Development of an effective design and justification of the parameters of the separation and cleaning section of raw cotton

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Abstract. The article provides an analysis of the existing structural removal of separation and cleaning devices. The constructive diagram and the principle of operation recommended by the separation and cleaning section of the refinery are given. The results of theoretical studies of the law of motion of a part of the fibrous material along the surface of the guide and the trajectory of falling of a part of the fibrous material in the separation zone are presented. The parameters of the system are substantiated. The results of production tests of the recommended design are presented.

1. Introduction
The existing separation and cleaning section of the cleaning shop includes a separator SS-15A, SHH-augers and two parallel cleaning units UKH [1]. The main disadvantage of the known design of the separation and cleaning section of the refinery is the uneven supply of cotton - the raw separator along its working length, the uneven distribution of the raw cotton along the cleaning units of the UKC due to the consistent distribution of cotton, as well as the low effect of cleaning cotton from small and - due to the imperfection of the working bodies of the UKH purification unit. In addition, the design is not possible to use in cluster industries, where a single flow line of cleaning with a capacity of (7 ÷ 8) t / h is advisable.

Figure 1. Separation and cleaning section of the cleaning shop.
Cotton-cleaning unit UKH, consisting of successively installed sections of fine and large cleaning, while the fine cleaning zone includes feed rollers and sequentially installed peg cylinders and mesh surfaces under them. Coarse cleaning zones include two saw cylinders and grates below them. In this case, small and large trash impurities fall into one screw conveyor [2].

The main disadvantage of the cleaner is the low cleaning effect of cotton due to the imperfection of the working parts.

The separator is a chamber divided by a mesh partition into two parts: cotton and air. A guide and a scraper are located in the cotton part, which cleans the raw cotton from the mesh located on the sides and directs it to the vacuum valve. The vacuum valve is designed to unload raw cotton from the separator chamber and create a tightness that prevents outside air from being sucked into the separator chamber through the discharge opening [3,4,5].

The air part of the chamber is limited by a mesh surface on the sides and separator cones. The raw cotton supplied to the separator by the air flow through the branch pipe hits the mesh surfaces installed on the two inner sides of the cotton chamber of the separator. In this case, the speed of the air flow in the separator drops sharply, and the main part of the raw cotton is dumped into the vacuum valve, and a certain part reaches the mesh surface and is dumped by the scraper into the vacuum valve [6]. A significant disadvantage of the known separator is low reliability in operation, due to the fact that during the removal of raw cotton by scrapers, the fiber, pressed by the air flow to the mesh surface, and the seeds are damaged. In addition, the usable area of the mesh surface is limited, which makes it difficult to completely remove part of the cotton.

In the cotton separator - raw material containing a separation chamber with an inlet and outlet nozzles, a perforated end mesh with a scraper installed at the end of the chamber, a vacuum valve with an impeller located in the lower part of the chamber, and a guide mounted at the inlet to the chamber, while at the inlet an upper guide is mounted in the separation chamber, oriented from the inlet to the vertical axis of the end mesh, made composite, including a curved main rigid plate, to which an outer plate and a lower guide are connected through a gasket having an elastically elastic deformation. The disadvantage of the separator is the low effect of air separation from cotton due to the small area of the mesh surface [7].

2. Materials and methods

2.1. Effective design of the cotton separation and cleaning section

In order to increase the continuity and uniformity of the separation of cotton from air in the separator along its length, increase the cleaning effect, ensure the combination of the separator and the cotton purifier, allowing the use in cluster production with a single flow line for cleaning cotton, the design, layout and combination of the separator and the cotton purifier have been improved, design of the elements of the purifier.

The design consists of a separator and a cotton cleaner (see figure 1).

The raw cotton separator consists of a separation chamber 2, on the ends of which mesh surfaces 3 are mounted, having a spherical shape with a radius of \( R = (1.25 \div 1.35) \cdot R_e \) (\( R_e \) is the inner radius of the cylindrical part of the chamber). Clips 5 with elastic blades adjacent to the mesh surfaces 3 are mounted on the drive shaft 4, which are also spherical with a radius \( R \). In the center of the chamber 2 there is an inlet nozzle 1, on the sides there is an outlet nozzle 6. A vacuum valve 7 is installed under the chamber 2. At the bottom of the separator a shaft 8 is installed and further feed rollers 9. The cotton cleaner includes zones of fine cleaning 10 and large cleaning 11 installed in the housing 12. In the fine cleaning zone 10 there are peg cylinders 13 and under them a mesh surface 14 and a debris outlet 15 for fine litter. The coarse cleaning zone 11 includes brush cylinders 16, serrated cylinders 17, a grate 18 under them, a removable brush cylinder 19, and at the bottom a screw conveyor 20 for removing large debris.
The feed rollers 9 are made with different outer diameters, moreover, \( d_1 = 1.2 d_2 \). The pegs 21 of the cylinder 13 are made multifaceted and in the form of a truncated body. In a large cotton cleaning zone, the gaps between the grate 18 and the saw cylinder 17 are made decreasing, while \( \Delta_{in} - \Delta_{out} = 17 - 13 = 4 \text{ mm} \) (minimum seed size), \( \Delta_{in} \) in is the gap between the saw cylinder 17 and the grate 18 in the initial zone of cotton pulling, \( \Delta_{in} \) out is the gap in the outlet part.

The separation and cleaning section of the cleaning shop works as follows. The raw cotton enters the separator through the inlet pipe 1. With the help of the upper and lower guides 4 with a curved working surface, the raw cotton and air are directed to the zone of increased winding of the raw cotton, that is, to the central section of the mesh surface 3. At the same time, mechanical impact on cotton. In addition, the lower guide 4 additionally prevents cotton from falling into the gap between the housing wall and the mesh surface 3. The guide 4 provides continuous and uniform distribution of cotton and air separation from it [8,9].

In this case, the air is sucked out by the pneumatic system through the mesh surfaces 3 and from the outlet 6 is carried outside the separator. The raw cotton hits the mesh 3, the speed of the air flow sharply feeds and the bulk of the raw cotton falls into the vacuum valve 7, and some of it settles on the mesh surfaces 3. It should be noted that due to the implementation of mesh surfaces 3 spherical with a radius \( R = (1.25 \pm 1.35) \cdot R \), the working surfaces of the meshes 3 are increased. This allows air suction through the meshes 3 without braking. The rotating shaft 4 sets in motion the paper clips 5, which, by moving the cotton flakes deposited on the spherical mesh surfaces 3, direct them into the vacuum valve 7. At the same time, due to the spherical shape of the mesh surfaces 3, the amount of raw cotton deposited on them will be evenly distributed and therefore their pull from the mesh 3 holes will not be difficult [10].

At the same time, the damage to the raw cotton fibers will be significantly accommodated and the reliability of the separator will increase. Further, from the vacuum valve 7 through the shaft 8, cotton enters the feed rollers 9. To eliminate the bottom in the feed zone, the left feed roller 9 rotates with a higher linear speed of their blades relative to the linear speed of the blades of the right feed roller 9. In the fine cotton cleaning zone, tapered polyhedral pegs 21 of cylinders 13 capture cotton, pulling them along the mesh surface 14, loosen. In this case, small trash impurities are removed by the variety breeder 15 separately from the large litter.

In the zone of coarse cleaning of cotton, the brush cylinders 16 transport cotton, which falls on the saw cylinders 17. The teeth of the saws of the cylinders 17, grabbing the cotton tapes, are dragged along the grate bars 18. In the initial cleaning zone, the cotton will be less loosened and therefore the gap between the saw cylinder 13 and the grate 18 is selected large \( \Delta\delta_{in} = 17 \text{ mm} \), and in the exit zone \( \Delta\delta_{out} = 14 \text{ mm} \). This ensures effective separation of trash impurities.

The design provides effective separation of cotton from air, combined operation of a separator and a purifier, and allows an increase in the cleaning effect of cotton from small and large litter, as well as the use of the recommended design in cluster production.

2.2. Analysis of the movement of a cotton particle along the curved surface of the separator guide

The design diagram of a particle with a curved guide surface is shown in figure 2.

The forces act on the cotton particle: \( \vec{G} \) - weight force, \( \vec{N} \) - reaction force, \( \vec{F}_b \) - air force (blowing flow), \( \vec{F}_f \) - friction force between the cotton particle and the guide surface.

Using the Lagrange equations of the second kind, we obtain:

\[
\begin{align*}
mx &= F_b \cos \beta - F_f + G \sin \alpha \\
my &= G \cos \alpha - F_b \sin \beta - N
\end{align*}
\]
When a cotton particle interacts with a surface guide, its movement along the y axis will be limited, because a cotton particle in this zone will contact the surface, i.e. $y = 0$.

Then the second equation of the system takes the following form.

$$N = G\cos \alpha - F_b \sin \beta$$

(2)

With stage given

$$G = mg; \quad F_b = kv^2$$

And substituting (2) into (1) we have

$$m\ddot{x} = mg \sin \alpha + kv_b \cos \beta - f\left(\frac{mg \cos \alpha - kv^2 \beta}{f}\right)$$

(3)

Where, $m$ is the mass of a cotton particle; $g$ acceleration of gravity; $kv_b$ is the air speed; $\alpha$ is the angle between the force vector and the y axis; $\beta$ is the angle between the vectors of the air blowing force and the x axis; $f$ is the coefficient of friction between the cotton and the surface of the guide.

Using the well-known analytical method according to [10], an expression was obtained to determine the law of motion of a cotton particle along the x axis:

$$x = \frac{1}{kv^2_b (f \sin \beta - \cos \beta)} \ln \left\{ \frac{g f - kv^2_b (f \sin \beta - \cos \beta)}{g (f \sin \alpha + \cos \alpha) - kv^2_b (f \sin \beta - \cos \beta)} \right\}$$

In this case, the speed of movement of the cotton particle is determined taking into account $x = R\sin \beta$:

$$v = \sqrt{\frac{g (\sin \alpha + f \cos \alpha) - kf - kv^2_b (f \sin \beta - \cos \beta)\beta - R \sin \beta (f \sin \beta - \cos \beta)}{f \sin \beta - \cos \beta}}$$

Figure 3 shows the graphical dependences of the change in the velocity of the release of a cotton particle when leaving contact with a curved surface on the change in the speed of the supplied air. The analysis of the graphs shows that with an increase in the air speed, the velocity of the cotton particles emerging increases according to a nonlinear pattern. It should be noted that a change in the moisture...
content of the original cotton leads to a change, not only in the mass of cotton particles, but also in an increase in the coefficient of friction. The higher the coefficient of friction, the lower the speed of cotton emergence (see figure 3, a, b, c; curves 1,2,3). The location of the cotton particles in the initial zone of interaction with the surface of the guide is important. In this case, the larger the angle α, the larger (see figure 3, c) \( v_x \). An increase in the radius of the surface of the guide of the separator also leads to an increase in the speed of the outflow of cotton particles. This is explained by the fact that with an increase in R, the surface also approaches the plane, this leads to a decrease in the deceleration of cotton particles (see figure 4, curves 1, 2, 3).

An increase in the coefficient of friction leads to a decrease in the velocity of the height of the cotton particles (see figure 5).

The recommended values of the system parameters are \( f \leq 0.35 \), \( m \leq (0.3 \div 0.4) \cdot 10^{-3} \text{ kg} \), \( v_b = (0.2 \div 0.25) \cdot 10^2 \text{ m/s} \), \( R = (0.6 \div 0.85) \text{ m} \).

3. Results and discussion

3.1. Results of comparative production tests of a separator - cotton cleaner

Based on the substantiated parameters of the separator, a prototype of the structure was designed and manufactured. Comparative production tests of the separator were carried out.

Figure 3. Graphically, the dependence of the change in the speed of emission of the cotton particle when it comes out of contact with the surface will be directed from the change in the speed of the supplied air.
Figure 4. Graphically, the dependence of the change in the velocity of emission of a cotton particle when it comes out of contact with the surface will be directed from the change in the radius of curvature of the guide.

\[ \begin{align*}
1 & \text{ at } f = 0.35, \quad a \text{ at } a = 20^\circ, \\
2 & \text{ at } f = 0.30, \quad b \text{ at } a = 35^\circ, \\
3 & \text{ at } f = 0.25, \quad c \text{ at } a = 45^\circ.
\end{align*} \]

Figure 5. Regularities of the change in the speed of emission of a cotton particle from a curved surface on the ruler from a change in the coefficient of friction.

![Graph](image1)

![Graph](image2)

Table 1. The test results are presented.

| Cotton grade | Mechanical damage to seeds, % | Analysis of pollution and moisture content of cotton, % |
|--------------|-------------------------------|-------------------------------------------------------|
|              | CC-15A                        | Improved separator                                    |                                                      |
| I            | 1.32                          | 1.08                                                  | C=2.05, W=8.6                                        |
| II           | 1.41                          | 1.21                                                  | C=2.05, W=8.6                                        |
| III          | 1.52                          | 1.38                                                  | C=3.98, W=10.92                                      |
| IV           | 2.07                          | 1.87                                                  | C=6.8, W=13.5                                        |
| V            | 3.38                          | 2.57                                                  | C=11.4, W=16.5                                       |

Analysis of the data in Table 1 shows that in the recommended separator, the surface of the seeds is reduced to (0.30 ÷ 0.35) %, and the weeds in cotton fit up to 20%.

4. Conclusions

A new design scheme of the separator - cotton cleaner has been developed. The parameters of the separator have been substantiated by theoretical studies. The results of comparative production tests have determined the efficiency of using the recommended design.

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