Study on the development of improved routing technology of CC-15A cotton separator

M T Khodjiev\textsuperscript{1}, D D Eshmurodov\textsuperscript{2}, and D A Ortqova\textsuperscript{2}

\textsuperscript{1}Gulistan State University, Gulistan, Uzbekistan
\textsuperscript{2}Tashkent State Institute of Textile and Light Industry, Tashkent, Uzbekistan

Email: glsu_rektor@edu.uz

Abstract. The present article examines the existing problems in pneumo-transporters. It also presents advantages of the proposed improved model and the results of research on the Uster HVI 1000 laboratory equipment with high average length, uniformity index in length, short fiber index. The ability to maximize the natural properties of the products and significantly extend the service life of the separator design through this improved device has been proven on the basis of theoretical and practical analysis.

1. Introduction

Increasing the efficiency of existing equipment and facilities in ginneries, improving the quality of products depends on the implementation of technical requirements for these devices, a correct choice of technological regulations and perfect observance of aerodynamic standards in pneumatic transport systems. An analysis of existing technological and aerodynamic conditions, selection and introduction of alternative options in production, identification of factors affecting production output, natural properties of cotton as well as the essence of present dissertation is to find ways to eliminate existing problems, make proposals to prevent the loss of cotton fiber in the aerodynamic system and its application in a wider production. An analysis of present research topic and finding a solution to the problem that arises from it involves a comprehensive in-depth analysis of separators that are widely used in ginneries today. A number of scientists around the world have also made in-depth analysis of aerodynamics, theoretical analysis and physical-mechanical properties of cotton from the process of air separation of primary processing technologies of cotton [1-4].

The technical and technological measures taken, which are of great importance in the current stage of development of the ginning industry, do not allow to harm the harvested raw cotton and it must ensure timely pre-processing and uninterrupted delivery of the obtained product to consumers, while maintaining its natural properties at a high level. The technological system of primary processing of seed cotton involves a process of cotton transportation as well as finished products on the territory and departments of an enterprise by various means of transport. At the same time, the transfer of seed cotton from the warehouses and closed warehouses to production, as well as one of the main devices used in the transfer of cotton from one department to another is pneumatic transport.

The efficiency of pneumatic transport equipment varies depending on the capacity of the gin. Their average operating productivity is 15 tons/h. The widespread use of machine picking and the growth of seed cotton production put the ginning industry ahead of the demand to increase production capacity, equipment productivity and finished product quality. The solution of these problems also depends in
many respects on the operation of pneumatic transport of seed cotton, as it is the first and foremost in the technological process of primary processing of cotton [5].

2. Problem Statement
At the entrance to the separators, the main goal was to ensure that the cotton layer did not hit its back wall at a high speed and ideally would evenly be distributed along the working lengths of the vacuum valve, preserving the natural properties of the cotton falling into the vacuum valve. In existing separators, a mixture of cotton and air enters the separation chamber through a pipe at a speed of 26-28 m/sec. As a result, the cotton mass is forced into the back wall of the separator. These are the disadvantages that lead to mechanical damage of the seeds, rapid erosion of the back wall of the separator and a decrease in the service life of the separator.
Long-term use of pneumatic transport to prevent premature failure of the inner wall of the separator and the vacuum valve by eliminating the air coming from the air in the separator CC-15A by hitting the right wall and directing it to the vacuum valve, reducing the speed by 7-8 m/s. The main goal of this scientific work is to create a separator that will work [6].
The purpose of the proposed improved separator (see Figure 1) is to maximize the natural properties of the products and embed a new device router (see Figure 2) into the separator design to significantly extend its service life [7].
The separator is fitted with a guide made of a rectangular metal sheet to ensure the stability of the equipment by filling it with a device mounted on the inside of the air separation chamber. In this case, the guide is set with the ability to rotate around its own axis.
The problem is that the guide is installed using existing bolt fasteners to increase the performance of the equipment along the connecting circuit with the air duct separator, in addition, the installation of the guide, especially its easy replacement, allows to increase the service life of the separator. If the router does not work, it can be easily replaced with a new one, while the effect of the raw cotton on the separating wall can be ruled out.

Figure 1. Cross-sectional view of the improved separator: 1- an air inlet pipe; 2. a suction pipe; 3 a guide/router; 4 scrapers; 5 mesh surface; 6,9- a shaft; 7 a rear wall of separator; 8-vacuum-valve 10- rubber blade
Figure 2. A-diagram showing the magnification of the router device: 1. an air inlet; 2nd suction pipe;Router 3

The essence of the proposed device is that the separator is equipped with a guide mounted inside the inlet separation chamber from the pneumatic pipe, which allows changing a direction of the transmitted raw cotton. When the raw cotton is piped to the entrance zone to the separation chamber, the built-in guide allows altering a direction of the raw cotton to the reinforced wrapping zone of the raw cotton, in to the central part of the mesh surface [8].

3. A Solution and Analysis of Results
Allow us first theoretically study and analyze the motion of a cotton ball under the action of a separator chamber guide.

We assume that the cutting surface of the separator chamber is a variable tube. Assuming that the particle moving with the flow does not affect the air flow then in that case, the motion of a particle of mass $m$ is influenced by the air flow, which is influenced by the active driving air force (Figure 3) [9].

Figure 3. Scheme of movement of cotton pieces in a separator chamber

If a power of the module is the air velocity, it is assumed to be proportional to the square of the difference between the air velocity and the particle velocity. Furthermore, by accepting a condition which is $\tan \alpha = k < 1$, we do not obtain the cross-sectional AB effect on the motion of the particle. In this case, the equation of motion of a particle is two-dimensional and follows along the $xy$ axes.
\[ m\ddot{x} = c\sqrt{(v_0 - \dot{x})^2 + y^2} (v_0 - \dot{x}) \]  \hspace{1cm} (1)
\[ m\ddot{y} = c\sqrt{(v_0 - \dot{x})^2 + \dot{y}^2} + mg \]  \hspace{1cm} (2)

We place the coordinate pressure at point C of the initial section of the pipe, with the OX axis in the direction of the air flow, and the OY axis perpendicular to it. Where \( c \) is the proportionality factor of the airflow force, \( v_0 \) is the air flow rate, the expression of which is expressed by the formulas given in 2.44.

\[ v_0 = \frac{Q_0}{L\rho_0 (b_0 - kx)} \hspace{1cm} 0 < x < l \]  \hspace{1cm} (3)
\[ v_0 = v_1(l) \hspace{1cm} l < x < l_1 \]  \hspace{1cm} (4)

Here \( l_1 \) - the length of the pipe. We see the following special case, in practice the condition \( \dot{y} < L(v_0 - \dot{x}) \) is fulfilled. Therefore, we write equations (1) and (2) in the following form.

\[ \ddot{x} = n(v_0 - \dot{x})^2 \]  \hspace{1cm} (5)
\[ \ddot{y} = n(v_0 - \dot{x})\dot{y} + g \]  \hspace{1cm} (6)

Here \( n = c/m \)

Equations (5) and (6) are nonlinear and numerical integration is required. If the airflow is not high enough, then \( v_0 < 5\nu/c \) - the air resistance force can be obtained in a linear form.

\[ m\ddot{x} = C_0(v_0 - \dot{x}) \]  \hspace{1cm} (7)
\[ m\ddot{y} = C_0 \dot{y} + mg \]  \hspace{1cm} (8)

The solution of equations (7) and (8) is obtained analytically. The initial conditions for them are as follows.

\[ x = 0, \hspace{0.2cm} y = y_0, \hspace{0.2cm} \dot{x} = v_n, \hspace{0.2cm} \dot{y} = 0 \]

Here \( y_0 \) is the initial ordinate of the fraction, \( v_n \) is the initial velocity of the fraction in the pipe (to the separator chamber), to determine it can be used efficiency in the transfer of raw cotton to the separator chamber

\[ v_n = \frac{Q_n}{Lb_0\rho_1}, \hspace{0.2cm} Q_n, \hspace{0.2cm} \text{- unit productivity of raw materials per unit time, (kg/s),} \hspace{0.2cm} \rho_1, \hspace{0.2cm} \text{- density of raw materials.} \]

Considering the expression of \( v_0 \) - air flow rate, equation (2.48) takes the following form.

\[ \ddot{x} + 2n_0\dot{x} = \frac{2n_0Q_0}{\rho_1L(b_0 - kx)} \]  \hspace{1cm} (9)

Here \( 2n_0 = \frac{C_0}{m} \)

Equation (5) is nonlinear and can be solved numerically. To make it linear, we accept the condition \( \varepsilon = (b_0 - b_1)/b_0 << 1 \) and use the following \( \varepsilon^2 \approx 0 \) equation for the following case:

\[ \frac{1}{b_0 - kx} = \frac{1}{b_0[1 - \frac{b_0 - b_1}{b_0}x]} \approx \frac{1}{b_0} \left[ 1 + \frac{\varepsilon x}{l} \right] \]

\[ \ddot{x} + 2n_0\dot{x} - 2n_0\varepsilon \dot{x}/l = 2n_0v_0 \]  \hspace{1cm} (10)

Here, \( \varepsilon = 1 - \frac{b_1}{b_0} \); \( v_0 = \frac{Q_0}{\rho Lb_0} \)

Equation (10) is linear, and its general solution is as follows:
\[ x = C_1 e^{k_1 t} + C_2 e^{k_2 t} - \frac{l}{\varepsilon} \tag{11} \]

If we use this condition \( x(0) = 0 \), \( \dot{x}(0) = v_n \)

\[ C_1 = \frac{lk_2 - v_n \varepsilon}{k_2 - k_1}; \quad C_2 = \frac{v_n \varepsilon - l k_1}{k_2 - k_1} \]

Here, \( k_1 = -n(1 + \sqrt{1 + \beta}) \), \( k_2 = -n(1 - \sqrt{1 + \beta}) \), \( \beta = 2n \varepsilon / nl \), \( n = C_0 / m \)

The motion of the particle along the axis is given by Equation (8) \( y(0) = y_0 \), in \( \dot{y}(0) = 0 \) condition is determined by integration. Its general solution

\[ y = A_1 e^{-2n t} + \frac{g}{2n} A_2 \quad y(0) = y_0 \dot{y}(0) = 0 \]

Will identify the conditions of \( A_1 \) and \( A_2 \).

\[ A_1 = \frac{g}{4n^2}; \quad A_2 = y_0 - \frac{g}{4n^2} \]

\[ y = -\frac{g}{4n^2} (1 - e^{-2n t}) + \frac{g}{2n} t + y_0 \tag{12} \]

Solutions (11) and (12) are obtained for the interval \( 0 < x < l \) and should be written for the equation in the interval \( v_0 = v_1(l) = \frac{Q_0}{\rho_0 L(b_0 - kl)} \).

\[ m \ddot{x} = (v_1 - \dot{x}) C_0 \tag{13} \]

The equation (13) is integrated in the following conditions: \( x(t_0) = l \), \( \dot{x}(t_0) = v_{1n} \) here

\[ v_{1n} = C_1 k e^{k_1 t} + C_2 k_2 e^{k_2 t} \]

\( t_0 \) from this condition \( C_1 e^{k_1 t} + C_2 e^{k_2 t} - \frac{b_0}{\varepsilon} = l \) will identify.

\[ x = x_2 = v_n - (v_0 - v_{1n}) [1 - \exp(-2n t)] / 2n \]

When studying the motion of the cotton piece in the separator chamber, a right angle was selected to ensure that it does not collide with the guide line. At such an angle of inclination of the guide, the cotton piece does not form a shock effect on the guide line in this zone. The following parameters were adopted during the calculation process.

\( L = 1.1 \text{M}, \quad l = 0.5 \text{M}, \quad b_0 = 0.5 \text{M}, \quad n = 0.35, \quad \rho_0 = 1.2 \text{kg} / \text{m}^3, \quad \rho_1 = 50 \text{kg} / \text{m}^3, \quad Q_n = 12000 \text{kg} / \text{h} \).

Figure 4 shows the trajectory of the motion under the torsion at two values of the angle in the first zone of the segment, in which 2 lines define the trajectory of the segment.

From the analysis of graphs it is observed that the trajectory of the segment is a straight line in the direction of the guide, the decrease in the angle \( \alpha \) of the guide with the horizon a decreases the velocity of the segment, as a result of which the trajectory of the segment may be farther [10].

\[ \alpha = 25^0, \quad \alpha = 15^0 \]

As well as, Figure 4 shows the graph of the change in velocity of the particle velocity in the separator chamber over time with two values of \( \alpha \). It has been shown that as the angle of the guide with the horizon increases, the velocity of the particle increases and the location of the eyelet can partially reduce the velocity of the particle.

Based on these theoretical analyzes an improved version of the CC-15A separator has been developed and tested.
As a result of our research on the improved separator, it was observed that in the separator with one additional device in an isolation chamber, an increase in the yield of fiber from the natural properties of cotton has been observed as well as a better prevention of deformation and loss of short fibers, let alone a mechanical damage to seeds. However, due to the use of a VTs-12 fan in the separator at the top of the drying drum and in the separator, it is observed that the cotton coming through the air hits the straight wall of the separator at high speed. As a result, the straight wall is torn, broken, patched, and there is an increase in mechanical damage to the seed.

![Figure 4](image)

Now, only when we conduct research in an improved directional separator, when the direction is 30 °, it directs 40-50% of the cotton coming through the air in a uniform plane to the vacuum valve. This prevents mechanical damage to the seed and ensures long-term operation of the proper wall of the separator. However, unfortunately, 50-60% of cotton coming through the air sticks to the net, and as a result of scraping it into the vacuum valve, the rest of the cotton has a decrease in fiber yield, in short fibers and a partial increase in the number of damaged seeds [11].

Instead of confirming these data, samples were taken from the front and back of the existing separator at the top of the cotton drying drum of the same variety, moisture and contamination, and it was tested using the DL-10 laboratory and the fiber was tested on HVI laboratory equipment later exposing the samples to Len, Unf, SFI modes. Longitudinal uniformity index and short fiber index were studied and recorded and are presented in Tables 1, 2, and 3.

**Table 1. Cotton fiber from Bunt**

| Sample | Mic | Mat | Len | Unf | Str | Elg | C-G | Rd | +b | T | Cnt* | Area | SFI | SCI |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|----|---|-----|------|-----|-----|
| 001    | 4.54 | 0.86 | 1.151 | 85.0 | 31.0 | 8.0 | 41-1 | 73.8 | 8.0 | 5 | 61 | 0.79 | 7.1 | 131.8 |
| 002    | 4.53 | 0.86 | 1.150 | 85.3 | 32.3 | 7.9 | 41-1 | 75.9 | 7.5 | 6 | 92 | 0.94 | 5.9 | 149.7 |
| 003    | 4.55 | 0.86 | 1.145 | 84.8 | 32.2 | 7.6 | 41-1 | 75.6 | 7.6 | 7 | 78 | 1.23 | 7.0 | 141.7 |
| 006001 mean | 4.54 | 0.86 | 1.148 | 85.0 | 31.8 | 7.8 | 41-1 | 75.1 | 7.7 | 6 | 77 | 0.99 | 6.7 | 141.1 |

**Table 2. Cotton fiber obtained after separation**

| Sample | Mic | Mat | Len | Unf | Str | Elg | C-G | Rd | +b | T | Cnt* | Area | SFI | SCI |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|----|---|-----|------|-----|-----|
| 001    | 4.45 | 0.86 | 1.145 | 84.5 | 32.0 | 7.8 | 31-2 | 76.9 | 8.1 | 5 | 77 | 0.81 | 7.4 | 146.4 |
| 002    | 4.51 | 0.86 | 1.137 | 85.2 | 31.5 | 7.4 | 41-1 | 75.3 | 7.3 | 7 | 107 | 1.26 | 6.8 | 146.0 |
| 003    | 4.49 | 0.86 | 1.139 | 83.5 | 32.2 | 7.9 | 41-1 | 76.1 | 7.4 | 8 | 80 | 1.75 | 7.9 | 140.8 |
| 002001 mean | 4.48 | 0.86 | 1.140 | 84.4 | 31.9 | 7.7 | 41-1 | 76.1 | 7.6 | 7 | 88 | 1.27 | 7.4 | 144.4 |
Table 3. Factory DL-Jinn-processed fiber

| Sample | Mic | Mat | Len   | Unf | Str | Elg | C-G | Rd  | *b | T | Cnt* | Area | SFI | SCI |
|--------|-----|-----|-------|-----|-----|-----|-----|-----|----|---|-------|------|-----|-----|
| 001    | 4.53| 0.85| 1.140 | 32.5| 8.2 | 41-1| 75.5| 7.2 | 7  | 73| 1.14  | 7.7  | 145.7|
| 002    | 4.57| 0.86| 1.135 | 31.6| 7.5 | 41-2| 74.2| 6.9 | 7  | 85| 1.19  | 7.2  | 132.5|
| 003    | 4.77| 0.86| 1.132 | 32.4| 8.2 | 51-1| 71.2| 6.5 | 7  | 100| 1.38  | 7.8  | 141.1|
| 001001 mean | 4.62| 0.86| 1.136 | 32.2| 8.0 | 41-2| 73.6| 6.9 | 7  | 86| 1.24  | 7.6  | 139.8|

Figure 5. Len, Unf, SFI indicators are listed on the Uster HVI 1000 laboratory equipment.

As a result of the study (Length), when the upper average length Uster HVI 100 was tested on laboratory equipment, the average cotton fiber obtained from the bunt was 1,148 inches, while the cotton fiber obtained after the separator was 1,140 inches, i.e., a decrease was observed. Also (Uniformity index) when the length uniformity index was checked, the average yield of cotton fiber from the bunt was 85.0%, the cotton fiber obtained after the separator was 84.4%, i.e., the average length of all fibers in the total sample was also reduced (see Figure 5).

In addition (Short fiber index) when the short fiber index was tested on this laboratory equipment, it was 6.7% in the fiber of cotton obtained from the bunt, it was observed that the fiber obtained of the cotton obtained after the separator was 7.4%, i.e. here, too, a violation of the natural properties of the cotton was observed. As a result of the overall analysis, an improved 25 ° isolation chamber and a guided CC-15A separator were recommended for use in production.

4. Conclusions
As a result of our theoretical and practical research, we can conclude the following:

a) Since the installation of the router changes the speed of the air flow, this situation in turn leads to a change in the speed of the individual particles.

b) It is theoretically justified that under the influence of the guide a piece of cotton can hit the separator wall. From the analysis of the calculations, it has been proven that the placement of the guide in the separator chamber can reduce the speed of the cotton piece to the accepted parameters.

c) In order to prevent the flow of cotton from hitting the back wall of the separator, a special guide device was created at the entrance to the chamber to guide the cotton. As a result, the mechanical friction of cotton seeds was reduced by 0.2-0.3%.
d) With the help of the proposed guide, the strength of the separator wall was ensured and its surface erosion was eliminated.

References
[1] Sahar A, Zafar MM, Razzaq A et al. 2021 Genetic variability for yield and fiber related traits in genetically modified cotton J Cotton Res 4 19.
[2] Guo C, Pan Z, You C et al. 2021 Association mapping and domestication analysis to dissect genetic improvement process of upland cotton yield-related traits in China J Cotton Res 4 10.
[3] Delhom CD, Hequet EF, Kelly B et al. 2020 Calibration of HVI cotton elongation measurements J Cotton Res 3 31.
[4] Wang Z, Feng X, Wang H 2016 Parameter optimization and experiment of funnel-shaped heavy impurity separator in seed cotton cleaning process Engineering 32(21) 30-36.
[5] Khodjiev MT, Murodov OJ, Eshmurodov DD, Eshnazarov DA 2020 Tests in the insulating cameras of the improved separator IOP Conference Series: Materials Science and Engineering 862 032025.
[6] Khodjiev MT, Murodov OJ, Eshnazarov DA, Eshmurodov DD 2020 Tests in the insulating cameras of the improved separator Int J Materials Science and Engineering 862.
[7] Khojiev MT, Usmanov XS, Tangirov AE, Ostanakulov MA, Usmanov ZS, Eshmuradov DD 2019 Patent UZ № FAP 01396 Seed cotton separator.
[8] Khodjiev MT, Murodov OJ, Eshmurodov DD 2020 Creation of Scientific-Based Construction of the Separator with Insulation Camera Int J Innovative Technology and Exploring Engineering 9 3231-3235.
[9] Khojiev MT, Juraev AD, Murodov, OD, Rakhimov AK 2019 Development of design and substantiation of the parameters of the separator for fibrous materials Int J Recent Technology and Engineering 8(2) 5806–5811.
[10] Khodjiev MT, Mardonov BM, Eshmurodov DD 2020 Theoretical study of the state of raw cotton moving on the surface of the separator mesh Mechanical Problems 1-2 143-147.
[11] Eshmurodov DD, Khojiev MT, Artikova DA 2021 Creation and development of advanced technology of CC-15A separator, International Conference on Engineering & Technology, Egypt.