

# Theoretical research of process of separating tobacco leaf from stem

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**Abstract.** The article is devoted to tobacco leaves harvesting in per leaf way, using a roller-type separating device acting on object of harvesting with rolling cutter having cutting flanges forming leaf-separating cells in working area. The subject of these studies is highly specialized and relates to field of agricultural engineering. Tobacco plants were chosen as an object of processing. The aim of research was theoretical substantiation of the interaction of tobacco stems with leaf-separating device in process of harvesting. The article has a research character, which is expressed in fact that theoretical analysis of interaction of tobacco plant with leaf-separating device of cutter-roller type in process of harvesting is carried out. In result of research there were obtained dependences that allow to determine constructive and technological parameters of separating device for separating tobacco leaf. Conclusions set out the main results achieved so far.

Agricultural production of tobacco raw materials together with enterprises for its industrial processing is designed to meet needs of population in high-quality and low-toxic smoking products [3]. For further improvement of tobacco industry efficiency, it is necessary to increase profitability of tobacco production, which is possible only with use of machine technologies [2].

Tobacco plants are characterized by consistent, tiered ripening of leaves on stem, so they are removed in several stages (break-ups).

Use of working body on harvester, working with use of actively rotating rollers with cutting flanges mounted on chain loops, as well as additionally equipped with a pneumatic system and holding rollers, will increase the completeness of leaves separation by changing cutting process, reduce injury to leaf plate due to faster removal of leaves from separation zone [1, 5].

According to constructive and technological scheme [4, 5], separation of tobacco leaf from stem is made by cutting rollers, which move  $V_{p.a}$  in closed chain loop, while obtaining axial rotation of  $\omega_b$  due to additional loop. In addition, machine moves on surface of  $V_m$ , which also complements components due to cutting edge of roller. For high-quality cutting of tobacco leaf, it is necessary to analyze interaction of cutting roller and tobacco leaf, including determining cutting force  $R$ , as this will determine the force of anti-cutting part (force of airflow  $F_{pres}$  to hold leaf).

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Analysis of interaction of cutting roller with tobacco leaf will begin with drawing up a trajectory of movement of arbitrary point  $B$  of flange of roller blade for arbitrary period of time  $t$ . Take a coordinate system as shown in Figure 4.

Then the motion of point  $B$  is described by equations:

$$\begin{cases} X_B = V_n t + V_{p.a.} t \cos \alpha + R \sin \omega t \cdot \cos \alpha, \\ Y_B = V_n t \cos \gamma + R \sin \omega t, \\ Z_B = H_H + V_{p.a.} t \sin \alpha + R \sin \omega t \cdot \sin \alpha. \end{cases} \quad (1)$$

where  $V_n$  – velocity of tobacco leaf supply to zone of leafseparation, which is equal to velocity of machine’s movement  $V_n = V_m$ , m/s;

$V_{p.a.}$  – velocity of rollers shifting to chain loop, m/s;

$\alpha$  – angle of roller’s installation to soil surface, degree;

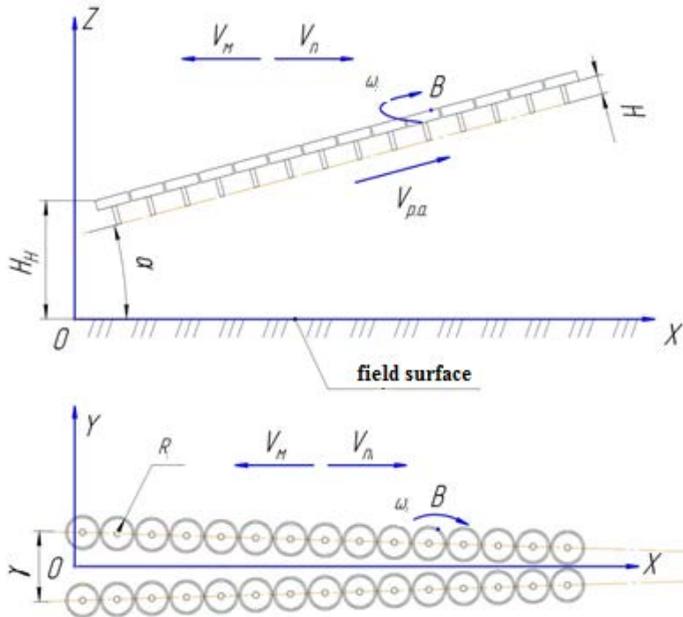
$R$  – radius with cutting flange of roller, m;

$\omega$  – angular velocity of a roller’s rotation, rad/s;

$\gamma$  – angle of rollers’ installation near each other, degree;

$H$  – height of wheel’s installation relative to roller, m;

$H_u$  – height of wheel’s installation relative to soil surface (height of starting of breaking up), m.



**Fig. 4.** Diagram of trajectory of blade’s flange of cutting wheel of leaf-separating machine

Having differentiated the system of equations (14) by time  $t$ , we obtain:

$$\begin{cases} V_{X_B} = \frac{dX_B}{dt} = V_n + V_{p.a.} \cos \alpha + R \cos \alpha \cdot \omega \cos \omega t, \\ V_{Y_B} = \frac{dY_B}{dt} = V_n \cos \gamma + R \omega \cos \omega t, \\ V_{Z_B} = \frac{dZ_B}{dt} = V_{p.a.} \sin \alpha + R \sin \alpha \cdot \omega \cos \omega t. \end{cases} \quad (2)$$

The equation (15) shows the projection of absolute velocity of arbitrary point *B* in coordinate axis. Then absolute velocity of arbitrary point *B* of flange of cutting wheel blade will be determined by the expression:

$$V_B = \sqrt{V_{X_B}^2 + V_{Y_B}^2 + V_{Z_B}^2} \tag{3}$$

Then components of the expression (16) after conversion will be equal to:

$$V_{X_B}^2 = V_n^2 + V_{p.a.}^2 \cos^2 \alpha + R^2 \cos^2 \alpha \cdot \omega^2 \cos^2 \omega t + 2V_n V_{p.a.} \cos \alpha + 2V_n R \cos \alpha \cdot \omega \cos \omega t + 2V_{p.a.} \cos \alpha R \cos \alpha \cdot \omega \cos \omega t, \tag{4}$$

$$V_{Y_B}^2 = V_n^2 \cos^2 \gamma + R^2 \omega \cos^2 \omega t + 2V_n \cos \gamma \cdot R \omega \cos \omega t,$$

$$V_{Z_B}^2 = V_{p.a.}^2 \sin^2 \alpha + R^2 \sin^2 \alpha \cdot \omega \cos^2 \omega t + 2V_{p.a.} \sin \alpha \cdot R \sin \alpha \cdot \omega \cos \omega t, \tag{5}$$

Let's specify  $A = R \omega \cos \omega t$ . After substitution and transformation of expressions (17, 18, 19) into expression (16), with regard to substitution, we obtain:

$$V_B = \sqrt{A^2 + 2V_{p.a.}A + 2V_n(\cos \alpha + \cos \gamma)A + V_n^2(1 + \cos^2 \gamma) + V_{p.a.}^2 + 2V_n V_{p.a.} \cos \alpha} \tag{6}$$

The expression (19) shows dependence of absolute velocity of arbitrary point *B* of flange of wheel blade depending on constructive and performance parameters. From the expression (19) it can be seen that formation of absolute velocity of flange of wheel blade is most influenced by velocity of movement of wheels  $V_{p.a.}$  on chain loop, feed rate of tobacco stem  $V_{sup}$  in a zone of leaf separation, radius  $R_b$  of cutting flange of wheel and angular velocity  $\omega$  of wheel rotation.

It is important to take into account that when separating tobacco leaf from stem, there is no discard of leaf from leaf area, which will be characterized by direction of absolute velocity of arbitrary point *B*. The change in direction of vector of absolute velocity of point *B* is characterized by directing cosines. For more convenient analysis, it is better to imagine the angle between coordinate axes and absolute velocity vector by expressions:

$$(V_B \wedge i) = ar \cos \frac{V_{X_B}}{V_B}, \tag{7}$$

$$(V_B \wedge j) = ar \cos \frac{V_{Y_B}}{V_B}, \tag{8}$$

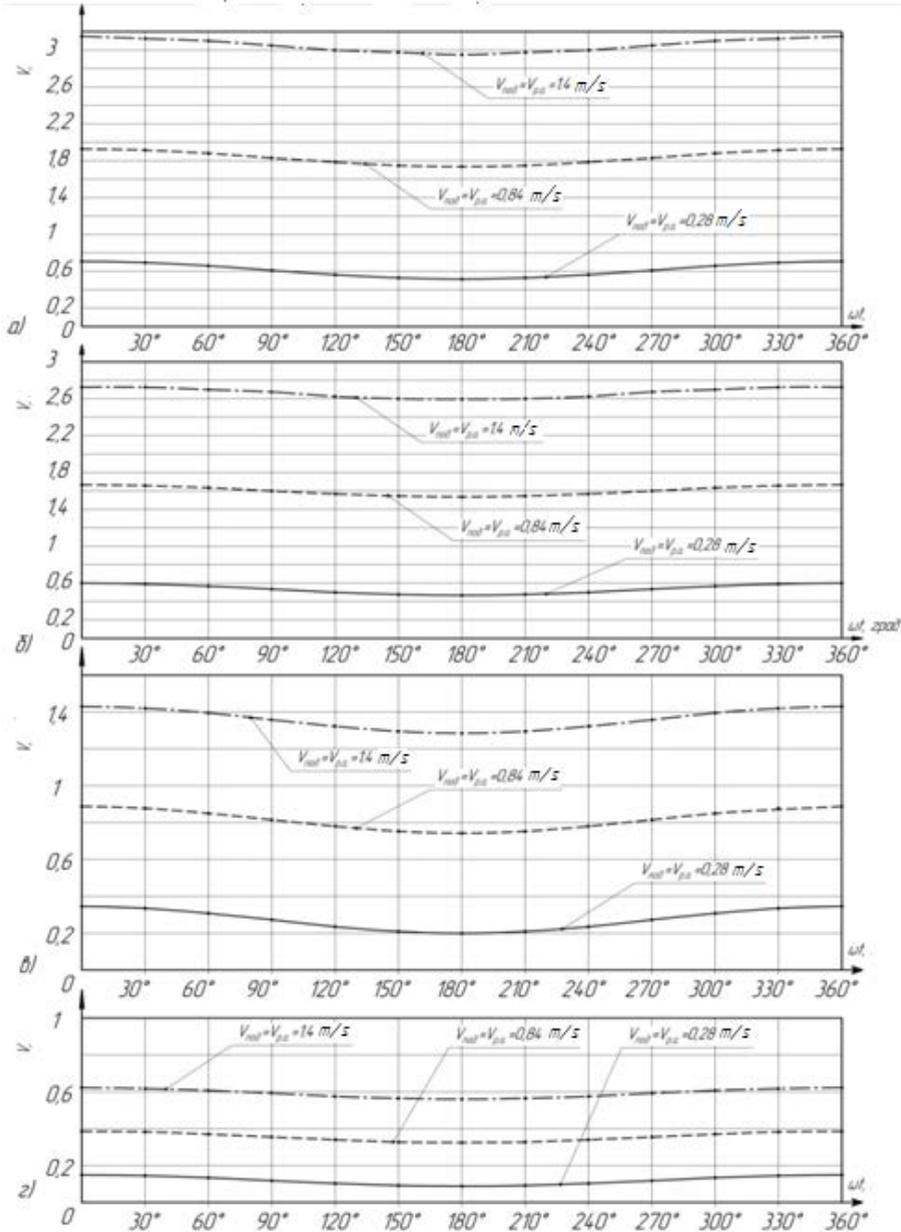
$$(V_B \wedge k) = ar \cos \frac{V_{Z_B}}{V_B}, \tag{9}$$

where  $i, j, k$  – singular vectors of appropriate axes.

Let's specify:  $(V_B \wedge i) = \varphi_X, (V_B \wedge j) = \varphi_Y, (V_B \wedge k) = \varphi_Z,$

To obtain visual representation of nature in absolute speed's change of point *B* in zone of leaf separation, it is necessary to build graphs (Figures 5 and 6): change in absolute velocity, change in projections of absolute velocity on coordinate axes and changes in

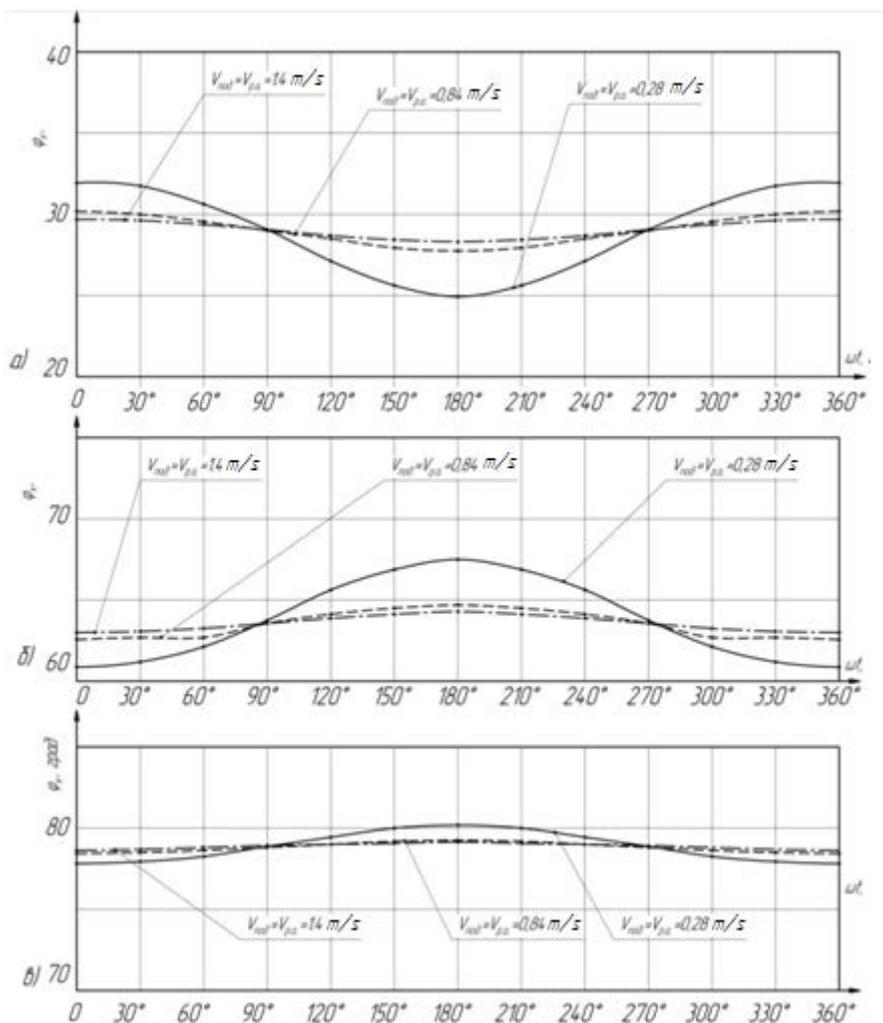
angles between vector of absolute velocity and coordinate axes when changing the angle of wheel's rotation.



**Fig. 5.** Graph of changes in absolute velocity of point B in leaf separation area: a – absolute velocity, b – axisOX, c – axisOY, e – axisOZ

In Figures 5 and 6 graphs are drawn at following values of constructional and regime parameters:  $\alpha_6 = 25^\circ$ ,  $R_6 = 0.072$  m,  $\gamma_6 = 14^\circ$ ,  $\omega_b = 1.01$  s<sup>-1</sup>. The graph (Figure 5, a) of change of absolute velocity of point B in zone of leaf separation shows that coincidence of direction of movement of wheels on chain loop  $V_{p,a}$  and angle of wheel's rotation in range of 180°-360°, absolute velocity grows along curvilinear dependence and reaches maximum when at the top point of coincidence with axis OX, and accordingly absolute velocity falls

in range  $0^{\circ}$ - $180^{\circ}$  and reaches minimum at the lowest point in coincidence with axis  $OX$ . With increase in supply rate  $V_{sup}$ , i.e. velocity of machine, change in velocity begins to approach linear dependence, but nature of its change does not vary significantly, but only absolute value changes.



**Fig. 6.** Graph of angle’s change between absolute velocity vector of point  $B$  in leaf separation area:  $a$  – axis  $OX$ ,  $b$  – axis  $OY$ ,  $c$  – axis  $OZ$

From graphs (Figure 5,  $a$ ,  $b$ ,  $c$ ) changes in projections of absolute velocity on coordinate axes it is clear that the nature of their changes in general are not changed, but its greatest change and, accordingly, the value is inherent in axis  $OX$ , and the smallest axes are  $OZ$ . The nature of change in absolute velocity along axis of  $OX$ , which in direction coincides with direction of cut leaf movement, it can be concluded that cut leaf will remain in area of leaf separation, which will increase the completeness of harvest.

As a result of research it can be concluded that:

1. There were obtained expressions characterizing dependence of absolute velocity of arbitrary point  $B$  in a flange of wheel blade from constructional and regime parameters of leaf separator;

2. Increase of machine's productivity implemented due to increase in supply rate of  $V_{sup}$ , i.e. by increase of machine with significant crop losses and by reducing the completeness of harvest will not be obtained.

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