

Impact of cleaning process modifications on the efficiency of improved working parts

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ABSTRACT – REZUMAT

Impact of cleaning process modifications on the efficiency of improved working parts

In the context of increasing demands for cotton fibre quality and energy-efficient processing, this study focuses on enhancing the effectiveness of cleaning systems by modifying working parts in fibre cleaning machines. The research investigates the influence of guiding devices and the geometric profile of grates on flow behaviour and pressure distribution in dual-drum saw-type fibre cleaners. A mathematical model based on the compressible flow of fibrous material was developed to describe the interaction between the fibre stream and the inclined grate surfaces. The pressure-density relationship and flow velocity were analysed through nonlinear differential equations, and analytical solutions were obtained under specific boundary conditions. Simulation results demonstrate that changes in the initial thickness of the fibre stream and the shape of the guiding device significantly affect the cleaning efficiency. An optimised profile of the guiding system reduces fibre loss and improves impurity removal by up to 15% compared to conventional systems. The proposed modifications offer a promising solution for adapting fibre cleaning equipment to handle machine-harvested, highly contaminated cotton in modern ginning operations.

Keywords: cotton fibre, fibre cleaner, guiding device, flow modelling, pressure distribution, cleaning efficiency

Impactul modificărilor procesului de curățare asupra eficienței pieselor de lucru îmbunătățite

În contextul cerințelor tot mai mari privind calitatea fibrelor de bumbac și eficiența energetică a procesării, acest studiu se concentrează pe îmbunătățirea eficienței sistemelor de curățare prin modificarea pieselor de lucru ale mașinilor de curățat fibre. Cercetarea investighează influența dispozitivelor de ghidare și a profilului geometric al grătarelor asupra comportamentului fluxului și distribuției presiunii în cazul curățătorilor de fibre cu doi tamburi de tip ferăstrău. A fost dezvoltat un model matematic bazat pe fluxul compresibil al materialului fibros pentru a descrie interacțiunea dintre fluxul de fibre și suprafețele înclinate ale grătarelor. Relația presiune-densitate și viteza de curgere au fost analizate prin ecuații diferențiale neliniare, iar soluțiile analitice au fost obținute în condiții limită specifice. Rezultatele simulării demonstrează că modificările grosimii inițiale a fluxului de fibre și ale formei dispozitivului de ghidare afectează în mod semnificativ eficiența curățării. Un profil optimizat al sistemului de ghidare reduce pierderea de fibre și îmbunătățește eliminarea impurităților cu până la 15% în comparație cu sistemele convenționale. Modificările propuse oferă o soluție promițătoare pentru adaptarea echipamentelor de curățare a fibrelor pentru a trata bumbacul recoltat mecanic și puternic contaminat în operațiunile moderne de egrenare.

Cuvinte-cheie: fibră de bumbac, curățător de fibre, dispozitiv de ghidare, modelare a fluxului, distribuția presiunii, eficiență de curățare

INTRODUCTION

Cotton is one of the most widely used natural fibres in the global textile industry due to its breathability, softness, and renewability. However, the quality of cotton fibre largely depends on its cleaning and processing stages. Contaminants such as seed coat fragments, leaves, stems, and soil particles significantly impact the performance of downstream operations such as spinning and dyeing, as well as the overall textile product quality. In response to the demand for higher quality and more sustainable production methods, recent research has focused on optimising the cotton cleaning process, especially in machine-harvested cotton, which typically contains higher levels of foreign matter [1, 2].

Traditional fibre cleaning machines rely on mechanical separation using saw cylinders and grates. However, excessive mechanical action often leads to fibre damage and increased short fibre content. Therefore, researchers have explored the design of modern cleaning systems that balance impurity removal and fibre preservation through the use of adaptive guiding devices, optimised grate geometry, and intelligent control [3, 4]. Studies using computational fluid dynamics (CFD) and experimental modelling have demonstrated that the thickness, speed, and pressure of the fibre flow significantly affect the cleaning efficiency [5, 6]. Controlling the uniformity of fibre feeding to the saw cylinders using specially designed guide elements has been shown to reduce frictional stress and increase impurity release [7, 8].

In particular, the implementation of double-drum fibre cleaners and modular cleaning units has been proven to enhance performance for difficult-to-clean cotton varieties. These machines allow more precise control of airflow and mechanical interaction within the cleaner, leading to improved impurity removal while reducing fibre loss [9, 10]. Research emphasises that the placement and curvature of guiding devices can significantly influence fibre flow distribution and thus directly impact the final quality of the cleaned cotton [11, 12].

Moreover, innovations in AI-based monitoring and automation are being integrated into cotton cleaning systems to adapt the process parameters in real time based on fibre type and contamination level [13, 14]. These adaptive systems offer a promising path for achieving consistent quality under varying input conditions while optimising energy consumption. Mathematical modelling, such as nonlinear pressure-density formulations and flow dynamics in inclined grate zones, has provided new insights into fibre interactions within cleaning machines [15, 16].

This research aims to assess the impact of modified guiding devices and structural improvements in 2VPM-type fibre cleaners on cleaning efficiency and fibre preservation. By combining theoretical modelling with practical experiments, the study seeks to offer applicable solutions for modernising cotton ginning processes to meet both quality and sustainability goals.

REVIEW OF FIBRE CLEANING EQUIPMENT AND RELATED RESEARCH

One of the most critical parameters influencing the quality of cotton fibre is the content of residual impurities and defects embedded in the fibre matrix. Fibre imperfections can originate from several sources, such as mechanical stress encountered during harvesting and post-harvest processing, or from external contaminants, including seed coats, stems, and soil particles attached during the cotton-growing season [17]. Among these, the residual organic and mineral matter that adheres to raw cotton in the field constitutes the majority of contamination requiring removal in the ginning process.

At modern cotton gin plants, impurities are separated through a multi-stage cleaning line, which typically includes stone catchers, pre-cleaners for coarse and fine contaminants, and dedicated fibre cleaners positioned toward the final stages [18]. While advanced equipment has improved impurity separation, the challenge of minimising fibre damage while maximising cleaning efficiency remains [19].

Historically, many cotton processors relied on three-drum fibre cleaners (e.g., 3OVP) to achieve adequate cleaning. However, due to high energy consumption, these systems were gradually replaced by more energy-efficient single-drum direct-flow cleaners such as the 1VPU model [10, 20]. Despite their lower energy usage, machines like the 1VPU faced

limitations. The single saw cylinder and its accompanying four grates could not adequately remove both fine and coarse contaminants, leading to subpar fibre purity, especially in high-grade cotton varieties [21]. Earlier experimental research by Krygin laid the foundation for analysing the impact of grate positioning on the efficiency of impurity separation, while Tursunov explored how the geometry and spacing of grates affected the trajectory of the fibre as it interacted with the drum surface [22, 23].

In processing medium-staple cotton, multi-drum setups are typically arranged in series to improve throughput and efficiency. International equipment manufacturers, such as Platt-Lummus, have introduced aerodynamic fibre cleaners as supplementary units to enhance cleaning, especially for machine-harvested cotton with higher debris loads [24].

American cotton gins widely implement modular systems with circulatory ducts and adjustable valves to tailor the cleaning sequence according to the contamination level of the incoming raw cotton [25].

In recent years, Uzbekistan has also integrated modern equipment within its cotton ginning plants. For example, a complete cleaning line including pneumatic KPK-3000 systems has been installed at the Zhuma gin facility in Samarkand, incorporating both local and Chinese engineering expertise. These upgrades were selected based on compliance with Uzbekistan's textile industry standards [26].

Pneumatic cleaners operate on the principle of differential inertial force, effectively separating lightweight cotton fibres from heavier contaminants via a sharp 120° air-induced turn within the pipeline, enabling waste to be diverted to a collection chamber [27].

Machine test results for these units have shown average cleaning efficiencies ranging from 10–15%, although lower than the declared 18–20% efficiency in the manufacturer's specifications. It was also observed that cleaning efficiency could be enhanced by modifying the shape of the rib edges within the grate, as smaller radii (e.g., 0.3 mm) increased the frictional engagement between fibre and the grate, improving impurity release [28].

As the Uzbek cotton industry transitions toward machine-harvested raw material, the proportion of highly contaminated cotton is expected to rise. This shift necessitates re-engineering existing cleaning systems to accommodate higher volumes and impurity loads. Current fibre cleaning principles, optimised for hand-harvested cotton, must therefore be revised and adapted to newer realities.

In this regard, a comprehensive structural analysis of fibre cleaning mechanisms and the development of adaptable designs is a crucial area of focus. This study continues along this trajectory by evaluating improved guiding and cleaning components through theoretical modelling and real-world implementation. These developments are expected to provide more robust, energy-efficient, and impurity-resistant fibre cleaning systems suitable for contemporary production requirements.

THEORETICAL ANALYSIS AND MODELING APPROACHES IN COTTON FIBRE CLEANING

Several researchers have proposed theoretical approaches to optimise cotton fibre cleaning by analysing fibre–machine interactions. Ismailov introduced a new design of fibre cleaning equipment based on aeromechanical separation principles with variable pitch drum configurations [29]. His work focused on the impulse behaviour of fibre bundles upon contact with differently shaped surfaces, providing experimental data to calibrate models of shock dynamics. These findings were used to define optimal drum geometries for industrial implementation. Similarly, Kotov investigated the aerodynamics and compression mechanics within a three-stage direct-flow cleaner [30]. He identified that minimising resistance in the compression zone could lead to higher throughput and less fibre damage. His work included the derivation of airflow and pressure loss equations to optimise the internal geometry of cleaner housings.

Tursunov applied material mechanics principles to model the impact of grate angle, curvature, and housing materials on fibre movement [23, 31]. He demonstrated that replacing conventional housings with those containing plastic additives reduced fibre waste and improved final yarn uniformity. Furthermore, a transcendental equation system was constructed to simulate the influence of transfer forces on yarn quality, enabling predictions of cleaning outcomes under different mechanical setups.

These theoretical investigations collectively provide a scientific foundation for understanding the dynamics of cotton flow, pressure distribution, and frictional forces in fibre cleaning systems. Building upon these models, this study integrates structural and aerodynamic modifications into a dual-drum cleaner to evaluate their practical impact on cleaning efficiency.

THE INFLUENCE OF THE GUIDING DEVICE ON THE EFFICIENCY OF FIBRE CLEANING

In the process of cleaning the fibre, on fibre cleaners, the amount of fibre released into waste occurs mainly in the brush area, which provides strength with the saw cylinder, which accepts the flow of fibre coming out of the saw gin, disk to the saw cylinder, by knocking the fibre into the kneaders installed under the cylinder, due to the low technological process of the saw cylinder. This condition occurs in the area of the first saw cylinder, which receives and cleans the fibre stream coming from the gin of a two-drum direct-flow fibre cleaner brand 2VPM. By increasing the viscosity of the fibre flow to the first cylinder of the saw, it is advisable to install a guide device in the area of the fastening brush to dramatically reduce the separation of fibre waste between the saw cylinder and the fastening brush and increase the amount of fibre produced.

We will conduct theoretical studies on the good adhesion of the moving fibre to the saw teeth of the saw cylinder of the guide device.

Numerous theoretical and practical studies have been conducted on the effect of the impact force applied to the flow of cotton fibre moving in the area of saw cylinders and grates on the cleaning efficiency. However, the process of changing the initial thickness of the cotton fibre using special guiding devices and the pressure exerted by the columns on the fibre flow of a given thickness has not been studied, and the effect of velocity changes on density changes has not been revealed. It is known that the thickness of the fibre stream varies from 4 mm to 15 mm when the fibre coming from the saw gin meets the first saw cylinder. We will make the following assumptions to simulate the effect of this range on the cleaning efficiency of the fibre cleaner.

1. We assume that the fibre mass, the contact medium, and the flow movement are stationary, and in this case, the fibre flow rate in the grate area is constant and equal to Q_0 . The impurities released from the stream during the cleaning Q_0 . The process does not affect performance.
2. The flow movement between the grates is considered to be one-dimensional.
3. We assume that the surface of the grates affected by the fibre has the shape of an inclined plane. They will be located at the same distance from each other in the cleaning area.
4. An arbitrary colony arrives in contact with a fibre stream, and its interaction is determined by Hertz's law or an experimental method. We denote the velocity, pressure, density (parameters), and cross-sectional area of the flow between each grate by v_i , p_i , and S_i accordingly. Here ($i = 1 \dots n$), n – number of columns.

First, we will determine the pressure change indicators between the first and second grades of the fibre cleaner.

Let's imagine that the parameters of the initial (without taking into account the grate area) flow indicators are equal to ρ_0 , v_0 , h_0 , and S_0 (figure 1). Let the thickness of the fibre stream in front of the first grate be equal, in this case, the flow performance is equal to $Q_0 = \rho_0 v_0 h_0 L$, where L is drum length.

The flow layer with the first grate is an interaction zone $A_1 B_1 C_1 D_1$, and flow parameters are determined in this zone. Let us place the origin at point 0. The flow layer with the first grate is an interaction zone $A_1 B_1 C_1 D_1$, and flow parameters are determined in this zone. To determine the flow layer between the first grate and the saw drum, we determine the starting and ending points A_1 and C_1 concerning the variable S :

$$b = [h + (h_0 - h)S/S_0]L_k \quad 0 < x < S_0 \quad (1)$$

where h_0 is primary fibre thickness; h – the maximum approximate distance of the grate to the ceiling; S_0 – length of the obliquely flat section of the grate; L – drum length; L_k – separation of fibres in contact with the grates, $k = L_1/L < 1$.

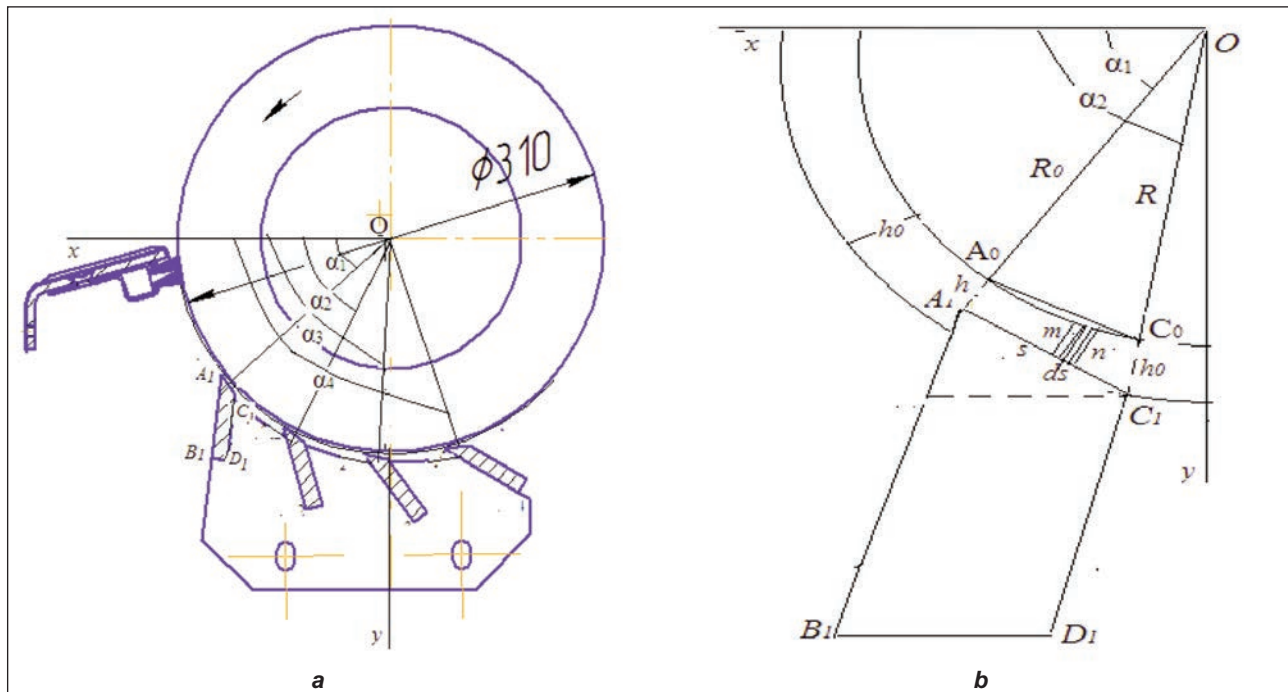


Fig. 1. Graph of the dependence of the flow thickness of the improved fibre cleaner h_0 : a – the layout of the grates in the cleaning area; b – the calculation scheme of the layer thickness at the location of the grates in the saw cylinder

For a separated element mn in stationary driving conditions, we formulate the Euler equation:

$$-[Sp + d(Sp)] + Sp - qL\beta dx = \rho v S dv \quad (2)$$

where $q = fp$ – lateral pressure; f_1 and f_2 – relative coefficients of friction between the fibre with the drum and the grates $f = f_1 + f_2$.

Considering the equation $S = b(S)L$ and the expression q , divide the expression into dx , we obtain the following equation.

$$\rho vb \frac{dv}{ds} = -\frac{d(pb)}{ds} - kfp \quad \text{here } b = h + \frac{h-h_0}{S_0} S \quad (3)$$

The unknowns ρ , v , b and p are involved in equation 3. To fill it out, we use the third formula.

To solve the problem, first assume and assume that the flow stationarity condition is the following:

$$\rho vb = \rho_0 v_0 b_0 = Q_0/L \quad (4)$$

Secondly, the equation of state of the medium should be appropriate. To do this, let's take the relationship between pressure and density. According to the research work of Sevostyanov A.G., a linear relationship between small pressure values is advisable ($p \leq 10^5$ Pa), t.e.

$$\rho = \rho_0 [1 + B(p - p_0)] \quad (5)$$

where p_0 is initial fibre pressure, B – coefficient obtained as a result of practical experiments.

Using relations 4 and 5, we determine the expression for pressure through velocity.

$$p = p_0 + \frac{1}{B} \left(\frac{v_0 h_0}{vb} - 1 \right) \quad (6)$$

$$\left(1 - \frac{c^2}{v^2}\right) \frac{dv}{dx} = -\frac{c^2}{v_0 b_0} [b' + fk(p_0 B - 1)] - \frac{c^2 fk}{vb}$$

If we substitute the expression $b' = x/R_0$ into this equation, then the equation will look like this:

$$\frac{dv}{dx} = -\frac{c^2}{v_0 b_0 a} \left[\frac{h_0 - h}{R_0} + fk(p_0 B - 1) \right] - \frac{c^2 fk}{vba} \quad (7)$$

here bulk compression modulus of the medium $a = 1 - c^2/v^2$, $c = \sqrt{K/\rho_0}$, $K = 1/B$.

Equation 8 defines the flow velocity in the gap in contact with the grate. The equation is integrated under the following initial condition $S = 0$, $v = v_0 = Q_0/\rho_0 h_0 L$. Since the equation is nonlinear, it is solved in a conical manner. In some cases, the equation can be reduced to a linear form. Let us solve the relationship 7 for the velocity.

$$v = \delta_1 = \frac{v_0}{1 + B(p - p_0)} \quad (8)$$

Because in the cleaning zone $\frac{p}{p_0} < 1$, then in the cleaning zone, there should be $\Delta p < 0$. In the case of small values $B \leq 1$ and the difference $\Delta p = p_0 - p$, we extend the expression to the line.

$$v = \delta_2 = v_0 [1 - B(p - p_0)] \quad (9)$$

By changing expression 8 to 9, we estimate the relative error $\Delta p = p - p_0$ in percent for different values of the coefficient B . We define them by the ratio of the difference δ to δ_1 .

$$\delta = \frac{100(\delta_1 - \delta_2)}{\delta_1} = 100B^2 \Delta p^2 \quad (10)$$

The table shows the maximum values of Δp_m each error $\delta(\%)$ for different values of B for a given pressure coefficient $\Delta p = p_0 - p$. If, when solving problem 9, the error $\delta(\%)$ used by the connection is given, then in this case the condition $\Delta p \leq \Delta p_m$ for pressure in the calculation process must be satisfied.

MAXIMUM PERMISSIBLE PRESSURE Δp_m AT DIFFERENT VALUES OF B AND δ (%)										
	$B = 0.0005 \text{ Pa}^{-1}$					$B = 0.001 \text{ Pa}^{-1}$				
δ (%)	1	3	5	8	10	1	3	5	8	10
Δp_m (Pa)	200	346.2	447.2	565.7	632.4	100	173.2	223.6	282.8	316.2
	$B = 0.0015 \text{ Pa}^{-1}$					$B = 0.002 \text{ Pa}^{-1}$				
δ (%)	1	3	5	8	10	1	3	5	8	10
Δp_m (Pa)	67.7	115.5	149.1	188.6	210.8	50	86.6	111.8	141.4	158.1

For example, if it is known for fibrous material $B = 0.0015 \text{ Pa}^{-1}$, then the pressure calculated from the results of the table should not exceed $\Delta p = p_0 - p 115.5 \text{ Pa}$ so that the error in using formula 10 does not exceed 3%. In order not to exceed the error, the pressure should not exceed $\Delta p = p_0 - p 210.8 \text{ Pa}$. Using the relationship (9), the equation takes the following form of a linear equation.

$$(M^2 h_0 - b) \frac{dv}{dx} = -(b' + fk)[(\rho_0 B + 1)v_0 - v] \quad (11)$$

If we put the expression b , then the variables of the equation will be separated

$$\frac{dv}{(\rho_0 B + 1)v_0 - v} = -\frac{b_0}{a_0 - S} ds \quad \text{at } 0 < S < S_0$$

where the speed of propagation of waves in a medium is

$$a_0 = \frac{M^2 h_0 - h}{h_0 - h}, \quad b_0 = \frac{h_0 - h + fk S_0}{h_0 - h} \quad (12)$$

$$M = v_0 / c, \quad c = \sqrt{1/(B\rho_0)}$$

The solution in the condition $v(0) = v_0$ of equation 12 according to the value of M looks like this:

$$M < \sqrt{h/h_0}:$$

$$v = v_0 \left\{ 1 + \frac{\rho_0}{\rho_0 c^2} \left[1 - \left(\frac{a_1}{a_1 + S} \right)^{b_0} \right] \right\} \quad 0 < S < S_0 \quad (13)$$

$$M = \sqrt{h/h_0}:$$

$$v = v_0 \left[1 - \frac{\rho_0}{\rho_0 c^2} \left(\frac{S}{S_1} - 1 \right) \right] \quad S_1 < S < S_0 \quad (14)$$

$$M > \sqrt{h/h_0}:$$

$$v = v_0 \left\{ \frac{\rho_0}{\rho_0 c^2} \left[1 - \left(\frac{a_2}{a_2 - S} \right)^{b_0} \right] \right\} \quad S_0 < a_2 \text{ at } 0 < S < S_2 \quad (15)$$

$$v = v_0 \left\{ 1 + \frac{\rho_0}{\rho_0 c^2} \left[1 - \left(\frac{a_2}{a_2 - S} \right)^{b_0} \right] \right\} \quad 0 < S < S_2,$$

$$v = v_1 \quad S_2 < S < S_0 \quad S_0 > a_2 \quad (16)$$

$$\text{here: } a_1 = \frac{(h - M^2 h_0) S_0}{h_0 - h}, \quad a_2 = \frac{(M^2 h_0 - h) S_0}{h_0 - h}$$

$$v_1 = v_0 \{ 1 - B\rho_0 [(1 - S_2/a_2)^{-b_0} - 1] \} \quad (17)$$

Since equation 12 has singular points when $M > \sqrt{h/h_0}$ at $S = S_0$ and where $M = \sqrt{h/h_0}$ at $S = 0$ (14–17) the distances S_1 , S_2 are obtained arbitrarily. From the analysis of formulas 13–16, it can be seen

that when the flow rate decreases, its speed decreases, and the density increases according to formula 5: $M \geq \sqrt{h/h_0}$. According to the requirements of the cleaning technology, in order for the cleaning process to be carried out, the flow density must be reduced. This can be observed when $M < \sqrt{h/h_0}$, therefore, for the calculation we will use the above formula 13.

ANALYTICAL MODELING AND NUMERICAL CALCULATIONS

According to the obtained equations, it is necessary to study the influence of the pressure in the grate on the influence of the density speed and the efficiency of the fibre cleaner with an initial raw material thickness from 4 mm to 15 mm. Here $\rho_0 = 15 \text{ kg/m}^3$, $h = 0.011 \text{ m}$, $f_1 = f_2 = 0.3$, $L = 2.4 \text{ m}$, $S_0 = 0.02 \text{ m}$.

Figure 2 shows the graphs of the change in flow rate (a) and raw cotton density (b) for two different values of the pressure coefficient B and initial pressure p_0 relative to the variable S in the layer between the grate and the saw cylinder. The calculations are performed for the following values of the parameters: $\rho_0 = 15 \text{ kg/m}^3$, $h_0 = 0.014 \text{ m}$, $h = 0.011 \text{ m}$, $f_1 = f_2 = 0.3$, $\beta = 0.5$, $L = 2.4 \text{ m}$, $S_0 = 0.02 \text{ m}$, $Q_0 = 4000 \text{ kg/hour}$. The error in the selected values of the coefficient B and pressure p_0 did not exceed 12% according to formula 11. From the analysis of the graphs it is evident that an increase in the initial pressure leads to an increase in the flow rate and, consequently, as a result, the fibre becomes thinner. This pattern is also observed with an increase in the coefficient B of fibre rigidity (the inverse of the compression modulus ($K = 1/B$)). For example, the salting coefficient is $= 0.001 \text{ Pa}^{-1}$ ($K = 10^3 \text{ Pa}$), then the variable is $S = S_0$, that is, after the zone of mutual contact with the first grate, the flow density decreases to 11.8 kg/m^3 if at $B = 0.002 \text{ Pa}^{-1}$ ($K = 5 \cdot 10^2 \text{ Pa}$), then this value is equal to 10.4 kg/m^3 .

Based on the expression of speed 14–17, the flow density can be determined by formula (4). In this case, based on the model proposed in the work, it is possible to theoretically study the process of cleaning the flow from contaminants.

According to this model, the reduction in cotton mass during cleaning is determined by the following relationship between the flow densities:

$$\frac{dm}{m} = \frac{1}{1+a} \frac{dp}{p} \quad (18)$$

where $a > 0$ is experimental constant coefficient.

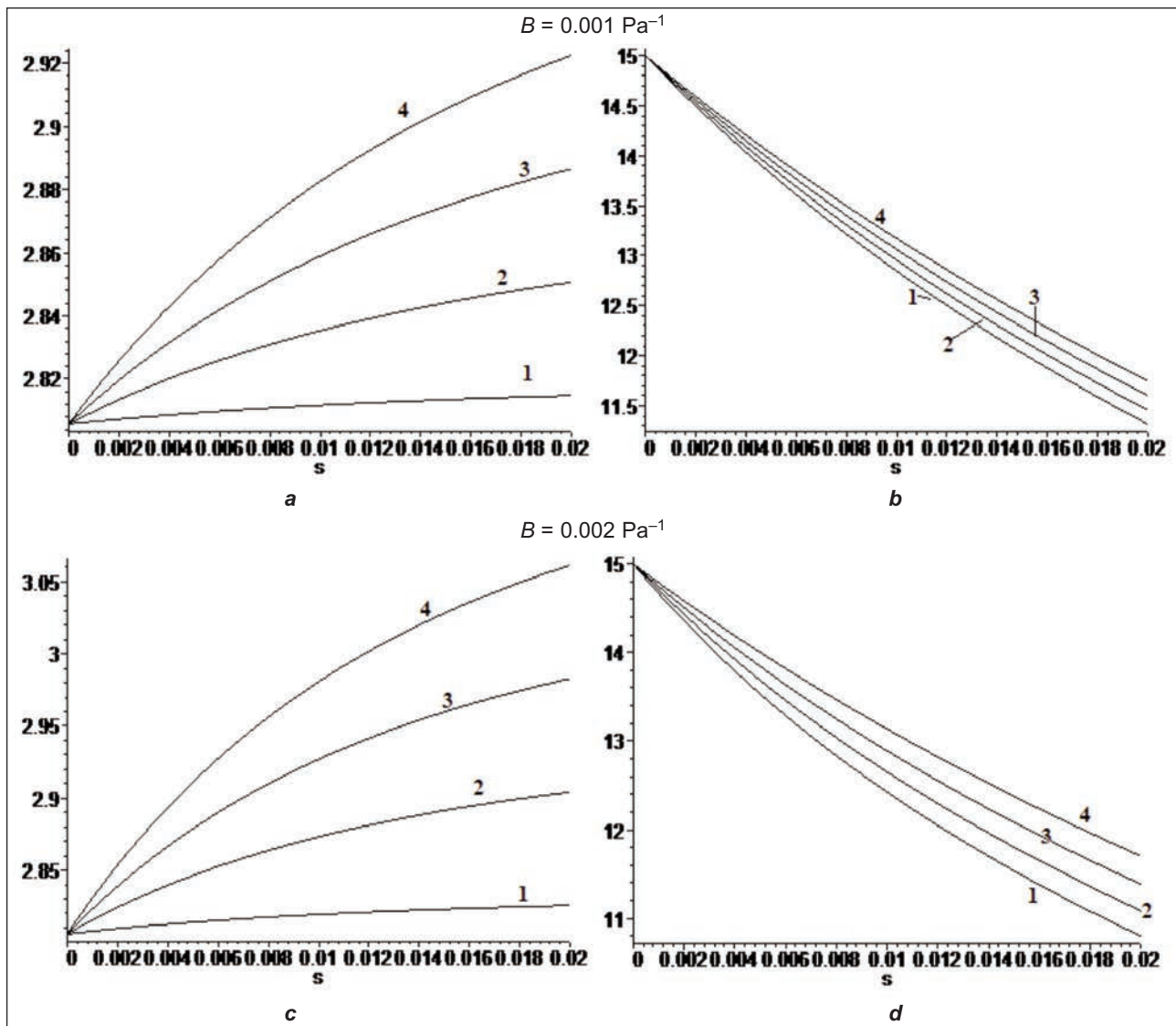


Fig. 2. Distribution graphs in the cleaning zone at different values of the second and initial pressure p_0 (Pa) of the salting coefficient B of raw cotton speed v (m/c) and the cleaning efficiency coefficient ε (%). 1 $\rightarrow p_0 = 5$, 2 $\rightarrow p_0 = 25$, 3 $\rightarrow p_0 = 45$, 4 $\rightarrow p_0 = 65$: a – flow velocity distribution at $B = 0.001 \text{ Pa}^{-1}$; b – fibre density distribution at $B = 0.001 \text{ Pa}^{-1}$; c – flow velocity distribution at $B = 0.002 \text{ Pa}^{-1}$; d – fibre density distribution at $B = 0.002 \text{ Pa}^{-1}$

We integrate equation 18 under the condition $m = m_0$, $\rho = \rho_0$, $S = 0$

$$\frac{m}{m_0} = \left(\frac{\rho}{\rho_0}\right)^\lambda$$

Here, m_0 is the mass of the fibre flowing into the zone per unit time. $\lambda = 1/(1 + a)$. This is the ratio:

$$\varepsilon = \frac{m_0 - m}{m_0} = 1 - \left(\frac{\rho}{\rho_0}\right)^\lambda \quad (19)$$

can be taken as the cleaning efficiency coefficient.

Using formula 5, we reduce expression 19 to the following form

$$\varepsilon = \frac{m_0 - m}{m_0} = 1 - \left(\frac{v_0 h}{v b}\right)^\lambda \quad (20)$$

Here, the speed is determined by the formula 14.

Figure 3 shows the distribution graphs in the cleaning zone at different values of the pressure p_0 and the salting coefficient B of the cleaning coefficient.

The plotted data clearly indicate that both the initial pressure p_0 and the salting coefficient B has a direct positive effect on the efficiency coefficient.

Figure 3 shows that the cleaning efficiency coefficient (as a percentage) depends on the device attached to the saw teeth to increase the cleaning efficiency in the cleaning area, which has been proven in theoretical studies, at different values of the solubility coefficient and initial pressure p_0 (Pa) 1 $\rightarrow p_0 = 5$, 2 $\rightarrow p_0 = 25$, 3 $\rightarrow p_0 = 45$, 4 $\rightarrow p_0 = 65$, ε (%). It can be seen from the graphs that the cleaning efficiency coefficient also increases with increasing pressure.

Figure 4 shows the appearance of a specially designed guide mounted on equipment when using fibre cleaners operating in an industrial environment and based on scientific research.

Several scientific studies have been conducted on the production of direct-flow fibre cleaners by improving technological parameters. Based on the research, a new scheme for a direct-flow fibre cleaner was

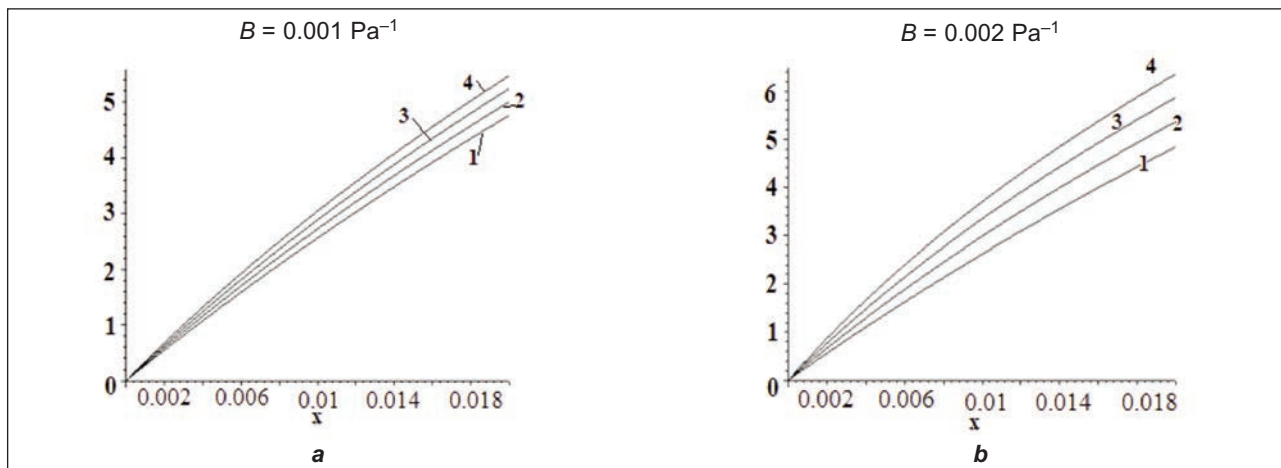


Fig. 3. Cleaning efficiency coefficient $\varepsilon(\%)$ under different initial pressures p_0 and salting coefficients B :
 a – distribution at $B = 0.001 \text{ Pa}^{-1}$; b – distribution at $B = 0.002 \text{ Pa}^{-1}$

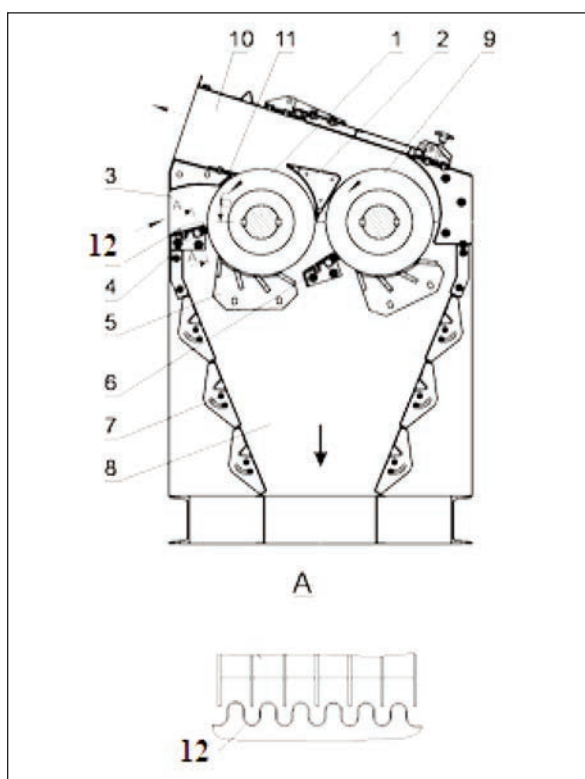


Fig. 4. Fibre cleaner of special design with integrated guiding device: 1 – saw cylinder; 2 – separating knife; 3 – inlet pipe; 4, 6 – attachment brush; 5 – grate; 7 – blinds; 8 – mud hopper; 9 – outlet pipe; 10 – upper housing; 11 – garbage chamber; 12 – specially designed guide

selected, and a specially designed guide was proposed, with which the drawings were made. We can see the proposed guide in figure 5.

To preserve the natural quality of machine-harvested cotton, Uzpakhtasanoat JSC, in particular, Zarbdor Pakhta Tozalash JSC, has introduced resource-saving fibre cleaning equipment [32–33].

Table 2

COMPARATIVE ANALYSIS OF FIBRE CLEANING EQUIPMENT		
Naming of indicators	Existing fibre cleaner	Improvements to the advanced fibre cleaner
Fibre performance	2000	2000
Cleaning efficiency (%)		
– in first grades	30–32	35–40
– in low grades	33–35	45–49
The number of fibres in the waste intended for spinning	25	20
Electricity consumed	5.5	5.5
Metal consumption	2518	2470

CONCLUSION

This study developed a theoretical model to evaluate the effect of structural improvements, particularly a guiding device, on the performance of dual-drum saw-type



Fig. 5. The proposed guide for a special design

cotton fibre cleaners. The analytical results show that modifying the initial thickness of the fibre stream from 4 mm to 15 mm using the guiding system allows controlling pressure and density distributions across the grate zone. For example, when the salting coefficient is set to $B = 0.001 \text{ Pa}^{-1}$ with an initial pressure of $K = 10^3 \text{ Pa}$, the cleaning efficiency increases significantly. A similar trend is observed for $B = 0.002 \text{ Pa}^{-1}$ at $K = 5 \cdot 10^2 \text{ Pa}$, where the effective flow pressure reaches 10.4 kPa/m^3 , enhancing impurity removal. From the graphs and simulations, it is confirmed that increasing the initial fibre pressure and flow regulation coefficient B leads to a higher cleaning efficiency.

The design of aeromechanical fibre cleaners must therefore include optimised guiding devices that align fibres more accurately with the saw teeth, reducing fibre loss and improving yield.

Based on the theoretical and experimental insights, it is recommended that the proposed guiding device be widely implemented in cotton processing plants, especially for machine-harvested cotton with high impurity content. The findings provide a validated modelling approach and a practical engineering solution for enhancing the performance of modern fibre cleaning systems.

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