

Theoretical study of the influence of the length of the spike on the cleaning effect of the fine litter cleaner

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Abstract. In the article, a schematic diagram and principle of operation of the recommended raw cotton cleaner from fine litter are provide. The article presents the results of theoretical studies of the effect of the length of the pegs on the cleaning effect of the raw cotton cleaner. Based on the study of the law of movement of raw cotton on the surface of the splitter, graphical dependences of the change in the length of the splitter on the change in the mass of cotton are constructed. Substantiation of the length of the drum heads of the corresponding areas for cleaning cotton from fine litter.

1 Introduction

Recently, several regionalized varieties of raw cotton have been grown in the Republic of Uzbekistan. Therefore, based on the selection varieties and the type of raw cotton harvest, the mode of cleaning the raw cotton is relevant. The choice of the cleaning mode for raw cotton includes the initial contamination, selection and industrial varieties, and the type of harvest. It is known that in the ginning industry for cleaning raw cotton, basic technological machines are used, such as IHK for cleaning raw cotton from small trash impurities, as well as a combined unit for cleaning raw cotton, UHK, in which both cleaning from small and large trash impurities [1].

From the analysis of the studies carried out in the United States of America and other countries growing raw cotton [2-5], it can be seen that foreign researchers studied the issues of improving the designs of purifiers, their working bodies, the rotation speed of the working bodies, and so on. And also for cleaning raw cotton, a cleaner is used, which contains a cylindrical shell with strips and pegs fixed on them, installed in longitudinal rows [6].

There are a number of studies in which some design solutions have been developed to increase the cleaning effect. For example, the author [7, 8] has developed a peg drum with elastic elements. Due to the vibrational movement of the splitter, additional shaking of the raw cotton occurs, the cleaning effect is increased due to the vibration of the splitters with a certain frequency and amplitude. At the same time, the influence of rigidity on the fastening of the heads of the raw cotton cleaner on the cleaning effect was determined [9].

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A.A.Safayev [10] carried out studies to improve the cleaning effect of cleaning raw cotton of fine-fibre varieties, with the improvement of shock-loosening devices of the fine litter cleaner. Research carried out by R.V.Korabelnikov and Kh.I.Ibrogimov [11] found that in order to reduce damage to seeds and entanglement of fibers during cleaning, splitting cleaners should be installed at the beginning of the technological process. And also in gin feeders, raw cotton is purified from weeds using peg drums [9-11].

In the existing cleaners of raw cotton from small trash impurities, the design of the pegs consists of eight identical drums, which, the diameter of the pegs is 400mm, the length of the pegs is 50mm, and the diameter is 12 mm.

2 Materials and Methods

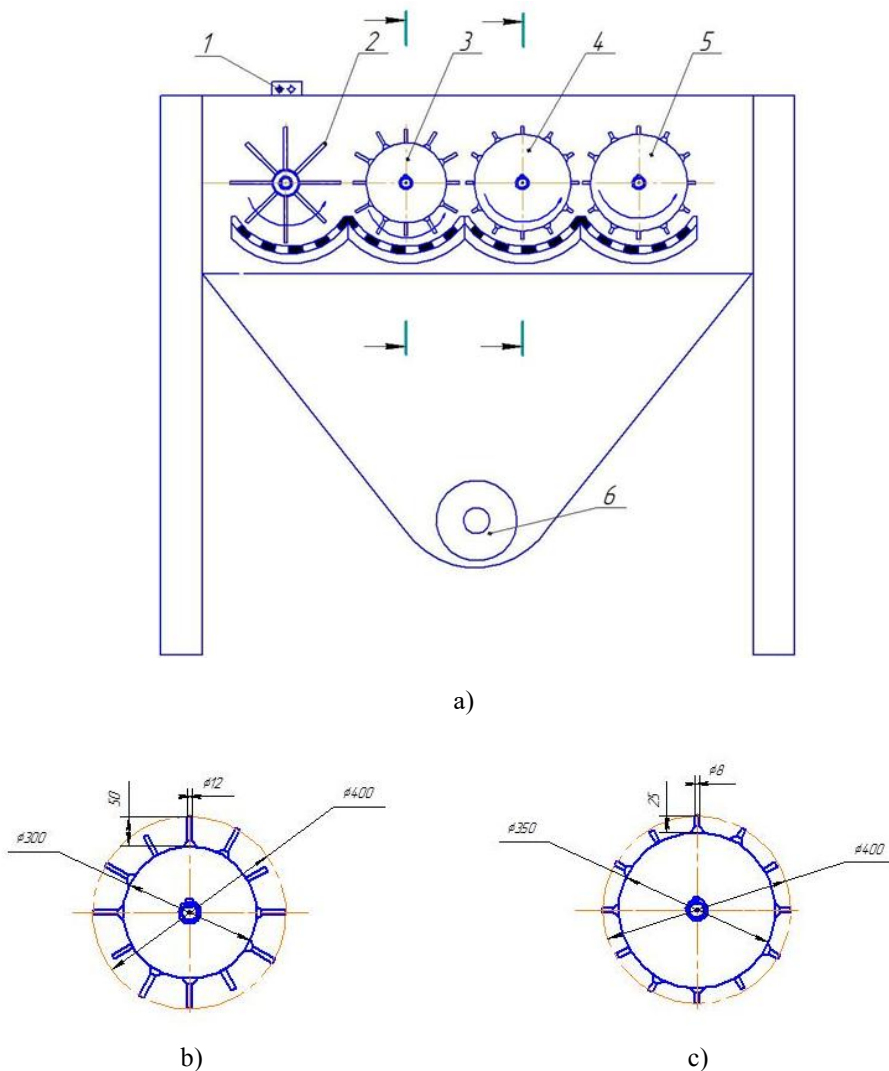


Fig. 1. Raw cotton cleaner: 1-feeder; 2-bar drum; 3-series peg drum; and, 4-5-suggested peg drums

The proposed design of the cleaner has drums with loosening elements of different heights, installed in groups of several identical drums in a row, and the first groups for raw cotton are sequentially docked with each other as the height of the loosening elements above the shaft or shell decreases, and in the latter, along the flow of raw cotton the group used ripping drums, made in the form of squirrel wheels in the direction of movement of raw cotton, the speed of rotation of the ripping drums in the group increases by 5% [11].

The design of the cleaner is shown in Fig. 1, showing a general view of the raw cotton cleaner. The raw cotton cleaner (Fig. 1a) consists of a feeder, a bar drum, a peg drum of a serial type, two drums (Fig. 1b) with pegs height and auger for removing trash (Fig. 1c). The splitting height of the serial peg drum is 50 mm, and in the proposed design (Fig. 1) 25 mm, the splitter diameter is 8 mm.

The cleaner works as follows. When the loosening drum rotates, the pegs interact with the raw cotton, capture and drag them along the mesh surface. At the same time, the forces of resistance to movement from raw cotton act on the splits. Drums with loosening elements of height l are installed over mesh surfaces. Due to a decrease in the height of the loosening elements above the shaft or shell, and in the last group along the course of movement of raw cotton, the leveling drums made in the form of squirrel wheels in the direction of movement of raw cotton, the rotation speed of the loosening drums in the group increases by 5%.

3 Results and Discussion

At a height from the splitting surface $h=Ha$ the following forces act on the raw cotton volatiles (Fig. 2):

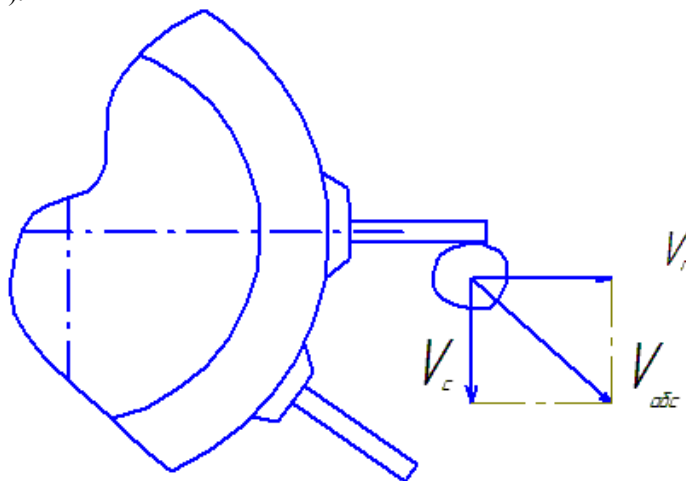


Fig. 2. Diagram of the movement of the raw cotton fly

In this case, the absolute speed of the flyout is determined from the expression [18]:

$$V_{aoc} = \sqrt{V_r^2 + V_c^2} \tag{1}$$

where: V_{aoc} - absolute speed, m/sec; V_r - normal speed, m/sec; and, V_c - tangential speed, m/sec.

A diagram of the movement of a raw cotton fly in section AB is shown in Fig. 3. Forces acting in the AB section on the flyout:

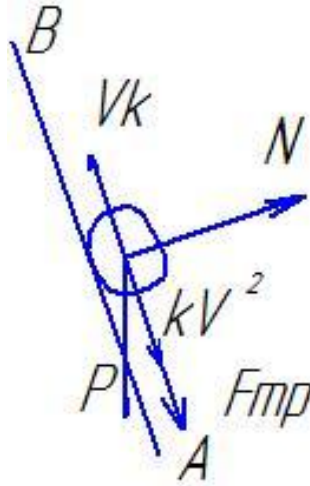


Fig. 3. Diagram of the forces acting on the section AB of the mesh surface of the cleaner
 Air resistance force, reaction force, friction force, weight force. Wherein:

$$k = Fc \frac{\gamma}{2\varphi}$$

where, $F = \pi R^2$; F - leafjet cross-sectional area, m^2 ; c - coefficient; γ - air weight, kg ; and, g - free fall acceleration, m/sec^2 .

According to the equilibrium condition of the raw cotton fly in the AB zone, we obtain an expression for determining the speed of the fly:

$$V_x = \sqrt{\frac{P(\sin \alpha + f \cos \alpha) \left(1 - e^{\frac{2kx}{m}} \right) + kV_x^2}{ke^{\frac{2kx}{m}}}} \quad (2)$$

Let us write the differential equation of motion of the raw cotton fly on the section AC of the mesh surface:

$$ma_c = -P \sin \alpha - kV_c^2 \quad (3)$$

After multiplying equation (1) by dx , we get the following expression:

$$\int \frac{mV_c dV_c}{P \sin \alpha + kV_c^2} = - \int dx_2 \quad (4)$$

Differentiating equation (4), we obtain:

$$-\frac{m}{2k} \ln(P \sin \alpha + kV^2) = x_c + c_1$$

Taking into account the initial conditions, we define the constant integration [19]:
 $t=0 \quad V_c=V_x \quad X_c=0$

$$C_1 = -\frac{m}{2k} \ln(P \sin \alpha + kV_x^2)$$

Velocity of the raw cotton fly at point C of the mesh surface of the cotton cleaner:

$$V_c = \sqrt{\frac{P \sin \alpha + kV_x^2 - P \sin e^{\frac{2kx}{m}}}{ke^{\frac{2kx}{m}}}} \tag{5}$$

In this case, the equation of motion of the raw cotton fly along the cleaning arc has the form [20]:

$$y_d = g \frac{m_d^2}{V_\sigma^2 k_d^2} \left(-e^{\frac{x_d k_d}{m_d}} + 1 \right)^2 \tag{6}$$

Based on the results of experimental studies, graphical dependences of the change in the effect of cleaning cotton on the change in the frequency of rotation of the peg drum at different heights of the pegs were built, which are shown in Fig. 4. From the analysis of the graphs it can be seen that with an increase in the rotational speed, the cleaning effect increases linearly. In this case, an increase in the length of the splitter leads to a slight increase in the cleaning effect. This is because long tuning pegs tend to interact more with cotton.

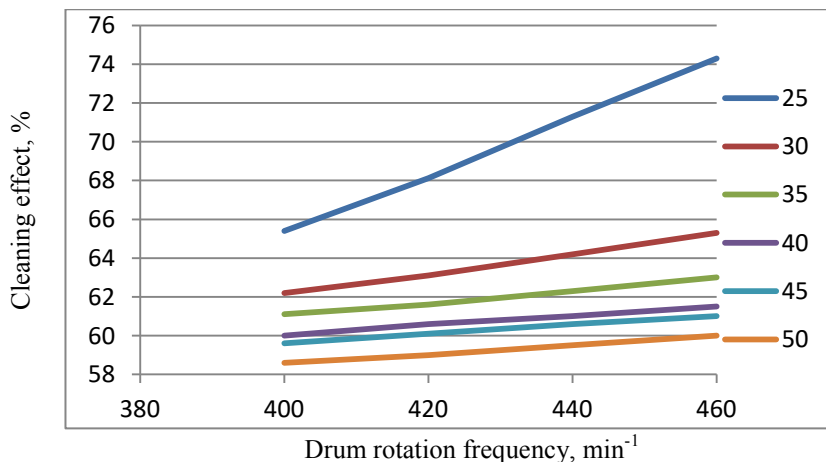


Fig. 4. Dependences of the change in the cleaning effect on the drum rotation frequency

During the operation of the cleaner, depending on the looseness of the raw cotton in each drum, a certain height of the picks is selected. Fig. 5 shows the design diagram of the movement of a cotton bat on a drum splitting:

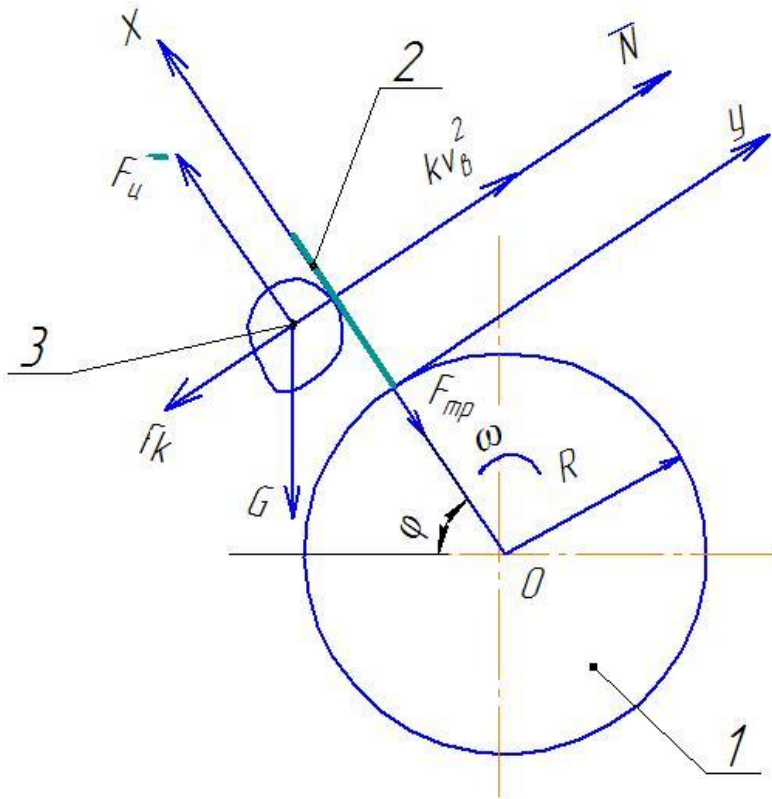


Fig. 5. Calculated scheme of the movement of a cotton bat on a drum splitting: 1-drum; 2-peg; and, 3-cotton flyer

According to the design scheme, it can be noted that the following forces act on the flyer; \bar{G} - weight force; \bar{F}_c - throttle force; F_{fr} - friction force of the flywheel on the splitting surface; N- reaction force; F_k - Caryolis force; kv_B^2 – air flow resistance.

According to the design scheme, we will compose the equations of motion, taking into account the d'Alembert method [11]:

$$\begin{aligned} m\ddot{x} &= -G\sin \alpha - F_{ff} + F_c \\ m\ddot{y} &= N - F_k \mp kv_B^2 - G\cos \alpha \end{aligned}$$

Considering that the movement of the fly along the Y axis will not, $y=0, \dot{y} = 0$ and considering that:

$$G = mg; F_c = m\omega^2 (R + x); F_B = kv_B^2; F_k = 2m\omega\dot{x}; F_{tp} = fN$$

we obtain from the equation above we obtain;

$$N = 2m\omega\dot{x} - kv_B^2 + mg\cos\alpha \tag{7}$$

Putting (7) into (6) we have:

$$m\ddot{x} = mg\sin\alpha + m\omega^2(R + x) - 2mf\omega\dot{x} + fkv_B^2 - fmg\cos\alpha \quad (8)$$

where, f - coefficient of friction of the fly on the splitting surface; m - the mass of the fly; k -coefficient of air flow resistance; α - the angle between the vector of the weight force and the X-axis; ω - drum angular velocity; R -radius of the drum; and, V_B - air flow rate.

The general solution according to the technique given in [19] is obtained in the form:

$$x = \left[\frac{fkRv_B^2}{mv^2} + \frac{(1-f^2)g}{2(1+f^2)\omega^2} - \frac{\left(R + \frac{(1-f^2)g}{2(1+f^2)\omega^2} - \frac{fkRv_B^2(f+\sqrt{f^2+1})}{mv^2} \right)}{2f} + \frac{g}{2(1+f^2)\omega^2} \right] * e^{-\omega t(f+\sqrt{f^2+1})} + \left[\frac{\left(R - \frac{(1-f^2)g}{2(1+f^2)\omega^2} - \frac{fk}{m\omega^2 v_B^2(f+\sqrt{f^2+1})} \right)}{2a} \right] e^{-\omega t(f+\sqrt{f^2+1})} + \frac{g}{(1+f^2)\omega^2} \left[f\sin\omega t - \frac{(1-f^2)}{2}\cos\omega t \right] \quad (9)$$

Analysis of the general solution to Equation (9) shows that the first two terms in the equation tend to zero with time. Therefore, the solution of the movement of the cotton bat along the splitting point was carried out in (9) only for the third term. The numerical solution was carried out taking into account the following values of the parameters:

$$m=(0.22\div0.26)*10^{-3} \text{ kg}; \omega=(4.2\div4.8) 10^{-1} \text{ sec}; R=(0.16\div0.2) \text{ m}; g=9.81 \text{ m/sec}^2; \\ f=0.25\div0.35; e=2.72 V_B=(0.35\div0.75)*10 \text{ m/sec}; k=0.8\div0.93.$$

By a numerical solution, graphical dependences of the change in the displacement of the cotton bat on the drum splitting were plotted depending on the weight of the bat (Fig. 5).

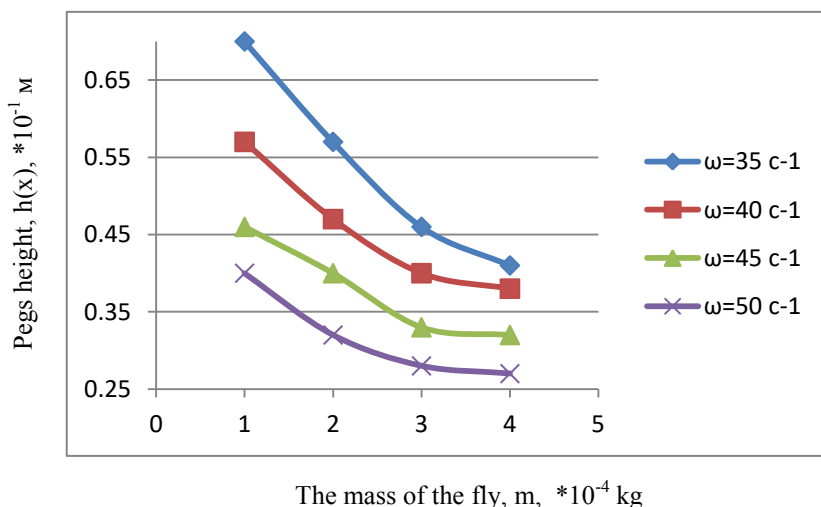


Fig. 5. Theoretical dependences of the change in the mixing values of a part of the cotton on the splitting of the drum on the change in its mass and the drum rotation frequency

Analysis of the obtained dependences in Fig. 5 shows that with an increase in the mass of the raw cotton particle by the drum splitting it leads to a decrease in the displacement values $h(x)$ along the drum splitting according to a nonlinear pattern. In case $\omega=35\text{c}^{-1}$ with an increase in the weight of cotton from 0.22g to 0.51g, the values of cotton displacement along the splitting from $0,41\cdot 10^{-1}$ m till $0,27\cdot 10^{-1}$ m by nonlinear regularity (see Fig. 6, graph 1). So, with an increase in the frequency of rotation of the peg drum up to 50 s^{-1} , the value of the mixing of cotton particles along the splitting of the drum decreases from $0,72\cdot 10^{-1}$ m till $0,424\cdot 10^{-1}$ m by nonlinear regularity. This is due to the fact that with an increase in the mass of cotton, its movement along the splitting becomes more difficult. With an increase in the frequency of rotation of the peg drum due to the inertial force, the value of h increases. According to the results of experimental data [15], in the zone of the first peg drum, the cotton mass is within $(0.55\div 0.85)\cdot 10^{-3}$ kg, and in the zone of the fourth peg drum, the cotton mass is within $(0.22\div 0.45)\cdot 10^{-3}$ kg. Therefore, at the frequency of the peg drum $(40\div 45)\text{ s}^{-1}$, the height of the pegs of the first drum should be selected $h\geq 0.7\cdot 10^{-1}$ m, the height of the pegs of the second drum within $h=(0.5\div 0.7)\cdot 10^{-1}$ m, the third drum $h=(0.40\div 0.45)\cdot 10^{-1}$ m, and the fourth output drum $h=(0.25\div 0.35)\cdot 10^{-1}$ m cotton seeds.

4 Conclusions

A new efficient design of a cotton cleaner has been developed. On the basis of theoretical studies, the values of the length of the pegs of the cleaner have been substantiated, taking into account the degree of looseness of the cotton and the frequency of rotation of the drums.

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