Open Journal of Science and Technology
Journal Homepage: http://readersinsight.net/OJST

Research Article

Theoretical research of the process of separating impurities from cotton flow on the vibrating inclined mesh surface

Salokhiddinova Makhliyo Nurmukhammad Qizi[1]*,
Muradov Rustam Muradovich[2]

[1,2]Department of Technology of Initial Processing Natural Fibers, Namangan Institute of Engineering and Technology, Namangan, Uzbekistan

*Corresponding Author email: salohiddinova.m@mail.ru

Submitted: 10 December 2020 *Revised: 25 January 2022* *Accepted: 10 February 2022*

ABSTRACT

The theoretical and experimental analysis of movement processes of raw cotton on the inclined surface (a tray) is given in the article and different factors influencing cotton cleaning process are studied. Based on developed models, there is an opportunity to determine the efficiency of raw cotton being cleaned under different angles of the inclined plane and the change in its volume. It was observed that pattern of change in coefficient of cotton cleaning efficiency by time as a result of vibration of a tray is closely dependent on compression module K and increase in cleaning efficiency was observed.

Keywords: *Raw Cotton; Raw Cotton Layer; Inclined Mesh Surface; Angle; Length of a Tray; Volume Compression; Provided Density; Cleaning Efficiency; Raw Cotton Delivery*

1. INTRODUCTION

Separator is one of the main elements of an equipment transporting cotton with the help of air in cotton cleaning enterprises. Currently, the SS-15A cotton separator is widely used. The separator is used to separate the raw material from the air which carries cotton. Currently, improving the efficiency of the technologic process, improving productivity, and maintaining the quality of cotton by improving the separators used at cotton cleaning enterprises are considered to be of utmost importance (1-3).

In the case of existing separator units at cotton cleaning enterprises cotton, in its process of falling into a vacuum valve, gets stuck to vacuum valve's blades and pressed to equipment's housing. As a result, the seeds and fiber are damaged. Accordingly, the authors proposed the following separator designs to prevent damage caused in the separator equipment (4).

According to the results of the research, in separating cotton from air 0.6 or 0.8% of cotton seed damage occurs in a separator. In turn, this results in different defects in the fiber content up to 0.2 ÷ 0.3% (5-8).

https://doi.org/10.31580/ojst.v4i4.1763

Therefore, by introducing the proposed separator unit (Fig. 1) to cotton cleaning enterprises, there will be an opportunity to increase the efficiency of the cotton transportation process, reducing its damage and eliminating minor impurities.

2. EFFICIENT CONSTRUCTION OF THE SEPARATOR

The proposed separator unit is equipped with a camera which has inclined mesh surface and a spring installed in the working chamber with the purpose of vibrating inclined mesh surface in the way which lets raw cotton to be directed to the centre of vacuum valve, to fall to spaces between vacuum valve blades, to be free of damage caused by vacuum valve blades and to have an opportunity to be cleaned from fine impurities.

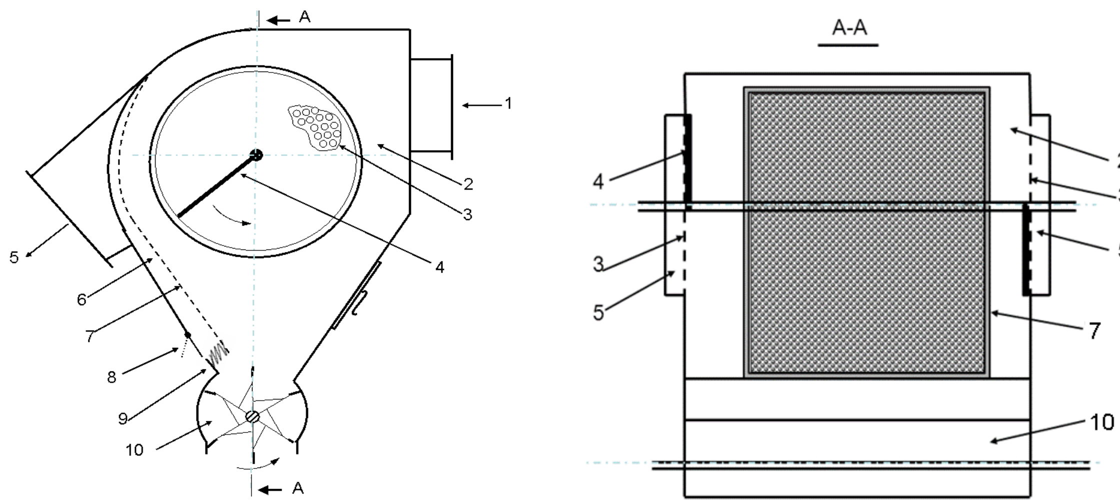

Fig. 1. Side and cross-section view of the proposed separator

1-inlet pipe, 2- working chamber, 3- mesh surfaces on the sides (lateral)of a working chamber, 4-scraper, 5-air outlet pipe, 6-impurity bunker, 7-inclined mesh surface, 8-lid, 9-spring, 10-vacuum-valve.

In order to partially solve the problem, an analysis of the vehicles used at the cotton cleaning enterprises was carried out and by taking into account the possibility of efficient use of inclined surfaces in cotton processing, these processes were theoretically analyzed and studied by researchers.

3. METHODS AND RESULTS OF THEORETICAL STUDIES

Let us assume that the raw cotton flow is in the stationary motion over the surface (tray), which is formed by the angle α and the vertical axis (Fig. 2).

OY axis is in its vertical direction. By directing OX and OZ axes to it, we would locate the beginning of coordinate at the point A. The inclined surface is connected by a hinge at point B, which is placed on the axis OY. Since the movement is uniform along the axis A, we examine the movement of the flow along the straight line BC on an inclined surface OZ.

We consider the tray as the most constant, and the flow velocity equation can be written as follows, by considering the flow weight and the frictional forces (10).

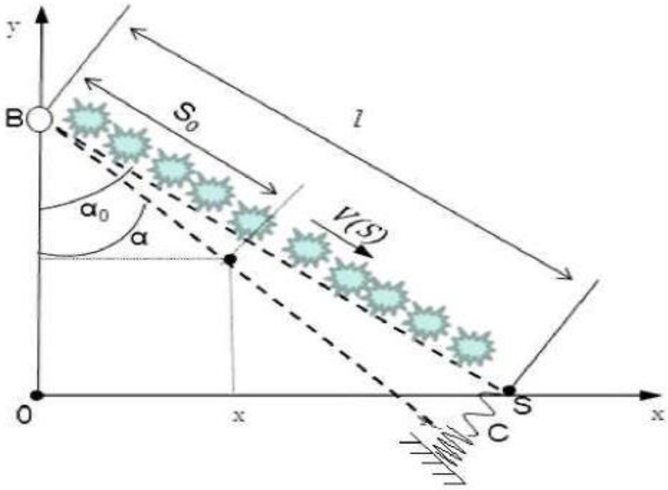

Fig. 2. Schematic movement of raw cotton layer's flow on the inclined surface (tray)

$$\rho v \frac{dv}{dx} = -\frac{dp}{dx} + \rho g(\cos\alpha - f\sin\alpha)$$

$$0 < x < l \qquad (1)$$

Here, $\rho = \rho(x)$ the flow density (kg / m3), $v = v(x)$ (m/s), $p = p(x)$ (Pa) the velocity and pressure of the flow at any point of the cross section BC, l -the length of the tray.

In equation (1), three unknowns $\rho(x)$, $v(x)$ and $p(x)$ are involved. To find them out, we use equations which determine the circumstance conservational and environmental laws:

$$\rho v = \rho_0 v_0 = Q / S \qquad (2)$$

$$\rho = \rho_0[1 + A(p - p_0)] \qquad (3)$$

Here p_0, v_0 - given density and velocity at the point B of the cross-section BC, Q - productivity of raw materials, $S = Lh$ -cross section of raw material in the tray, L -the width of the raw material, h - the thickness of the raw material, $A = 1/K$, K - compression module (Pa) of raw cotton volume, which is determined by an experiment.(2) We obtain links as follows when $A << 1$:

$$v = \frac{\rho_0 v_0}{\rho} = -\frac{v_0}{(1 + Ap)} \approx v_0[1 - A(p - p_0)] \qquad (4)$$

Given the links (2) and (4) we write equation (1) with respect to pressure p :

$$(1 - \rho_0 v_0^2 A)\frac{dp}{dx} = [\rho_0 g A(p - p_0) + \rho_0 g](\cos\alpha - f\sin\alpha)$$

We accept the following mark:

$$\gamma = \frac{\rho_0 g A(\cos\alpha - f\sin\alpha)}{(1-\rho_0 v_0^2 A)},$$

then,

$$\frac{dp}{dx} = \gamma\left[p - p_0 + \frac{1}{A}\right] \quad (5)$$

When solving equation (5), considering $1-\rho_0 v_0^2 A$ > 0, we see two cases:

$\cos\alpha - f\sin\alpha > 0$ or $ctg\alpha > f$ here $\alpha < \alpha_k = arcctgf$. Then, $\gamma > 0$, the solution of equation (5) in case $p(0) = p_0$ is:

$$p = \frac{1}{A} = [\exp(\gamma x) - 1] + p_0 \quad (6)$$

From equations (2) and (6) we determine the density and velocity.

$$\rho = \rho_0 \exp(\gamma x) \qquad v = v_0[2 - \exp(\gamma x)] \quad (7)$$

For speed to have a physical meaning, the following condition $v > 0$ must be met in the interval $0 < x < l$, which results in the following inequality: $\exp(\gamma x) - 2 < 0$.

If the γ parameter expression is taken into account, this inequality can be determined for the coefficient K

$$K > K_{np} = \frac{\rho_0[gl(\cos\alpha - f\sin\alpha) + v_0^2]}{\ln 2}$$

Fig. 3 shows graphs of variation of volume compression module K_{np} at values at different angles (radians) of the (Pa) in respect to starting velocity of raw material v_0 (m/s). In the calculations, the values $\rho_0 = 60кг/м^3$, $\rho_0 = 60кг/м^3$, $l = 2$ are assumed.

In case of a change in interval $0 < \alpha < \alpha_k$ of angle α, in order to provide the verifiable mode of movement of the raw material's flow on a tray, primary compression module of raw material in volume must satisfy the condition $K \geq K_{np}$. With the angular increase of an inclined surface, in the mode of analysis it was detected that there is a decrease in the boundary volume compression module K_{np} for the movement of the raw material flow.

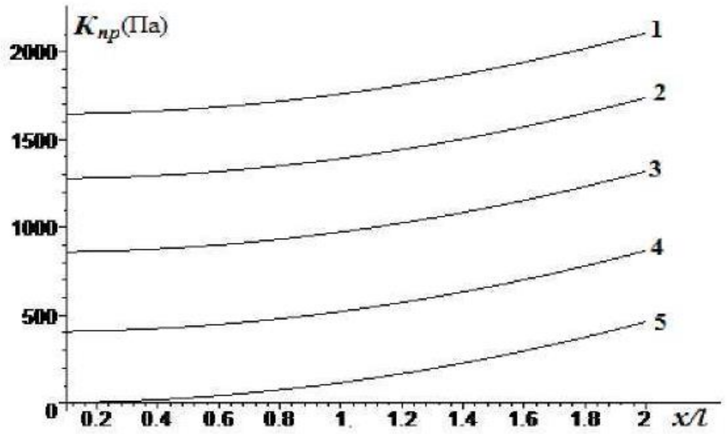

Fig. 3. Variation in volume compression module K_{np} (Pa) of raw material with respect to the initial velocity (m / s) at different angles (radians): 1- α = 0.6, 2- α = 0.8,

3- α = 1,4- = 1.2, 5- α = α_k = 1.373

2. $\cos\alpha - f\sin\alpha < 0$ or $ctg\alpha < f$ here $\alpha > \alpha_k = arcctgf$. Then $\gamma < 0$, and the solution of equation (5) is as follows:

$$p = -\frac{1}{A}\left[1-\exp(-\gamma_1 x)\right] + p_0 \tag{8}$$

Here it is $\gamma = \dfrac{(f\sin\alpha - \cos\alpha)\rho_0 gA}{(1-\rho_0 v_0^2 A)}$.

The density and velocity of the environment are determined by the following equations:

$$\rho = \rho_0 \exp(-\gamma_1 x); \quad v = v_0\left[2-\exp(-\gamma_1 x)\right] \tag{9}$$

From the analysis of the formula (8), if this condition is met, the pressure in the section $s_1 = \ln 2/\gamma_1$ of layer $A < 1/p_0$ can be zero. Given that this point lies at the bottom boundary of the layer, we get the following inequality from $s \le 1$:

$$\gamma_1 l \le \ln\frac{1}{(1-p_0 A)}$$

Fig. 4 and 5 show distribution graphs of raw material density and velocity along the tray length.

Suppose the mass of the raw layer freed from fine impurities changes from m_0 to m. We subtract an optional element ds from the layer in a planned time. Let the length of it to be dx before deformation. If we define the deformation ε_v, its expression is determined by the change in volume using this formula $\varepsilon_v = (V - V_0)/V_0$ and from the second side, if we take into account equations $V = m/\rho$, $V_0 = m_0/\rho_0$ we will obtain the following expression:

$$\varepsilon_v = \left(\frac{\rho_0 m}{\rho m_0} - 1\right) \quad (10)$$

We determine the length of the selected element

$$ds = (1 + \varepsilon_v)dx = \frac{\rho_0}{\rho}\frac{m}{m_0}dx \quad (11)$$

Let us assume that the reduction in the mass of the raw material is caused by the impurities that are separated from it. We use the model proposed by AG Sevostyatov to explain mass reduction processes (11). According to this model, the reduction intensity of an element ds is proportional to the multiplication of separated element by its quantity, that is

$$\frac{dm}{m} = -\lambda ds \quad (12)$$

Here we use of the proportionality factor λ in the links(11) and (12)

$$\frac{dm}{m} = -\lambda \frac{\rho_0}{\rho}\frac{m}{m_0}dx$$

According to formulas (7) and (9)

If $\frac{dm}{m} = -\lambda \exp(-\gamma x)\frac{m}{m_0}dx$, $\alpha \le \alpha_k$;

if $\frac{m}{m_0} = \frac{1}{1 + \lambda x}$, $\alpha = \alpha_k$;

if $\frac{dm}{m} = -\lambda \exp(-\gamma_1 x)\frac{m}{m_0}dx$, $\alpha \ge \alpha_k$.

Integrating the above equations in terms of $\varepsilon = (1 - m/m_0)$, we determine the law of reduction in mass present in content of raw cotton on an inclined surface

If $\frac{m}{m_0} = \frac{\gamma}{\gamma + \lambda[1 - \exp(-\gamma x)]}$, $\alpha \le \alpha_k$, if $\frac{m}{m_0} = \frac{1}{1 + \lambda x}$, $\alpha = \alpha_k$,

if $\frac{m}{m_0} = \frac{\gamma_1}{\gamma_1 + \lambda[\exp(\gamma_1 x) - 1]}$, $\alpha \ge \alpha_k$, $\lambda = 0.1$, $\lambda = 0.5$.

Fig. 6 shows the distribution graphs of efficiency coefficients $\varepsilon = (1 - m/m_0)$ at different angles α in respect to x. From the graph analysis, it is observed that the efficiency of cleaning increases with the large values of angle α. It was also found that the effect of proportionality λ on the efficiency increase was high. Let us assume, then, that one end of cotton flow is connected to a hinge plate and the other end to elastic element (Fig. 2).

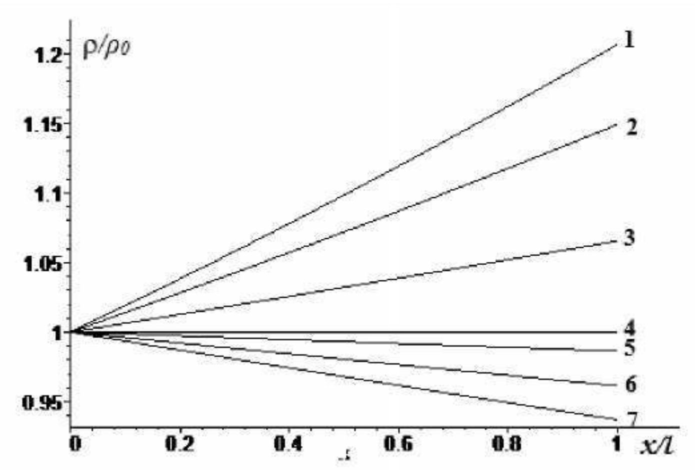

Fig. 4. Distribution of raw material density ρ/ρ_0 in different angles (radians) α by length of layer x/l: 1- $\alpha = 1$, 2- $\alpha = 1.1$, 3- $\alpha = 1.25$, 4- $\alpha = \alpha_k = 1.373$ 5- $\alpha = 1.4$, 6- $\alpha = 1.45$, 7- $\alpha = 1.5$

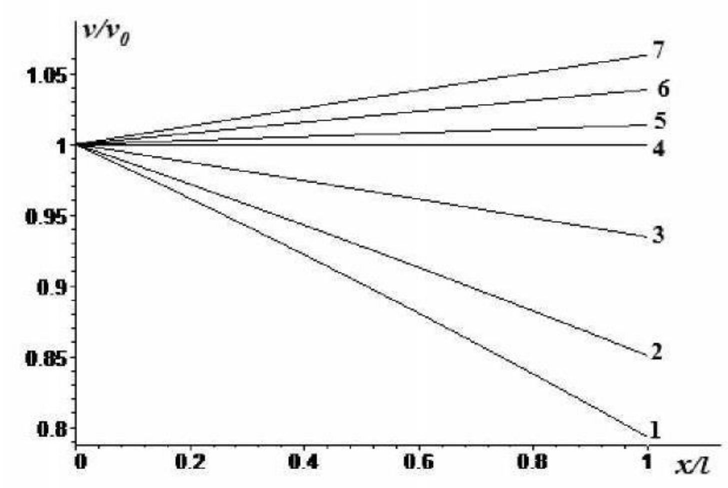

Fig. 5. Distribution of the velocity of raw material v/v_0 in different angles (radians) α by the length of the tray x/l: 1- $\alpha = 1$, 2- $\alpha = 1.1$, 3- $\alpha = 1.25$, 4- $\alpha = \alpha_k = 1.373$ 5- $\alpha = 1.4$, 6- $\alpha = 1.45$, 7- $\alpha = 1.5$

For accuracy, the movement of the flow across the plate is stationary, and the effect of the vibration can only be expressed by the time variation of angle α. Let us first denote the change of angle α by time t by a harmonic law. $\alpha = \alpha_0(1 - \cos\omega t)$, where α_0 is the maximum angle of an inclined surface formed with the vertical axis, the ω-vibration frequency. Fig. 6 shows the graphs of relative changes in separated impurities in different sections in raw cotton at two values of volume compression module K (Pa), when

$\alpha_0 = 1 pad$, $\omega = 5c^1$. Graphical analysis shows that as the module value increases, the efficiency of impurity separation decreases.

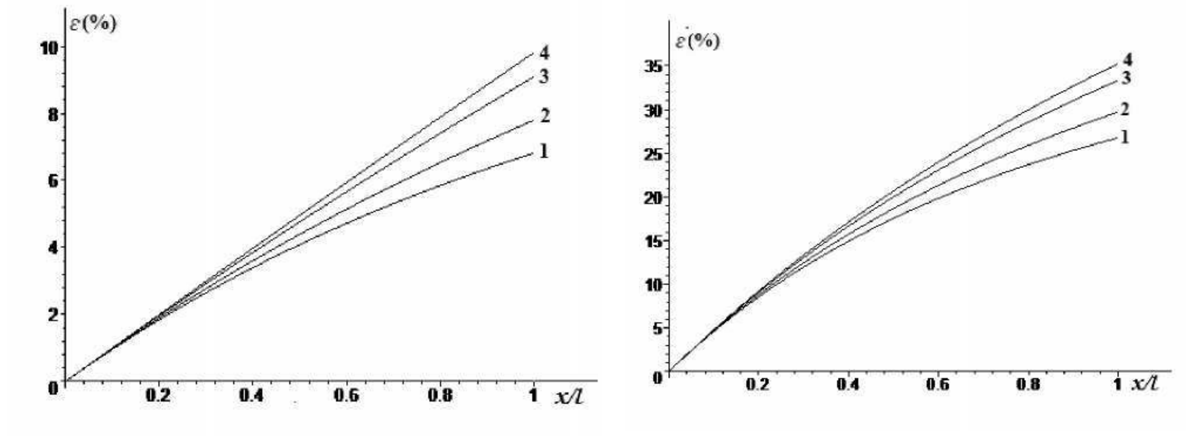

Fig. 6. Distribution of cleaning efficiency $\varepsilon = 100(1 - m/m_0)$ at different angles (radians) α along Ox : 1- $\alpha = 0.6$, 2- $\alpha = 1$, 3- $\alpha = \alpha_k = 1.374$ 4- $\alpha = 1.55$

K =1000 Pa K =2000 Pa

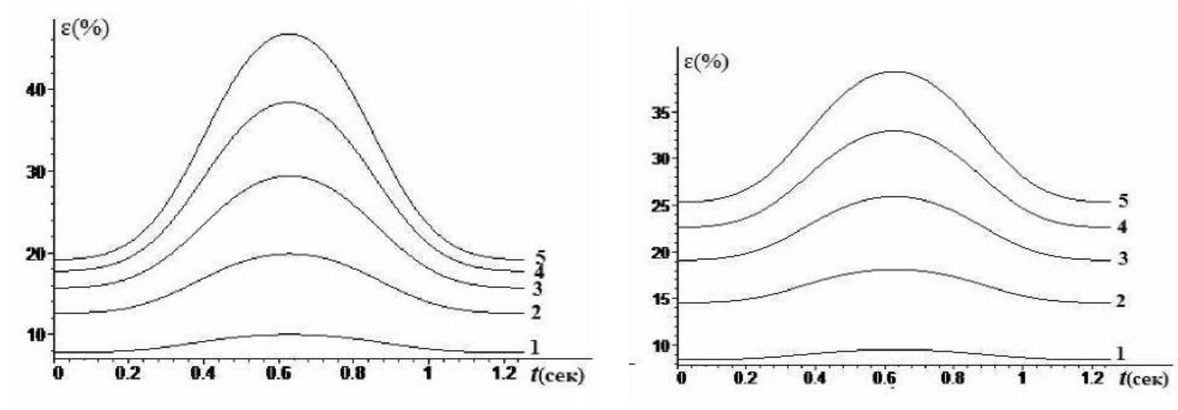

Fig. 7. Variation graphs of Efficiency coefficients, Two values of volume compression module for cleaning efficiency $\varepsilon = 100(1 - m/m_0)$ and of different sections of the raw material layer by time t (sec): 1- $x/l = 0.2$, 2- $x/l = 0.4$, 3- $x/l = 0.6$, 4- $x/l = 0.8$, 5- $x/l = 1$

Carried out theoretical researches are confirmed by researches carried out by researchers in India. Researchers at the (CIRCOT) Institute for scientific research of Cotton Technology (12) have created drum cleaners of inclined type consisting of 6 drum cleaners to extract fine impurities in the fiber, with a working width of 120 mm. Spiky drums and fans were used to clean the cotton from the impurities. The total efficiency of the newly created machine for primary cleaning of raw cotton was 20.2%.

4. METHODS AND RESULTS OF EXPERIMENTAL STUDIES

The authors obtained 500 kg of an Andijan-35 industrial variety of cotton which is 4th sort of 2nd grade to carry out the experiment. Indicators were checked in the main laboratory room of the Cotton Cleaning Factory before and after carrying out the experiment. The efficiency of cleaning of the new separator is determined by sampling the cotton entering and coming out of the separator using the pre-existed method.

The results of the researches conducted on determining the cotton cleaning efficiency of a separator, results obtained by repeated passage of cotton with the 14.8% of cotton contamination through separator during separating cotton from air are shown in Table 1.

Table 1. Impact of cotton moisture on its change in contamination

Cotton moisture, %	Efficiency of the cleaning cotton from impurities in the separator, %			
	Passage 1	Passage 2	Passage 3	Passage 4
8,2	17,8	15,4	13,8	10,1
11,6	16,6	14,8	12,2	9,8
14,9	15,7	13,9	11,7	9,1
17,4	13,6	11,5	10,9	8,9

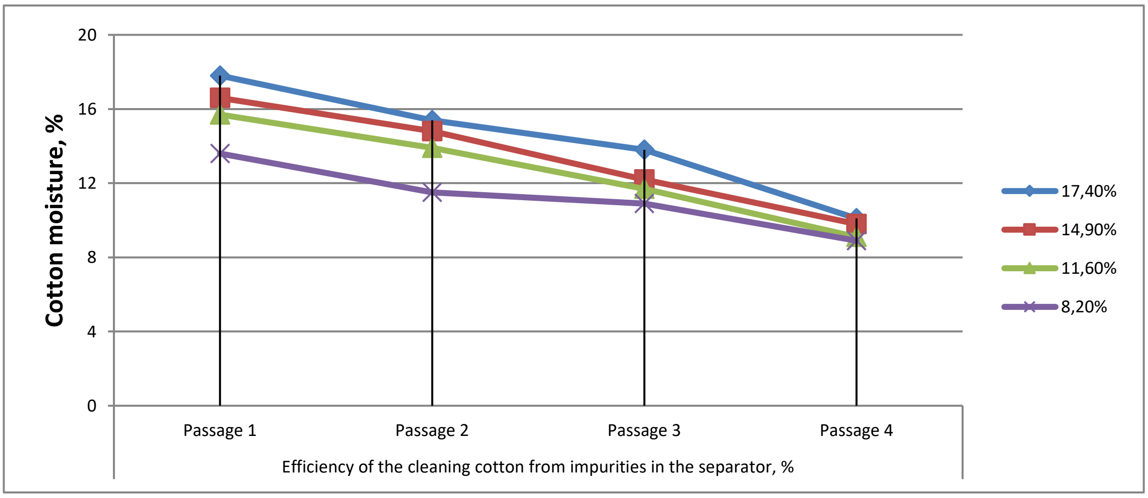

Fig. 8. The graph of the effect of cotton moisture on its impurity change

As can be seen from the table, the efficiency of the new separator equipment on impurity varies between 16 and 18% depending on the changes in the moisture content of the cotton.

So, fine impurities separated from vibrating surface of the separator's working chamber designed for separating cotton from air are shown in Fig. 9.

Fig. 9. Fine impurities separated from the content of cotton.

The inclined mesh surface mounted on the separator's working chamber provides not only cleaning fine impurities from content of cotton, but also lets cotton properly fall to vacuum valve housing. As a result, cotton will not fall to space between vacuum-valve blades and its housing, and cotton seeds will not be damaged.

Installation and operation of a new separator for separating cotton from the air will result in an average 1.8% decrease in impurities and fiber defects together.

5. CONCLUSION

1. Theoretical studies have revealed the movement of raw cotton on the inclined surface Q - the productivity of raw materials and the dependence of the volume compression module K on the angle formed from inclined surface and vertical axis. Laws of distribution along he axis of a tray were determined, particularly based on their values, the possibility that raw material's movement can pass in two modes is justified.
2. It has been observed that the cleaning efficiency increases with the large angle α values, and it has been determined that the effect of the proportionality ratio λ on it is high.
3. It is observed that as a result of tray's vibration the pattern of change in cleaning efficiency coefficient ε by time is directly related to the compression module K and with its decrease the efficiency of cleaning is increased.
4. As a result of experimental studies, efficiency of the proposed equipment on impurity is around 16-18% depending on the changes in the moisture content of the cotton. Installation and operation of a new separator for separating cotton from the air resulted in an average 1.8% reduction in the total amount of defects in cotton fiber and seeds.

Reference:

1. Zikriyoev E. Z. Textbooks under the general editorship. Primary processing of raw cotton, Tashkent. Mehnat, 1999, pp. 258-269.
2. R. Muradov. Ways to improve the efficiency of the cotton separator. Namangan edition, 2005, pp. 62-63.
3. R. Muradov. Cotton Basics of an air carrier to increase the effectiveness of the device. Science. Tashkent, Navuz edition, 2014, pp. 15-16.
4. Salokhiddinova M.N., Muradov R. M. & Mamatkulov A. T., Investigation of Separating Small Impurities and Heavy Compounds Using the Cotton Separator Equipment. // American Journal of Science, Engineering and Technology. 2017; 2(2): pp. 72-76 http://www.sciencepublishinggroup.com/journal/paperinfo?journalid=325&doi=10.11648/j.ajset.20170202.13
5. A. Dzhuraev, R. Kh. Makkudov & Sh. Shukhratov "Improving the designs of the working parts of the cotton separator" J. "Problems of textiles" No. 3-4, 2013, pp.128-131.

6. Salohiddinova M, R. Muradov, A. Karimov & B. Mardonov. The Shortfalls of the Vacuum Valve Cotton Separator // American Journal of Science and Technologyю USA. 2018; 5(4): pp. 49-55. ISSN: 2375-3846 http://www.aascit.org/journal/ajst
7. A. Karimov, O. Mamatkulov & M. Salokhiddinova. Investigating the effect of a drum in the efficient operation of the separator. STJ FerPI. 2017, No.3. pp. 160-164.
8. R. Muradov, O. Mamatkulov & M. Salokhiddinova. Separating small impurities and heavy compounds using the cotton separator. ISCIENCE.IN.UA Actual scientific research in the modern world: XV Collection of the Faculty of international scientific-practical conference, Pereyaslav-Khmelnitsky// 2016. - No. 7(15), s. 1. pp. 60-65.
9. Muradov R. M., Karimov A. I., Mardanov B.M. (2014) Theoretical and Experimental Studies of the Effect of Inclined Scraper on Removal of Raw Cottonfrom Mesh Surface. World Journal of Mechanics. 4, 371-377. http://dx.doi.org/10.4236/wjm.2014.412036
10. Ishlinsky A. Yu. Renting and Drawing in high velocity rates of deformation. Application tasks of mechanics. Book 1, M. Science, 1986, pp.263-269.
11. Sevostyanov AG & Sevostyanov PA. Modeling of technological processes. M. Light Industry, 1984. 344s.
12. Patil P.G., Anap G.R. & Arude V.G. Design and development of cylinder type cotton precleaner. Agricultural Mechanization in Asia, Africa and Latin America. 2014, ISSN: 00845841.