Investigation of spindle activity of horizontal spindle cotton harvesting machine

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Abstract. This article describes the current state of the work on the cultivation and harvesting of cotton dressing in the world and also in our country and the recommendations of the research work carried out in this direction, the quality indicators of the currently used horizontal type of cotton-harvesting machines, the compliance of the machines with the current conditions of private ownership and, the study of the possibilities of interaction of the teeth on the surface of a horizontal spindle cone with an opened cotton swab is devoted to determining the position of the spindle tooth in space, the velocity vector direction of the displacement of the points on the surface of the spindle cone, the absolute velocity of the tip of the spindle tooth.

1. Introduction

The authors consider world leading manufacturer of energy-efficient and high-efficiency cotton picking machines. “The total area under cotton in the world is 32.4 million hectares, and the harvested cotton fiber is 25.6 million tons. The development of new cotton-picking machines with high quality and productivity and energy-saving is one of the important tasks. In this regard, great attention is paid to the development of cotton harvesting machines with a high technical level, which allows harvesting high-quality cotton in a short time [1].

In recent years, the country has been research working for developing machines and equipment by used on the sowing [2-4], cultivation, and harvesting [5-10] and processing of cotton [11-16]. Currently, there are more than 3.0 million people in our republic per year tons of cotton raw materials are grown. In Uzbekistan, the relatively low number of sunny hot days necessary for the cultivation and harvesting of cotton crops, that is, due to the large number of days of precipitation in the spring season, the delay of planting of seeds and the rapid onset of days of precipitation in the autumn, the level of opening of cotton in the bud does not exceed 90%.

For example, the results of field experiments conducted at HS CHM showed that the quality of cotton picked and the completeness of the harvest are not enough when harvesting when the opening rate of the cocoons is up to 90%. the quality of the cotton crop is below the required level and the moisture level is above the norm, which corresponds to the low varieties according to the technical conditions of UzStateSTANDART [5-10].

The study of the trajectories of the points of the working bodies plays an important role in the theory of agricultural machinery. Therefore, in the work of M.V. Sablikov, H.H. Usmonkhodjaev, N.
Landsman, D.M. Shpolyansky, A.D. Glushenko, A.S. Sadriddinov and others on the fundamental problems of CHM focus on the impact on quality indicators.

To date, research on this issue has been based mainly on the theoretical study of the object of processing (cotton stalk, piece of cotton, etc.) as immovable, that is, without taking into account the laws and trajectory of the actual movement. For example, these are M.V. Sablikov's theory and criteria of dental activity, A.D. Glushenko and D.M. Shpolyansky. These shortcomings are characteristic of D.M. Shpolyansky's theoretical work on substantiation of the basic dimensions of the gear working body affecting cotton.

GSH PTM research carried out in the scientific periodic data in the press and dissertations are scarce, there is also no data brought into a particular system, not at the level of holistic methodology. HS CHM, which is used in our country, is intended for harvesting cotton without deterioration of its natural quality, ensuring its full and high yield. It is not enough to pay attention to the characteristics of the cluster system, as well as new varieties introduced in farmer farms, in the conditions of modern private ownership and market economy. In particular, the issues of the development of machine-picking compatibility criteria for the harvest of grain varieties, equipping the machine with modern automatic control and control systems, ensuring the completeness of the harvest and the required level of quality of the harvested cotton, substantiating the parameters and modes of harvesting have not been adequately studied [9, 17].

Therefore, the development of the methodology for the selection or synthesis of the main parameters of the threaded working body of the term HS and VS, suitable for specific climatic conditions of Uzbekistan and cotton varieties, is an urgent task the issues were not sufficiently studied.

This study mainly involves the development, calculation and prediction of machine quality indicators based on the criteria developed for the horizontal spindle tooth activity criteria. In practice, there are various methods for determining the trajectory of the working bodies of machines [18, 19]. However, analytical representation of the trajectory of the spindle is performed by selecting the coordinate system, in the construction of the trajectory is considered only the object of processing, and outside it does not make sense to build a trajectory [20, 21].

2. Materials and methods

The HS CHM spindle is in complex motion in the working process, and its trajectory consists of a spatial curve. The GSh is in four elementary kinematic motions, i.e., forward with the machine, rotating with the spindle drum, rotating the crankshaft cassette and the spindle attached to it according to a certain law around the cassette axis, and the spindle rotating around its own axis. All of these actions are taken into account in determining spindle activity (Figure 1).

![Figure 1](image-url)  
Figure 1. Scheme for the construction of the HS CHM spindle motion equation.  
1-curveship; 2-cassette; 3-reference corridors
A coordinate system was chosen to analytically represent the HS CHM spindle trajectory (Figure 1):
- the abscissa axis is parallel to the forward motion of the HS CHM and passes at a distance equal to $R_d$ from the center of the spindle drum;
- the ordinate axis passes through the center of the spindle drum at $z = 0$.
Elemental time (relative to $t_0$) makes the machine move a distance $S_1$ along the $OX$ axis. $S_1 = V_m t$ the cassette axis shifts to $S_1 + R_d \cos \theta$ and is equal to:

$$X_{cas} = V_m t + R \cos (\alpha_1 t + \theta_d^0)$$

(1)

The projection of the horizontal spindle on the $OX$ axis is determined from the following equation:

$$S_1 = R_d \cos \theta + l_k \cos (\alpha_1 t + \theta_d^0) X_{sp,a} = V_m t + R_d \cos (\alpha_1 t + \theta_d^0) + l_k \cos (\alpha_1 t + \theta_d^0)$$

(2)

For the general case, we obtain the projection of an arbitrary point (tooth) lying on the surface of the horizontal spindle cone on the $OX$ axis:

$$X_1 = V_m t + R_d \cos (\alpha_1 t + \theta_d^0) + l_k \cos (\alpha_1 t + \theta_d^0) + r_{sp} \cos (\alpha_1 t + \theta_d^0 \cos (\alpha_1 t + \theta_d^0)$$

(3)

The following parameters of the “Case-Cotton 2022” HS CHM were obtained as initial data [4, 9]:
- machine velocity $V_m = 6.19$ km/hour;
- the number of revolution of the spindle drum - $n_d = 158$ min$^{-1}$;
- radius of spindle drum - $R_d = 128.27$ mm;
- minimum radius of conical spindle - $r_{min} = 2.63$ mm;
- maximum radius of conical spindle - $r_{max} = 5.325$ mm;
- the number of revolutions of the spindle - $n_{sp} = 3000...4125$ min$^{-1}$.

3. Results and Discussions

Figure 2. Scheme of placement of teeth on the surface of the spindle cone
The angle formed by the displacement velocity vector \( \vec{V}_k \) vector of the points on the surface of the horizontal spindle cone with the abscissa axis is determined by the above parameters (Fig. 2):

\[
\varepsilon_1 = \arctg \left( -\frac{R_d \omega_d \cos \theta_d}{V_m - R_d \omega_d \sin \theta_d} \right);
\]

Where: \( R_d \) - radius of spindle drum, \( R_d = 128.27 \text{ mm} \);
\( \omega_d \) - angular velocity of spindle drum, \( \omega_d = 16.54 \text{ rad/s} \);
\( V_m \) - velocity of the machine (1-working velocity 1.72 m/s).

Meeting condition \( 0 < \Delta < 180^\circ \)

\[
\Delta \leq \psi_k - \varepsilon_1
\]

The spindle taper angle is equal to the parameters of the working bodies of the “Case-Cotton 2022” CHM typewriter.

Where: \( \psi_k \) - the point under study is the angle formed by the axis of the lying cone surface conceiver \( OX \), \( \psi_k = -90^\circ + 3^\circ 24' = -86.5^\circ 36' \);

\[
\Delta = -86^\circ 36' - (-70^\circ 36') = 16^\circ ;
\]

\( \Delta = 16^\circ \) means \( A_4, B_4 \) and \( C_4 \) do not meet with cotton slush points.

We determine the linear velocity \( \vec{V}_h \) in the relative motion of the spindle (rotation around its axis):

\[
\vec{V}_h = r_{\text{min..max}} \cdot \omega_{sp} = 1.14...2.3 \text{ m/s},
\]

where: \( n_{sp} \)-spindle rotation frequency, 3000...4125 \text{ min}^{-1}, \( \pi = 3.14, \omega_{sp} = 314.6...431.97 \text{ c}^{-1} \),
minimum and maximum radius of conical spindle \( r_{\text{min..max}} = 2.63...5.325 \text{ mm} \).

Because our spindle moves in a straight parallel motion, each point has the same velocity in the portable motion.

The directions of the absolute velocities of the spindle points are determined from the following expression, for example, in section \( A-A \) (Figures 2, 5):

\[
\vec{V}_{abs} = \sqrt{\vec{V}_{act}^2 + \vec{V}_{sp}^2 - 2 \vec{V}_{act} \vec{V}_{sp} \cos \gamma};
\]

**Figure 3.** Graph of the change in the absolute velocity of the points on the surface of the spindle cone

Here is the angle between the linear velocity of the spindle \( \vec{V}_{sp} \), the velocity vector of the machine \( \gamma = 90^\circ + \theta_d \) and the linear velocity vector of the drum (Fig. 3).
It consists of the sum of actions (portable velocity $\vec{V}_p$ - $\vec{V}_m$ and $\vec{V}_d$ (Figure 5), $\vec{V}_m = r_\omega \cdot \omega_m = 1142.38$ mm/s, $\vec{V}_d = R_d \cdot \omega_d = 2121.6$ mm/s.

$$\vec{V}_p = \sqrt{V_m^2 + V_d^2 - 2V_mV_d \cos(90^\circ + \theta_d)}.$$ \hfill (6)

When calculating the absolute velocity by putting the above values in equation (5)

The absolute velocity for the spindle tooth is determined from the following expression

$$\vec{V}_{abs} = \sqrt{V_p^2 + V_n^2 - 2V_pV_n \cos \xi}$$ \hfill (7)

Here, the angle between the $\xi$ -relative motion vector $\vec{V}_n$ and the portable motion vector $\vec{V}_k$ is as follows (Figure 4):

In $\theta_d = 30^\circ$ for $I_1$ also $\xi_{I_1} = 180^\circ - 70^\circ 36' = 109^\circ 24'$
Spindle taper angle $\alpha$ angle $A-A$ is equal to the angle in the first position $\alpha_{A}=\alpha_{B}=30^\circ 24'$. The spindle taper angle angle $A-A$ is equal to the angle in the first position of the cut. In determining the angle, the counterclockwise rotation is assumed to be positive, so that the angle of the cone on the side where point 4 is located is $\alpha_{A}= 30^\circ 24'$ relative to the axis of the $OY$, or $\alpha=-26^\circ 36'$ in section $A-A$ if we see in the IV quarter.

Hence, when $\alpha<\xi$, in all sections, point 4 is directed towards the spindle body, (the spindle moves) so that this point does not meet the cotton ball.

4. Conclusion
From the above calculations, it was found that during the return of the spindle from the working chamber, 4 points in sections $A-A$, $B-B$, $C-C$ of the spindle cone surface are directed towards the spindle body, so the teeth of the spindle at these points do not meet the cotton ball. When the spindle enters the working chamber of the typewriter, it is pierced by the cotton in the bowl, and when returning from the working chamber, the spindle teeth are not pierced by the cotton in the bowl, and the spindle is not active. This means that the horizontal spindle is only active during access to the working chamber.

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