, 7, 8-saw cylinder; 3-grinding brush; 4-fire-grate; 5-separating knife; 6. outlet pipe of fiber; 9-chute of impurity; 10-guide; 11-air blind

Types of variables are independent – cotton fiber, dependent – saw cylinder (fig.6), controlled – fiber cleaning



machine 1ВП (fig.5).

Fig.6. Saw cylinder of fiber cleaning machine

1 – shaft; 2 – lock nut; 3 – taper washer; 4 – saw blade; 5 – inlay

Analysis of research results. In the process of studying the effect of working bodies on the aerodynamic parameters of fiber cleaning machines, it is important to calculate the air flow generated around the cylinder with the saw in the process.

The air flows formed in the fiber cleaner have a significant impact on the process of separating weed impurities from the fibers. Consider the air flows created by the saw cylinder during its rotation. The movement of the fiber strand depends on which flow is laminar or turbulent, which will directly affect the cleaning process. During the rotation of the disk, air flows move along its side surfaces. They have a laminar character at low rotational speeds, and at higher velocities – turbulent. Laminar air flow over the disk is possible at a Reynolds number < 25000.

$Re = \omega r/\nu$ (1)

where ω - the angular velocity of rotation of the disk, rpm; r - the current radius of the disk, m; ν - the kinematic viscosity of the air, m^2/s.

From formula (1), the maximum radius of the laminar flow zone will be

$$r_{max} = \sqrt{\frac{250000\cdot\nu}{\omega}} \quad (2)$$

Take $\nu = 15.06 \cdot 10^6$, m^2/s. Knowing that $\omega = \pi n/30$, we rewrite equation (2)

$$r_{max} = \sqrt{\frac{250000\cdot\nu\cdot 30}{\pi\cdot n}}$$

When the fiber cleaner is in operation, the saw rotates at a frequency of n = 1500 rpm, with rmax = 0.157m = 160 mm (Fig.3).

As you can see, there is no laminar flow outside the saw blade Ø310 mm. (Table 3)

Table 3

n, rpm	1000	1500	2000	2500	3000
r_{max}, m	0.193	0.157	0.136	0.122	0.111

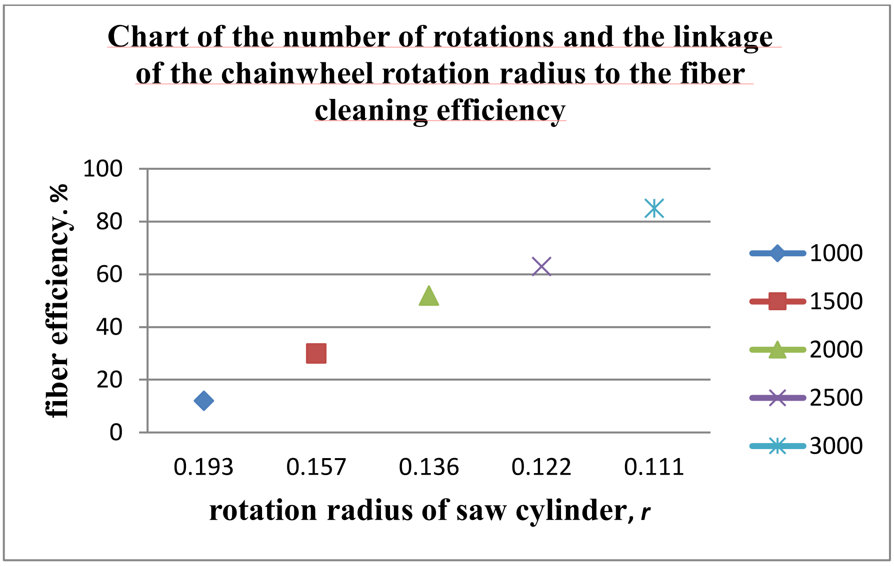


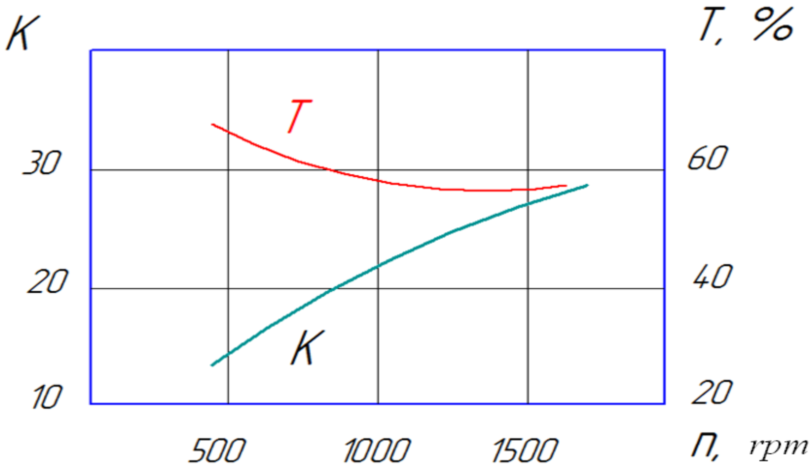
Fig.3.

This justification makes it possible to explain the reason for the industry's refusal of the cleaning rate at 1000 min^{-1} and its transition to 1500 min^{-1}. An increase in the number of revolutions gives an increase in the cleansing effect, which has been proven by repeated experiments (Fig. 7).

An increasing in the number of revolutions gives an improve in the cleaning effect, which has been proven by repeated experiments.

With the rotation speed of the saw cylinder over 1750 rpm, an unacceptable increase in its vibration is observed.

Fig. 7. The increase in the cleaning effect as a result of a change in the number of rotation of the saw cylinder depends on the amount of fiber contained in K and waste B



Improvement of the cleaning zone of the fiber cleaner. Research by scientists has established that cleaning raw cotton fiber from impurities and lint is most favorable immediately after it exits the gin. At this time, the fiber is in a loosened state, and the weight of its individual strands is only 15–20 mg. The bulk density of the fiber after removal from the gin saws does not exceed 0.15–0.25 kg/m³. Due to these conditions, it is advisable to install fiber-cleaning machines at cotton processing plants to clean the fiber from trash, lint, and other foreign impurities and defects in the ginning line before it is pressed into bales. The fiber cleaner is an element of the production line, and its productivity must match the gin's productivity in individual operation, as well as the battery of gins in a battery configuration [38; pp. 17-20].

The aeromechanical method of fiber cleaning, which combines mechanical and aerodynamic methods, has proven to be more effective and is increasingly used in domestic machine designs. Single-stage machines with this cleaning method have shown a cleaning effect of 20–23 % for high-grade cotton and 25–28 % for low-grade cotton. Increasing the cleaning effect is achieved by adding more cleaning stages in a single machine. However, increasing the number of stages incurs additional economic costs [38; pp. 93-94].

In the cotton industry, preference is given to individually designed fiber-cleaning machines, as they are less complex, have a higher cleaning effect, and offer better reliability compared to battery-operated fiber cleaners. The development of fiber cleaning is moving towards the creation of highly efficient individual aeromechanical fiber-cleaning machines. Among machine designs, straight-through fiber-cleaning machines, which feed fiber to the working mechanism directly after ginning in a loosened state, have gained widespread popularity due to their simplicity and high efficiency. These include individual single- and multi-stage machines [39; pp. 31-34].

At the cotton-cleaning plant of the LLC "APK BUKA" cluster, serial double-drum fiber cleaners of the VP-90 brand are used for fiber cleaning. However, these machines are unable to achieve the required cleaning effect due to imperfections in the design of the cleaning mechanisms. The low cleaning efficiency of the machines and the incomplete removal of difficult-to-remove fractions, such as broken seeds and husks, significantly hinder the process of preserving and processing the fiber in the textile industry.

As a result of studying the ВП-90 fiber cleaner at cotton plants in the republic, it was found that the actual cleaning effect is low, averaging 26-29 %, which does not ensure the quality of the fiber in accordance with the O'zDst 604:2016 standard "Cotton Fiber. Technical Specifications," especially when processing selective varieties. Additionally, due to design flaws in the fiber cleaner, up to 17% of the fiber passes through without cleaning, leading to a deterioration in the quality indicators of the produced fiber and a reduction in the cleaning efficiency of the machines.

Furthermore, fiber cleaners for cleaning fiber are known [40; pp. 90-98], which include a saw cylinder with saws. These exhibit low cleaning efficiency and significant fiber loss, with fibers being diverted to waste after cleaning.

The purpose of the saw disc, i.e., the cleaning element, is to capture fibers with the teeth of the saw disc and beat them against trash-removing surfaces (grids), where the separation of trash occurs. The technological requirements for the cleaning element, i.e., the saw disc, are to maximize the removal of trash impurities from the fiber with minimal fiber loss in the waste, prevent fiber damage, and regulate the removal of trash impurities and fiber loss.

To eliminate the identified shortcomings, saw discs with stamped petals have been created for the fiber cleaner. These discs ensure the creation of an aerodynamic air flow that affects the trajectory of the fiber bundle captured by the saw tooth, enhancing the removal of trash impurities from the grid zone (Fig. 8). By strengthening the air flow from the saw cylinder, which consists of saw discs with stamped petals, the cleaning effect of the fiber cleaner is improved by 10-15 %. Additionally, the quality of the fiber is increased by 3-3.5 %, ensuring compliance with the O'zDst 604-2016 standard "Cotton Fiber. Technical Specifications," and fiber loss in the waste is reduced to an average of 20% during fiber cleaning.

The essence of the improved saw disc lies in ensuring a full impact of the fiber bundle against the edge of the grids, which enhances the shaking out of trash impurities from the fiber bundle. The full impact is achieved by strengthening the air flow created by the stamped petals. The air flow is generated by the rotation of the saws in the saw cylinder and the flow coming from the fiber feed chute. Additionally, the centrifugal force acting on the fiber strand also contributes to its deviation from the surface of the saw cylinder, bringing it closer to the edge of the grids. An additional air flow is generated by the petals, which are stamped out of the saw disc body, giving them a specific inclination to the surface of the saw disc and directing the base of the petals along the radial line of the saw disc or at an angle to it. These petals, rotating with the saw, create an air flow towards the periphery of the saw discs, promoting full deviation of the fiber strand from the surface of the saw cylinder and effective cleaning of the fibers from trash impurities. Moreover, this enhanced air flow prevents air suction and the release of trash impurities from under the grid bars (from the waste chamber).

By ensuring more complete processing of the fiber bundle at the edge of the grids, preventing the return of trash impurities to the fiber cleaning zone, and facilitating the complete removal of fibers from the saw teeth after cleaning, the cleaning effect of the machine is improved.

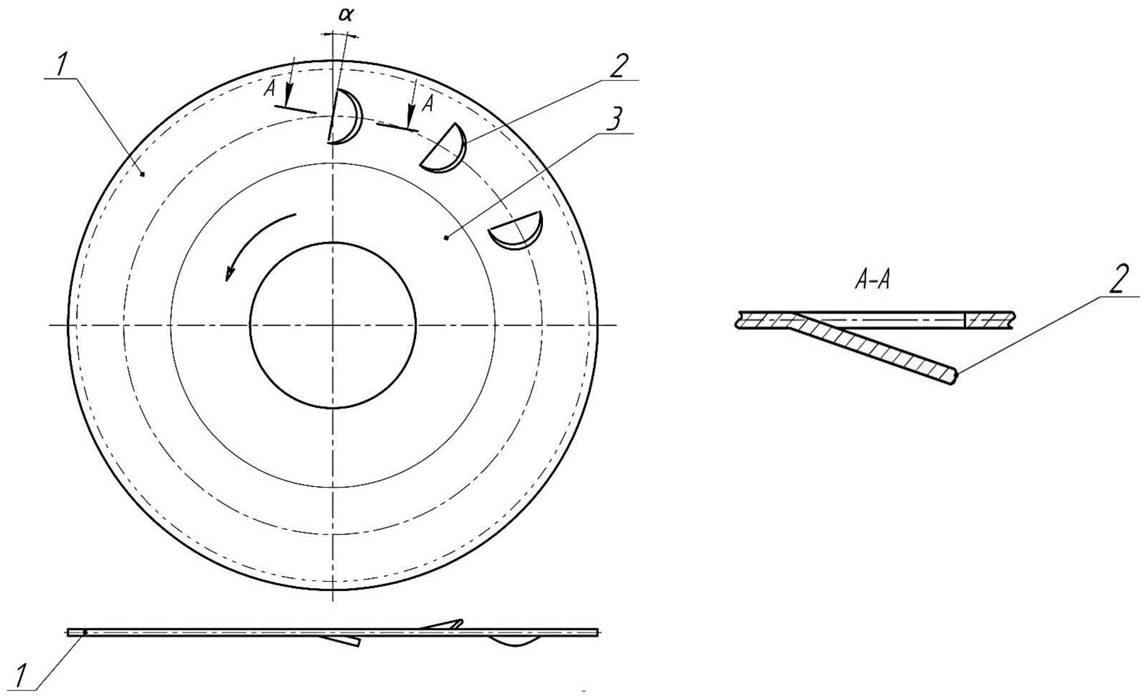
The improved saw disc is illustrated in the drawings, where: in Fig. 8, a, the saw disc 1 is shown from the front and top views, with stamped petals 2 on both sides of the saw disc. The petals are stamped around the circumference of the saw disc, alternating sides. In Fig. 8, b, section A-A of the stamped petal 2 is shown. The stamped petal has a semicircular shape [41; 3 p., 42].

Simulation of the rotational motion of air particles on the surface of the saw blade. Simulating the process of interaction of an additional air flow associated with the presence of lobes, we use a hydrodynamic model of stationary rotational motion of air particles on the surface of the disk.

The basic equations of two-dimensional air flow motion in the inter-core space are written as [43]:

$$\rho\left(V_r\frac{\partial V_r}{\partial r}+\frac{V_\theta}{r}\left(\frac{\partial V_r}{\partial \theta}-V_\theta\right)\right)=-\frac{\partial p}{\partial r} \tag{1}$$

$$\rho\left(V_r\frac{\partial V_r}{\partial r}+\frac{V_\theta}{r}\frac{\partial V_r}{\partial \theta}+\frac{V_rV_\theta}{r}\right)=-\frac{\partial p}{r\partial \theta} \tag{2}$$



1- saw blade, 2 – stamped lobe, 3- saw blade gasket

Fig.8. Improved saw blade of the fiber cleaner

where V_r, V_θ - radial and angular velocity of air particles;

r, θ – the polar coordinate with the origin on the axis of rotation of the saw cylinder;

$\rho-$ stability, $p = p(r,\theta)$ – the pressure at an arbitrary point in the flow zone of the inter-core space occupying the region $R_2 < r < R_1$ and $\theta_1 < \theta_2 + \theta_0$.

θ_0 - the central angle of the flow passage zone (Fig.9).

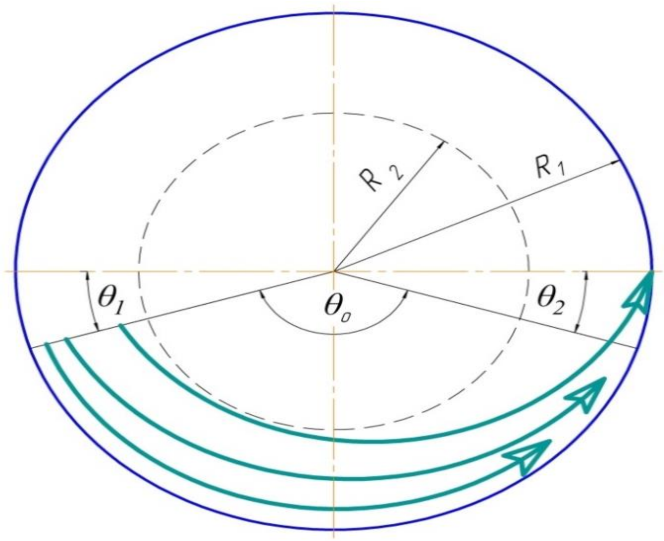


Fig.9. Flow diagram in the zone of the interpolar space

Under these assumptions, equations (1) and (2) take the form

$$(\omega+\omega_0)\frac{d\omega}{d\theta}-\omega_0^2=-\frac{P(\theta)}{\rho r} \quad (3)$$

$$\omega_0\frac{d\omega}{d\theta}+2\omega\omega_0=-\frac{1}{r}\frac{\partial P}{\rho\partial\theta} \quad (4)$$

Excluding the derivative $\frac{\partial P}{\partial\theta}$ from (2), we obtain a second-order equation with respect to *ω(θ)*

$$\frac{d}{d\theta}\left[(\omega+\omega_0)\frac{d\omega}{d\theta}\right]-\omega_0\frac{d\omega}{d\theta}-2\omega\omega_0=0 \quad (5)$$

Assuming $\overline{\omega}=\omega+\omega_0$ and introducing the function $y=\frac{\overline{\omega}}{\omega_0}$, get

$$y\frac{d^2y}{d\theta^2}+\left(\frac{dy}{d\theta}\right)^2-\frac{dy}{d\theta}-2(y-1) \quad (6)$$

Equation (6) is integrated with at $y=1+\omega_{00}/\omega_0$, $\frac{dy}{d\theta}=0$ - the angular velocity of the air at $\theta=0$.

Equation (6) with respect to the derivative of $\frac{dy}{d\theta}=Z$ reduces to the form

$$\frac{dZ}{dy}+\frac{Z-1}{y}-\frac{2(y-1)}{yZ}=0 \quad (7)$$

Now equation (7) is integrated under the condition $Z=0$ for a $y=1+\omega(0)/\omega_0$.

Figure 10 shows the curves of the dependence of the rotational velocity of air particles (assigned to $v=\frac{w(\theta)}{w_0}$) in the inter-core space from the polar angle for different values of the initial angular velocity of the air supply (assigned to w_0) $\overline{w}(0)=w(0)/w_0=\overline{w}_0$

Analysis of the dependence of the ratio on the polar angle for different ratios. It follows from the analysis of the graphs that the dependence of the reduced velocity of air particles depends on the polar angle practically depends on a linear law, and an increase in air velocity in the initial arc of entry in the zone of the inter-core space also leads to an increase in velocity when particles exit space. The absolute velocity of air particles can be calculated using the formula

$$V_r=rw_0\sqrt{\overline{w}^2(\theta)+1}$$

From the last formula, we note that the absolute velocity of air particles in the inter-core space depends non-linearly on the polar angle θ.

$\overline{w}_0=0.2$ $\overline{w}_0=0.4$

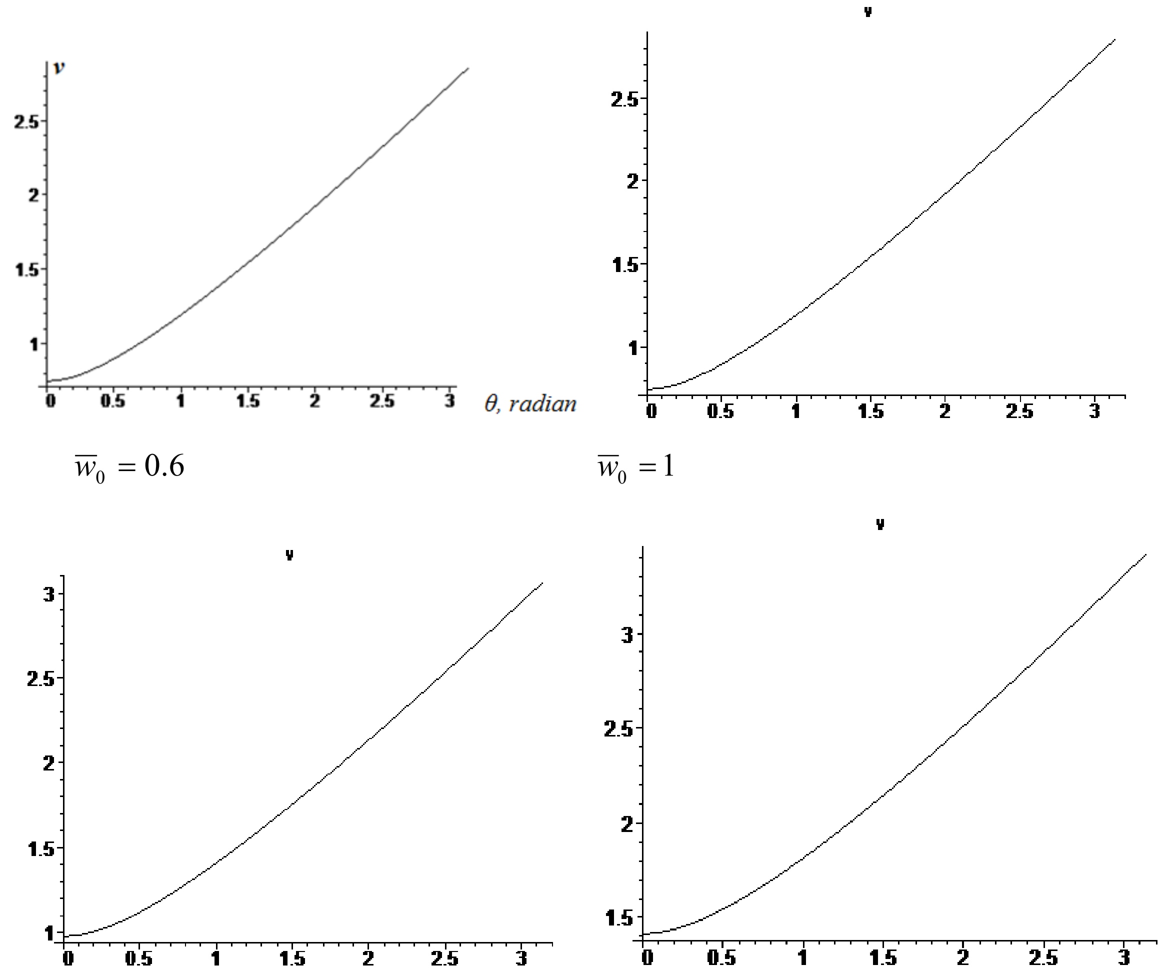


Fig.10. Curves of dependence of the ratio $v = \dfrac{\omega}{\omega_0}$ on the polar angle θ at different values of $\overline{\omega}_0 = \omega(0)/w_0$

Discussion. With an increase in the rotation frequency of the saw cylinder, the diameter of the laminar flow decreases, therefore, the saw teeth and grates are located in the boundary zone of the turbulent flow. If the strand moved in the zone of a confident turbulent flow, then such a flow would contribute to the unraveling of the strand of fibers, thereby facilitating the release of weed impurities due to the strength of their connection with the fibers. Aerodynamic equilibrium of a freely rotating saw cylinder due to the presence of friction forces arising between the saw blades and air and atmospheric pressure cannot be overcome by centrifugal forces acting on the air mass during rotation.

Conclusion. This paper shows that as a result of the influence of working bodies of fiber cleaning machine on aerodynamic parameters. When the fiber cleaner is in operation, the saw rotates at a frequency of n = 1500 rpm, with rmax = 0.157m = 160 mm. As you can see, there is no laminar flow outside the saw blade Ø310 mm. This justification makes it possible to explain the reason for the industry's refusal of the cleaning rate at 1000 min^{-1} and its transition to 1500 min^{-1}.
The conducted studies show that the dependence of the reduced velocity of air particles depends on the polar angle practically depends on a linear law, and an increase in air velocity in the initial arc of entry in the zone of the inter-core space also leads to an increase in the velocity when particles exit space, as well as the absolute velocity of air particles in the inter-core space non-linearly depends on the polar angle.

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