Features of picking cotton from the spindles of a vertical-spindle cotton picker with their variable kinematic modes

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Abstract. The paper considers the problem of increasing the efficiency of removing cotton from the spindles of vertical-spindle devices. The possibility of increasing the time of action of the stripper on the winding of cotton in the process of removing cotton from the spindles using an elliptical spindle drum based on a planetary-cam-lever mechanism is shown. Universal analytical expressions have been obtained to determine the limit and time of interaction of the stripper and the spindle with elliptical and circular trajectories of the spindle, the numerical experiment of which has carried out a comparative analysis of the work of the cotton picker in the area of picking cotton from the spindles. Some advantages in the operation of an elliptical drum in the removal zone are shown.

1. Introduction

The effectiveness of the puller: a vertical-spindle cotton picker in practice is estimated by counting the percentage of cotton removed from the spindles, relative to the total mass of cotton wound on the spindle in the collection zone.

As it is known, when the spindle passes by the stripper, its brushes process a certain part of the cotton winding and remove it from the spindles, therefore, from the point of view of theory, the removal efficiency is estimated by the magnitude of the impact zone of the stripper brushes on the winding. In many works of the 70-80s of the last century, devoted to the study of cotton picking from spindles, the size of the impact zone was determined by the central angle on the spindle, within which the brush strips act on cotton [1, 2] and research work on cotton pickers is also ongoing [3-7].

From a theoretical point of view, these provisions, in essence, reflect the process of interaction of the puller with the cotton wound on the spindle. Previously developed graphic, graphic-analytical and Analytical methods for assessing the efficiency of removal allow, to a certain extent, to objectively evaluate the work of the remover in relation to the parameters of other organs. However they are useful only when studying the process of picking cotton from the spindles of a serial-round drum.

2. Methods

When analyzing the interaction of the stripper brushes with cotton winding, the authors of [1, 2], the initial and final stages of interaction, rightly consider the point of contact of the conditional circles of the stripper and the cotton winding, respectively, when entering and exiting from the impact of the stripper (Fig. 1, points A and B). With such a scheme, it is easy to determine the position of the spindle, which corresponds to the initial and final stages of the impact of the stripper on the winding.
With a non-circular trajectory of the spindle relative to the apparatus, the picture of the interaction of the stripper on winding cotton changes somewhat and this can significantly affect the course of the process of removing cotton from the spindles [8].

It should be noted the variability of the kinematic parameters of the main drum links and some other technical systems based on lever and cam-lever mechanisms. A large number of works have been devoted to the kinematics of such mechanisms. However, we note the works [9-11], where effective algorithms were obtained for calculating the kinematic and geometric parameters of the actuator.
Figure 2. Determination of the zone of impact of the stripper on winding cotton in an elliptical drum

In [10], a method is proposed for determining the speed and acceleration of the spindle center in an elliptical drum, which takes into account not only the variability of speed modes, but also the variability of the radius of curvature of the spindle trajectory. This provision must be adopted in this work.

The determination of the impact zone of the stripper on winding cotton in an elliptical drum. We determine the position of the spindle corresponding to the initial and final stages of the impact of the stripper on the winding, when the spindle in relative motion describes an ellipse with the canonical equation

\[ y = b \cdot \sqrt{1 - \frac{x^2}{a^2}} \]  

where \( a \) and \( b \) are the major and minor semiaxes of the ellipse.

In this case, we assume that the cotton is wound on the spindle in a ring-shaped manner and the stripper has a cylindrical surface.

As it can be seen from the diagram (Figure 2), when the conditional circles of the removable drum and cotton winding come into contact at points A and B,

\[ c = O_mO_c = (r_m + H) + r_c - \Delta \]  

where \( r_m \) and \( r_c \) are the radii of the spindle and stripper; \( H \)-thickness of cotton winding; \( \Delta \)-value of the deepening of the stripper brushes between the spindle teeth, \( \Delta = 1 \div 1.5 \) mm.

In other positions, the distance \( c \) takes on the values

\[ c < (r_m + H) + r_c - \Delta \]  

(3)
The minimum distance between the centers of the stripper and the spindle is obtained when \( H = 0 \), and other.

\[
c_{\text{min}} = r_w + r_c - \Delta \tag{4}
\]

Therefore, the task is reduced to determining such spindle positions when condition (2) is satisfied. For a straight line segment with at this time, we can write

\[
(x - x_c)^2 + (y - y_c)^2 = c^2 \tag{5}
\]

where \( x \) and \( y \) are the coordinates of the spindle center on the elliptical drum; \( x_c \) and \( y_c \) - coordinates of the stripper center,

\[
\begin{align*}
x_c &= L \cdot \cos \mu_c \\
y_c &= L \cdot \sin \mu_c
\end{align*} \tag{6}
\]

\( L = O_w O_c \)-distance between the centers of the stripper and the origin of the coordinate system (center of the spindle drum); \( \mu_c \)-angle that defines the position of the stripper relative to the abscissa axis.

Taking into account expressions (6) and (1), equations (5) takes the form

\[
(x - L \cdot \cos \mu_c)^2 + \left( b \cdot \sqrt{1 - \frac{x^2}{a^2}} - L \cdot \sin \mu_c \right)^2 = c^2 \tag{7}
\]

After some modifications, we get an equation of the fourth degree for \( x \):

\[
A^2 x^4 - 4 A^3 x^3 A \cdot a^2 \cdot L \cdot \cos \mu_c + 2 A^2 \cdot \left[a^2 \cdot (B + L^2) \cdot A + 2 \cdot a^4 \cdot L^2 \cdot \cos^2 \mu_c + a^4 b \cdot L \cdot \sin \mu_c - 2 A \cdot a^4 L \cdot (B + L^2) \cdot \cos \mu_c + a^4 \cdot (B + L^2)^2 - 2 a^4 a^2 b \cdot L \cdot \sin \mu_c \right] = 0 \tag{8}
\]

Where \( A = a^2 - b^2; \ B = b^2 - c^2 \).

From Figure 2 we define \( L = L(\theta) \) and \( \mu_c = \mu_c(\theta) \).

For the sake of brevity, condition (4) is called “central,” which is shown in the diagram by the angle \( \theta \). In a serial cotton picker, when the spindle reaches the “central” position, the axis of the drum, spindle and stripper lie on the same line (Figure 1).

When the spindle center describes a line that differs from the circle, condition (4) is achieved when the circle of the stripper, the spindle and the curve along which the spindle center moves have a common normal \( n - n \).

Of \( O_w O_m O_c \)

\[
L = \sqrt{\rho^2 + (r_c + r_w - \Delta)^2 - 2 \cdot \rho (r_c + r_w - \Delta) \cos(\alpha - \theta)} \tag{9}
\]

where \( \rho \) is the radius of the ellipse vector; \( \alpha \) is the angle of inclination of the normal \( n - n \), determined from the expression

\[
\tan \alpha = \frac{y - y_a}{x - x_a} \tag{10}
\]
where $x_u$ and $y_u$ are the coordinates of the center of curvature of the ellipse at the point $O_{in} (x_0, y_0)$ [10]:

$$x_u = \left(a - \frac{b^2}{a}\right) \cdot \cos^3 \varphi$$

$$y_u = \left(b - \frac{a^2}{b}\right) \cdot \sin^3 \varphi$$

(11)

where $\varphi$ is the parameter of the ellipse associated with the angle $\theta$ by the expression

$$\varphi = \arctan \left(\frac{a}{b} \cdot \tan \theta\right)$$

(12)

Taking into account (11) and (12), formula (10) can be written

$$\alpha = \arctan \left(\frac{y - \left(b - \frac{a^2}{b}\right) \sin \varphi \arctan \left(\frac{a}{b} \tan \theta\right)}{x - \left(a - \frac{b^2}{a}\right) \cos \varphi \arctan \left(\frac{a}{b} \tan \theta\right)}\right)$$

(13)

Then formula (9) takes the form

$$L = \sqrt{\rho^2 + (r_c + r_{in} - \Delta)^2 - 2 \cdot \rho (r_c + r_{in} - \Delta) \cos \left(\arctan \left(\frac{y - \left(b - \frac{a^2}{b}\right) \sin \varphi \arctan \left(\frac{a}{b} \tan \theta\right)}{x - \left(a - \frac{b^2}{a}\right) \cos \varphi \arctan \left(\frac{a}{b} \tan \theta\right)}\right) - \theta\right) - \theta}$$

(14)

The angle $\mu_c$ is also determined from Fig. 2,

$$\mu_c = \theta + \mu^*$$

(15)

where $\mu^*$ is the angle between the polar radius and the straight line connecting the centers of the stripper and the spindle drum; from $\Delta O_{in}O_{n}O_c$

$$\mu^* = \arccos \frac{t^2 - \rho^2 - (r_c + r_{in} - \Delta)^2}{2t \rho L}$$

(16)

Together, solving equations (8) and (1), we determine two pairs of roots $x_n, y_n$ and $x_k, y_k$ for each position of the stripper. One of the pairs of roots $(x_n, y_n)$ defines the coordinates of the spindle center, corresponding to the beginning of the stripper impact on the winding, and the second $(x_k, y_k)$ to the end.

Numerically solving equation (8), it is possible to determine for each position of the puller, the common boundaries (coordinates of the spindle center) within which, the puller brushes process the winding of cotton, which makes it possible to study the influence of various factors on the removal of cotton from the spindles during contact with the puller.

Duration of the puller’s exposure to cotton. The winding of cotton, passing near the stripper, is under the influence of the stripper for a certain time. The estimated residence time of cotton under the influence of the puller in a serial device is within 0.05-0.06 sec [1, 8, 9], which in some cases is not enough time to completely release the cotton from the spindle [2].

It is necessary to note that the analysis of the operation of the apparatus with elliptical drums showed (that at different angles of the location of the strippers relative to the drum, it should be noted
that the residence time of the cotton in the contact zone with the stripper), the residence time of the cotton in this zone has different values.

As it can be seen from the diagram (Fig. 3), the stripper acts on the winding within the line bounded by the points $O_{m}^{h}$ and $O_{m}^{n}$, which corresponds to the positions of points $D_{1}$ and $D_{2}$ of the crank rotating at a constant angular velocity $\omega_{1}$.

The angle of rotation of the crank from position $D_{1}$ to position $D_{2}$ can be determined as:

$$\psi_{1,2} = \psi_{2}(\theta) - \psi_{1}(\theta) = \omega_{1} \cdot t$$

(17)

where $\psi_{1}(\theta)$ and $\psi_{2}(\theta)$ are the angles of the crank position, correspond to the beginning and end of the impact on the cotton winding; $\omega_{1}$ is the time of turning the crank at an angle $\psi_{1,2}$.

Theoretical time of action of the puller on winding cotton on one spindle

$$t = \frac{\psi_{2}(\theta) - \psi_{1}(\theta)}{\omega_{1}}$$

(18)

From Figure 3.

$$\psi_{1}(\theta) = \theta_{n} + \arccos \left( \frac{r^2 + \rho_{1}^2 + t^2}{2r\rho_{2}} \right)$$

$$\psi_{2}(\theta) = \theta_{k} + \arccos \left( \frac{r^2 + \rho_{2}^2 + t^2}{2r\rho_{1}} \right)$$

(19)

where $\theta_{n}$ and $\theta_{k}$ are the angles of the spindle center position, correspond to the beginning and end of the impact of the stripper on the winding:

Figure 3. Scheme for determining the impact time of the stripper on winding cotton in an elliptical drum

$$\theta_{n} = \arctan \frac{y_{n}}{x_{n}}, \quad \theta_{k} = \arctan \frac{y_{k}}{x_{k}}$$
\( \rho_n, \rho_k \) - polar radii, determine the position of the center of the spindle, which corresponds to the beginning and end of the impact; \( r \) and \( l \) are the lengths of the crank and the connecting rod of the elliptical drum mechanism.

Taking into account (19), the time interval of the impact of the stripper on winding cotton on one spindle, depending on the angle of the stripper position, corresponds to:

\[
t = \frac{(\theta_k - \theta_n) + \left( \arccos \frac{r^2 + \rho_k^2 + l^2}{2r \rho_k} - \arccos \frac{r^2 + \rho_n^2 + l^2}{2r \rho_n} \right)}{\omega_1}
\]  

(20)

From this it follows that for \( \rho_k = \rho_n \) formula (20) takes the form

\[
t = \frac{\theta_k - \theta_n}{\omega_1}
\]  

(21)

Figure 4 shows the results of the machine calculation of the impact time of the stripper on cotton in the form of the dependence \( t = f(\mu_c) \) for a given conditional winding thickness within \( H = 0 \div 20,0 \) mm. The angle of installation of the stripper relative to the longitudinal axis of the elliptical drum changed within \( \mu_c = 0 \div \pi \).

The purpose of comparing the time spent by cotton in the contact zone, with a stripper in the apparatus, with serial elliptical drums is the number of revolutions of the drum shaft and the dimensions of the remaining structural elements of the apparatus included in the formula (20) are taken equal to the serial one:

\[ b = 0,146 \ m; \ \omega_1 = 105,0 \ \text{turnover/minutes}; \ r_e = 0,05 \ m; \ r_w = 0,012; \ \Delta = 0,001 \ m. \]

Semi-major axis \( a \) varies within \( 0.175 \div 0.205 \) m every 15 mm.

Figure 4. Change in the time of action of the stripper on the winding on the spindle in elliptical and serial drums, depending on the relative position of the stripper: 1–\( a = 0,175 \) m; 2–0,190 m; 3–0,205 m;

From the obtained dependences it can be seen that the residence time of the cotton winding on the spindle in the elliptical drum in the contact zone with the stripper is strongly dependent on the angle of the latter. So, when the stripper is installed about \( \mu_c = \pi / 3 \), the duration of the spindle being in the
contact zone with the stripper in an apparatus with elliptical drums reaches its maximum, and it is more than the serial one, angle which is about $\mu_c = \frac{5\pi}{6}$ minimum, much less than the serial one. In this case, it is necessary to take into account the influence on this parameter of the magnitude of the semi-major axis (with a fixed value of the semi-minor axis $b=0.146$ m), as well as the thickness of the cotton winding located on the spindle.

One of the ways to increase the completeness of the removal of cotton from the spindles with a puller is to increase the time spent on the spindle with the cotton winding under the influence of the puller [9].

To assess the difference in the duration of the spindle in the contact zone of the cotton with the stripper in elliptical and serial drums, we denote the difference in percentage:

$$\Delta \tau = \frac{\tau_e - \tau_s}{\tau_s} \times 100\%$$

where $\tau_e$ and $\tau_s$ are the duration of the stay of the spindle in the contact zone of the cotton with the stripper, respectively, in the elliptical and serial drums, are determined by formulas (20) and (21).

Using formulas (20), (21), and (22), a numerical experiment was carried out to determine $\Delta \tau$ at various values of the major semiaxis: $a=0.175$ m, 0.190 m, 0.205 m and with a winding thickness $H=0$ and $H=20.0$ mm.

From the analysis of the results of a numerical experiment, it follows that by using an elliptical drum on a cotton picking machine, by installing a stripper relative to the longitudinal axis of the drum with an angle $\mu_c = \frac{\pi}{6} + \frac{5\pi}{12}$, it is possible to increase the spindle dwell time under the influence of the stripper.

3. Conclusion

We note the significant influence on the exponent $\Delta \tau$ of the value of the major semiaxis of the ellipse $a$. So, in the absence of winding on the surface of the spindle ($H=0$) and with $a=0.175$ m; 0.190 m; 0.205 m and $\mu_c = \frac{\pi}{3}$ we can reach $\Delta \tau=20.5%$; 26.3%; and 64.7%, respectively. In the presence of winding on the spindle (for example, $H=20.0$ mm), we have $\Delta \tau=9.7%$; 12.4%; and 29.4%.

For a more objective assessment of the effect of the dimensions of the links of the elliptical drum mechanism on the efficiency of removing cotton from the spindles, it is necessary to conduct research in the direction of determining the effect of these parameters on the size of the processing area of the spindle surface by the stripper.

References

[1] Sablikov V M 1985 Moskow Agropromizdat 152
[2] Turgunov U T 1994 Development of a cotton picker puller with increased efficiency and reduced labor intensity of adjustment. Abstract ... Ph.D. T.
[3] Matchanov R, Rizayev A, Astanakulov K, Tolibaev A and Karimov N Combined cotton picker with interchangeable devices IOP Conf. Series: Earth and Environmental Science 677 (2021) 052021
[4] Rizaev A, Malikov Z, Yuldashev A, Kuldoshev D, Temirov D and Borotov A 2021 Materials Science and Engineering 1030, 012175
[5] Rizaev A, Yuldashev A, Kuldoshev D, Ashurov N 2020 IOP Conference Series: Materials Science and Engineering 883(1) 012166
[6] Rizaev A, Yuldashev A, Kuldoshev D, Abdillaev T, Ashurov N A 2020 IOP Conference Series: Materials Science and Engineering 883(1) 012157
[7] Rizaev A, Matchanov R, Yuldashev A T, Kuldashev D A, Djuraeva N B, Karimov N, Ashurov N A 2021 IOP Conference Series: Materials Science and Engineering 1030 (1) 012173
[8] Ravutov Sh T, Uljayev E, Ubaydullayev U M 2020 International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 06.
[9] E Uljayev et al 2020 IOP Conf. Ser.: Earth Environ. Sci. 614 012139
[10] Gayrat Bahadirov et al 2021 IOP Conf. Ser.: Mater. Sci. Eng. 1030 012160
[11] Abdukarimov A, Bakhadirov G, Saidakhmedova N, Saidakulov I 2014 *International Journal of Modern Manufacturing Technologies* ISSN 2067–3604, Vol. **VI**(1)