Theoretical study of the impact aimed at improving the efficiency of fiber cleaning

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Abstract. Since cotton cleaning in Uzbekistan is carried out mainly manually, this paper discusses the methods and technologies established in the process of cleaning cotton and fiber. The process of fiber cleaning is one of the important processes that complete the technological process of cotton processing, given that the quality of fiber largely depends on the efficiency of this process, the research work on the mechanization of the type of collection and improving the efficiency of its cleaning is analyzed.

In order to improve the efficiency of cleaning cotton collected on the machine, information is provided on the need to improve the equipment for cleaning fiber used in cotton gins. The research results are based on the need to replace a special structural device that guides the fiber to the correct tooth of the first sawtooth cylinder located on two drum cleaning plants. New fiber-cleaning equipment was installed in the Jizzakh regional JSC "Zarbdor cotton cleaning" and experimental tests were conducted in production conditions. In addition, the process of changing the pressure, density and speeds in the furnace and the effect of their cleaning efficiency has been modeled and theoretically analyzed, when the efficiency of cleaning the cotton fiber flow using a column system allows changing the raw material from 4 mm to 15 mm based on the device. By results of the conducted analysis it was shown that the increase of efficiency of purification depends on the device attached to the saw teeth, factor of the taxation of the distribution coefficient $B$ and $P_0$ efficiency factor of increasing the initial pressure and coefficient of efficiency savings from the analysis of graphs, which present graphs of the distribution depending on the type of saw teeth. Based on the results of the research, recommendations are given for the widespread introduction of fiber cleaning equipment installed at enterprises of primary cotton processing, with the installation of a special structural guide device.
1. Introduction
In recent years, in Uzbekistan and in countries where cotton industry is developed, special attention has been paid to the production of high-quality completed products that ensure competitiveness in the world market based on the improvement of technologies and technologies of the cotton and textile industries, and deep processing of raw cotton. The decree States that cooperatives for the cultivation and processing of cotton raw materials have been established on the basis of voluntary Association of farms. They are charged with the task of providing services for receiving, storing and processing cotton raw materials grown by cotton gins (mill method), organizing the introduction of advanced foreign experience and resource-saving innovative technologies in order to effectively use agricultural land and increase productivity. Deep processing of grown raw cotton is the most important task facing the scientists of the industry and cooperation in providing high-quality products both in the domestic and foreign markets [1].

95 percent of the cotton grown in Uzbekistan is harvested by hand. The Cabinet of Ministers has developed resolution No. 21 of January 14, 2020 to gradually implement the reduction of manual cotton harvesting on cotton harvesters. The resolution has developed a 6-year program to dramatically increase the production and supply of cotton harvesters, providing for phased mechanized production of raw cotton until 2026. Currently, our equipment and technologies installed in cotton gins and cluster enterprises are also based on manual Assembly. To clean the cotton collected on the machine, it is necessary to improve the equipment available at the enterprise [2]. At cotton gins, the process of cleaning fibers is one of the important processes that complete the technological process of processing cotton [3, 4]. The quality of the fiber depends largely on the efficiency of this process. To increase the efficiency of the cleaning process, improve the quality of the fiber produced from cotton raw materials using complex cleaning selection varieties and machines, it is necessary to widely implement the 2 vpm type fiber cleaning technological system with improved working parts with two drums instead of one drum for cleaning the fibers.

Currently, the improvement of machines for cleaning cotton fiber, which are being developed in the technology of the first processing of cotton, is one of the urgent issues of ensuring high-quality output of fiber, improving its quality, increasing efficiency and productivity. Taking this into account, it is necessary to conduct a constructive analysis of the fiber cleaning equipment [5, 6].

2. Methods
The quality of the fiber cleaner is evaluated depending on the amount of clean fibers in the waste and the effect of cleaning the machine [7, 8].

The amount of pure fiber mixed in the waste is determined by the formula

\[
B = 100 \frac{q_m}{q_{out}}
\]
Here is the amount of pure fiber mixed in qm- waste:

\[ B = 100 \frac{q_{\text{m}}}{(q_{\text{m}} + q_{\text{w}})} \]

Here is the amount of pure fiber mixed in qm- waste:

- \( q_{\text{out}} \) - the amount of waste combined with clean fiber
- \( q_{\text{m}} \) - the amount of dirty mixture.

The coefficient denoting the amount of pure fiber added to waste, in \( K_m \), can be found as follows

\[ K_m = \frac{q_{\text{m}}}{q_{\text{pc}}} \]

Or

\[ K_m = \frac{B}{(100 - B)} \]

The efficiency of fiber cleaning can be found as follows

\[ K = \frac{q_{\text{out}}(100 - B)}{G_1 S_2 + q_{\text{out}}(100 - B)} \times 100 \]

Or

\[ K = \frac{S_1 - S_2}{S_1} \times \frac{1}{1 - \frac{S_2}{100 - B}} \times 100 \]

Such: \( G_1 \) cleaned fiber mass; \( S_1 \) and \( S_2 \) total number of defects and waste in the fiber before and after cleaning.

The fiber yield reduction coefficient shows how much (%) the fiber suitable for spinning in a fiber cleaning machine dies

\[ K_{\text{nob}} = 100 \frac{B_1 \cdot B_2}{B_1} \]

This is the next fiber output before the B1 and B2 fiber cleaning machine.

The effect of an improved guide device installed on a fiber cleaner on the efficiency of fiber cleaning, on the efficiency of fiber cleaning, with the improvement of the function of the saw cleaner, to improve the performance, cleaning efficiency and the number of fibers suitable for use in waste, on the efficiency of fiber cleaning, has been theoretically studied.

### 2.1 Experimental Apparatus

Many studies have been conducted on the impact of cotton fiber flow on the impact cleaning efficiency of the grate system. But to model the process of changing the pressure, density and speed in the grate and the effect on the cleaning efficiency, we accept the following hypotheses, allowing you to change the raw material from 4 mm to 15 mm based on the guide device for the initial thickness.

1. The Cotton mass is perceived as a stationary environment and flow movement, while the flow performance remains unchanged in the grate area equal to \( Q_0 \) impurities released from the flow do not affect the performance of \( Q_0 \).
2. Colossians consider the flow behavior to be one-dimensional.
3. When exposed to the fibers, we take the form of a flat surface of grates, which are located at the same distance from each other in the cleaning zone.
4. Optionally, the grate interacts with a stream of fibers, the interaction of which is determined either by Hertz's law, or based on experience. We determine the speed, pressure and density (parameters) and the surface of the flow section between each grate, respectively \( v_i, p_i \) and \( S_i \). \( (i = 1..n) \) \( n \) is the number of the grates. Let's determine the pressure parameters first between the first and second colossi.

Assume that the initial flow parameters (other than the grate zone) are \( P, v, h, \) and \( S \). Before interacting with the first grate, let the thickness of the flow be equal to \( h_0 \), then the working capacity of the flow in this case will be equal to \( Q_0 = \rho_0 v_0 h_0 L \), where \( L \) is the length of the drum.

The interaction zone of the flow layer with the first Wheeler-A, B, C, D, we determine the flow parameters in this zone. We place the coordinate head at the o Point (Figure 1). In order to determine the current layer between the first grate and the saw drum, we define relative to the variable \( S \), the starting and ending points of which are A and B:

\[
b = \{h + (h_0 - h)s / s_0\}Lk \quad 0 < x < s_0
\]

(1)

here \( H_0 \) is the initial thickness of the raw material— \( s_0 \) the maximum approximate distance of the grate to the flow \( s_0 \) is the length of the planar section of the grate, \( k = L_k / L < 1 \), \( L \) is the length of the drum shaft, \( L_0 \) is the proportion of grates in the shaft when in contact with the raw material. Let's make the Euler equation in stationary motion for the selected element [9]:

\[
-[Sp + d(Sp)] + Sp - qL_0dx = \rho v Sdv
\]

(2)
Here \( q = fp \)-the lateral pressure, \( f = f_1 + f_2 \), \( f_1, f_2 \) - the coefficients of friction between the drum and the grate with cotton, respectively

\[ S = b(s)L \]

reduce the equation \( q \) to the denominator (2) the expression is equal to \( dx \), we get the following equation:

\[
\rho vb \frac{dv}{ds} = - \frac{d(pb)}{ds} - kfp
\]  

Here \( b = h + \frac{h - h_0}{s_0} \)

The equation (3) involves unknown \( p, v, \) and \( p, \) and we use two formulas to fill it in.

First, the steady state condition of the flow

\[
\rho vb = \rho_0 v_b h_0 = \frac{Q_0}{L}
\]

(4)

The second formula implies that the equation of state of the medium should be appropriate.

To do this, we obtain a relationship between pressure and density [10, 11]. For small pressure values ( \( p \leq 10^5 \text{Pa} \)), in accordance with the works, it is advisable to connect them linearly.

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

(5)

\( p_0 \) the initial pressure in the raw material \( B \) is the test coefficient.

(4) and (5) define the pressure expression by velocity using references

\[
p = \rho_0 + \frac{1}{B} \left( \frac{v_b h_0}{v} - 1 \right)
\]

(6)

\[
(1 - \frac{c^2}{v^2}) \frac{dv}{dx} = - \frac{c^2}{v_b b_0} \left[ b' + f(k(p_0 B - 1)) \right] - \frac{c^2 f k}{v b}
\]

if we put an expression in this equation \( b' = x/R_0 \)

\[
\frac{dv}{dx} = - \frac{c^2}{v_b b_0} \left[ \frac{h_0 - h}{R_0} + f(k(p_0 B - 1)) \right] - \frac{c^2 f k}{v ba}
\]

(7)

here \( a = 1 - c^2 / v^2, \ c = \sqrt{K / \rho_0}, \ K = 1/B \) is the compression module environment

The equation (7) defines the flow rate in the range that is in contact with the grate.

The equation is integrated into condition \( v = v_0 = \frac{Q_0}{\rho_0 h_0 L} \) at the initial \( s = 0 \) below. Since the equation is nonlinear, it is solved in a bloody way. In some cases, the equation can be converted to a linear representation. In Equation (6), we allow connection with respect to speed
\[ v = \delta_1 = \frac{v_0}{1 + B(p - p_0)} \]  
\[ (8) \]

Since \( p/p_0 < 1 \) is located in the cleaning zone, it must have \( \Delta p < 0 \). Decompose the expression into a string (8), having \( B\Delta p << 1 \) in small values \( B << 1 \) and \( \Delta p = p_0 - p \)

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

In equation (8), the relative error when converting the expression to (9) we estimate as a percentage in different values of the \( \Delta p = p - p_0 \) coefficient \( B \). They determine the ratio of division \( \delta_1 \) to \( \delta \)

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

**Table 1.** Coefficient \( B \) and relative error \( \delta(\%) \) when using the connection in different values (9) maximum values of \( \Delta p_m \) (Pa) / \( \Delta p \)

| \( B \) = 0.0005Pa\(^{-1}\) | \( B \) = 0.001Pa\(^{-1}\) |
|---|---|
| \( \delta(\%) \) | 1 | 3 | 5 | 8 | 10 | 1 | 3 | 5 | 8 | 10 |
| \( \Delta p_m \) (Pa) | 200 | 346.2 | 447.2 | 565.7 | 632.4 | 100 | 173.2 | 223.6 | 282.8 | 316.2 |
| \( B \) = 0.0015Pa\(^{-1}\) | \( B \) = 0.002Pa\(^{-1}\) |
| \( \delta(\%) \) | 1 | 3 | 5 | 8 | 10 | 1 | 3 | 5 | 8 | 10 |
| \( \Delta p_m \) (Pa) | 67.7 | 115.5 | 149.1 | 188.6 | 210.8 | 50 | 86.6 | 111.8 | 141.4 | 158.1 |

Table 1 shows the maximum values of each error \( \delta(\%) \) in different values of the specified pressure coefficient \( B \) \( \Delta p = p_0 - p \) \( \Delta p_m \). When solving the problem (9), a reference is given, error \( \delta(\%) \), then the condition \( \Delta p \leq \Delta p_m \) for the pressure in the calculation process must be met. For example, for raw material \( B = 0.0015\)Pa\(^{-1}\), it is known that the error when using formula (9) should not exceed 3%, the pressure calculated based on the results of the table should not exceed \( \Delta p = p_0 - p \) 115.5Pa, the pressure should not exceed \( \Delta p = p_0 - p \) 210.8Pa, so that the error does not exceed 10%.

Using the equation (9), we will reduce the equation to the form of a linear equation in the following form

\[ (M^2 h_0 - b) \frac{dv}{dx} = -(b' + fk)(p_0 B + 1)v_0 - v \]  
\[ (11) \]

If we put the expression in \( b \), then the variables of the equation are split
\[
\frac{dv}{[(p_0 B + 1)v_0 - v]} = -\frac{b_0}{a_0 - s} ds \quad \text{this } 0 < s < s_0
\]

Here
\[
a_0 = \frac{M^2 h_0 - h}{h_0 - h}, \quad b_0 = \frac{h_0 - h + f k s_0}{h_0 - h} \quad M = v_0 / c, \quad c = \sqrt{1 / B \rho_0} \quad \text{the speed of wave propagation in the environment.}
\]

The solution of the equation (12) \( v(0) = v_0 \) in conditional expression for the value of \( M \) is as follows:

\[
M < \sqrt{h / h_0}
\]

\[
v = v_0 \left(1 + \frac{p_0}{\rho_0 c^2} \left[1 - \left(\frac{a_1}{a_1 + s}\right)^{b_0}\right]\right) \quad 0 < s < s_0
\]

(13)

\[
M = \sqrt{h / h_0}
\]

\[
v = v_0 \left(1 - \frac{p_0}{\rho_0 c^2} \left[\frac{s}{s_1} - 1\right]\right) \quad s_1 < s < s_0
\]

(14)

\[
M > \sqrt{h / h_0}
\]

\[
v = v_0 \left(1 + \frac{p_0}{\rho_0 c^2} \left[1 - \left(\frac{a_2}{a_2 - s}\right)^{b_0}\right]\right) \quad s_0 < a_2 \quad \text{when, } 0 < s < s_0
\]

(15)

\[
v = v_1 \quad s_2 < s < s_0 \quad s_0 > a_2 \quad \text{when,}
\]

(16)

Here
\[
a_1 = \frac{(h - M^2 h_0) s_0}{h_0 - h}, \quad a_2 = \frac{(M^2 h_0 - h) s_0}{h_0 - h}, \quad v_1 = v_0 \{1 - B p_0 [(1 - s_2 / a_2)^{b_0} - 1]\}
\]

In equation (12), since for \( s = 0 \) and \( M > \sqrt{h / h_0} \), when equation \( M = \sqrt{h / h_0} \) has \( s = s_0 \) special points (14)-(16) the distances \( s_1 \) and \( s_2 \) in formulas are optional (13)-(16) from the analysis of the formula, it can be observed that when the flow velocity \( M \geq \sqrt{h / h_0} \) decreases its speed and (4) increases its density in accordance with the formula. According to the requirements of the cleaning technology, the flow density must be reduced so that the cleaning process can be
performed. This state can be observed in \( M < \sqrt{h/h_0} \) accordingly, we use the formula given above (13) When performing calculations.

2.2 Problem Formation

Place The resulting equations should be studied when the initial thickness of the raw material is from 4 mm to 15 mm, the influence of pressure in the grate on the compaction speed and efficiency of fiber cleaning. Such \( \rho_0 = 15, h = 0.01m \), \( f_i = f_2 = 0.3 \), \( L = 2.4m \), \( s_b = 0.02m \)

Figure 2 shows a graph of changes in the flow rate (a) the density of raw materials (b) between the grate and the cylinder saw in two different values of the pressure coefficient \( B \) relative to the variable \( s \) in the layer and in different values of the initial pressure \( p_0 \).

**Figure 2.** Raw material velocity \( \nu (m/s) \) (a) and purification efficiency coefficient \( \varepsilon (\%) \) (b) of emptiness coefficient \( B \), two and initial pressure \( p_0 \) (Pa) at different values of distribution zones in the purification zone: 1) \( p_0 = 5 \), 2) \( p_0 = 25 \),

\[ 3 - p_0 = 45, 4 - p_0 = 65 \]
Calculations were performed for the following parameters: \( \rho_0 = 15\text{kg/m}^3 \), 
\( h_0 = 0.014\text{m} \), 
\( h = 0.011\text{m} \), 
\( f_1 = f_2 = 0.3 \), 
\( \beta = 0.5 \), 
\( L = 2.4\text{m} \), 
\( s_0 = 0.02\text{m} \), 
\( Q_0 = 4000\text{kg/h} \)  
The error in the selected values of the coefficient \( B \) and pressure \( p_0 \) (10) did not exceed 12% according to the formula. When analyzing the graph, exceeding the initial pressure leads to an increase in the flow rate and, as a result, to the thinning of the fiber. This pattern is also observed when the coefficient of friction of fibers increases \( B \) (the inverse size of \( K = 1/B \) by the modulus of elasticity). For example, if the tax rate is \( B = 0.001\text{Pa}^{-1} \) \((K = 10^3\text{Pa})\), then the variable is \( s \). That is after the interaction zone with the first grate the current density decreases to \( 11.8\text{kg/m}^3 \) this value will be \( 10.4\text{kg/m}^3 \) when you have \( B = 0.002\text{Pa}^{-1} \) \((K = 5\times10^2\text{Pa})\)  
Based on the expression of velocity (13)-(16), the flux density can be calculated by the formula (4). In this case, based on the proposed model it is possible to carry out a theoretical study of the process stream purification from impurities.

3. Results and Discussion

When using fiber cleaners working in production conditions, and based on scientific research, a special design guide installed on the equipment is shown in Figure 3. 

![Figure 3. Special design fiber cleaner with guide device: 1.9-Saw cylinder; 2, 11-separator Blade; 3-inlet pipe; 4, 6 - strengthen brush; 5-grate fence; 5-grate; 7-blinds; 8-dirty bunker; 10-output pipe; 11 - exhaust camera; 12-special design fixture](image-url)
A number of scientific studies have been carried out to improve the technological parameters of cleaning products made of direct-flow fibers [12, 13, 14]. Based on the research, a new scheme for cleaning fibers with a direct flow was selected, and a special design of the guide was proposed, from which drawings were made. The proposed abstract can be seen in Figure 4.

Figure 4. Proposed special design guide rail

3.1 Overall Efficiency
In order to preserve the natural quality of machine-picked cotton, resource-saving advanced fiber-cleaning equipment was introduced in March 2020 at the enterprise of the Uzpakhtasanoat JSC system, in particular at the enterprise of Zarbdor cotton cleaning JSC. The comparative analysis of the fiber cleaning equipment is given in Table 2.

| Name of indicators              | Available fiber cleaner | Improved fiber cleaner |
|---------------------------------|-------------------------|------------------------|
| Fiber performance               | 2000                    | 2000                   |
| Cleaning efficiency, %          |                         |                        |
| - in the first varieties        | 30-32                   | 35-40                  |
| - low varieties                 | 33-35                   | 45-49                  |
| The amount of fiber suitable for spinning in the composition of waste | 25                      | 20                     |
| consumable electric energy      | 5.5                     | 5.5                    |
| Metal consumption               | 2518                    | 2470                   |

Regarding to the energy consumption, thanks to the improvement of the equipment, energy consumption is saved by 12-15%.

By installing a new design device in the fiber cleaning equipment, it will be possible to separate 20-25% of the fiber from the waste suitable for production.

4. Conclusions
As can be seen from this, to clean fibers from the machine and hand dialed the cotton material based on structural analysis of fibrous Aeromechanics cleaners used on cotton plants, it is necessary to change the guide unit to the special design of the receiving fiber cleaning saw guide to the correct tooth of the cylinder. Many studies have been conducted on the effect of cotton fiber flow on cleaning efficiency when striking the grate system. However, when changing the pressure,
density and speed in the grate, as well as the effect on the cleaning efficiency, experiments were conducted to model the process, allowing you to change the raw material from 4 mm to 15 mm based on the guide device to the initial thickness. Based on the analysis, it is recommended to widely introduce the guide device into production.

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