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DEFINE OF KINEMATIC PARAMETERS OF POTATO-PLANTER

In this paper the design features of potato-planter conveyor apparatus are covered. The trajectory of the absolute motion of a feature point of apparatus at all stages of the work and the duration of these stages in time are defined

APPARATUS, PINNING DEVICE, COULTER, RING-SCOOP, NEEDLE, SOIL, POTATO, TRAJECTORY

Statement of the problem. State of the problem. The area of agriculture in Ukraine is not quite flat, as there are lands that are located on hills and even on steep slopes. To ensure a quality work in conditions of unequal relief the existing machines to work in plain conditions are not suitable and therefore they must either convert or equip with additional devices to work in these external conditions. Disadvantages of flat machines begin to appear already on the slopes of 3º-5º. If on agricultural operations related to solid tillage (without the presence of plants) the demerits of these machines do not lead to catastrophic consequences, on the operations related with plants (seeding, planting, harvesting etc.) these demerits may cause damage to plants and significant yield loss.

For quality work of potato-planters is very important in this aspect to ensure the accuracy of the kinematic parameters, which in turn ensure the accuracy of technical parameters and agronomic parameters, such as the exact location of potatoes in a ring-scoop without loss of potatoes from this scoop, releasing the potatoes from the scoop in time, straight trajectory of potatoes falling and, therefore, a direct hit to the bottom of the furrow that is made by coulter, any potatoes missing in a row, any injury of potatoes. The accuracy of kinematic parameters is important at all stages of potato-planters work by transport potatoes from the bunker (after its catching by ring-scoop) to the coulter.

The least negative facts at work in difficult environmental conditions occur when compact equipment is using, including small potato-planters.

Analysis of recent research and publications. Today, there are many designs of potato-planters, including conveyor type devices [1, 2, 5, 7]. The length of such device is not large and therefore by the longitudinal axis of the unit there is still plenty of space for operations of worker when using a small form of machines, in particular with the motor-block.

But here is did not ensure the quality capture of potatoes by the ring-scoop and keeping them strong there, especially if the size of potatoes vary quite widely. The latter circumstance is very important to ensure the quality of the kinematic regime of the potato-planters apparatus.

It should be noted that the great advantage of the apparatus of such design is that they have the possibility of improving the design through its minor changes or of addition of simple elements that can significantly improve the parameters and thus the final results. Very important is the term of good maintenance potatoes in the ring-scoop during its transportation all the way from the moment of capture until the release.

In various scientific papers the attention paid to potato-planer apparatus, but not quite the theoretical problem of determining of kinematic parameters at all stages of data are covered [2, 3, 4, 6].

Problem. The trajectory of absolute motion of characteristic point of potato-planter machine at all stages and duration of these stages in time are defined.

The main research material. We have proposed various potato-planter devices, the basis design of which is the pinning device. Their designs are closely described in scientific papers and patents [8, 9]. This special interest is the study of kinematic parameters, namely the trajectory of the characteristic point (there is a point at the center of the ring-scoop). In the paper [8] the trajectory of the movement is discussed in part, namely on the two stages of the movement of the ring-scoop. However, in this type of conveyor apparatus the motion of ring-scoop is divided into three stages. One stage (call it first) is characterized by the straight-line motion of ring-scoop up from the bottom to the top of the branch of the apparatus. Another stage (call it third) is characterized by straight-line motion of ring-scoop from the top point vertical down until it reaches the lower horizontal section. Another stage (we call it the second), and which is not described in the paper [8], is characterized by the circular motion of the ring-scoop in the area of the top sprocket. At this stage, the movement of the ring-scoop is on indirect (circular) trajectory, and therefore there is a very great danger of potatoes ascent of the ring due to changes in the direction of the forces acting on the potato. This is particularly evident by the working of machine in difficult environmental conditions (slopes, uneven terrain and etc.).

We describe cinematically all three stages. Work of the potato-planter with conveyor apparatus is carried out by the laws of complex motion: translational motion with the speed of machine $V_{\text{м}}$ and the relative motion with the speed of conveyor $V_{\text{к}}$ with rings-scoops. The latter speed $V_{\text{к}}$ is equal to circular (linear) velocity of the sprocket. All elements of the apparatus are moving in a plane that coincides with the direction of the machine motion.

For the first stage we take origin of coordinates, which coincides with the center O' of the lower ring-scoop of apparatus, axis x - directed toward the machine motion and the axis y - up (Fig. 1). So, let the center point of the ring-scoop at the initial time is at the origin of coordinates (point O'). After a certain period of time $t_{A'}$ it moves from point O' to point A', the coordinates of which are determined by the equation:

$$x_{A'} = V_{\text{м}}\, t_{A'},$$
$$y_{A'} = V_{\text{к}}\, t_{A'}. \quad (1)$$

Kinematic regime characterized by index λ, which is equal to the ratio of the speed of the conveyor $V_{\text{к}}$ to machine speed $V_{\text{м}}$, i.e. $\lambda = V_{\text{к}}/V_{\text{м}}$. Replacing to λ the value in the expression (1), we obtain:

$$x_{A'} = V_{\text{м}}\, t_{A'},$$
$$y_{A'} = V_{\text{м}}\, t_{A'}\, \lambda. \quad (2)$$

Equation (2) express the trajectory of absolute movement of characteristic point, which geometrically is a straight line with a certain angle β to the horizontal axis, depending on the value of λ (β = arctg λ). By lower values of λ the angle β of the trajectory line to the x-axis and is smaller and, respectively, with higher values of λ - given angle β is greater.

For the most complete description of this process we will determine the magnitude of the absolute velocity V_{a1} of characteristic point. Assuming that the expressions (2) describe the trajectory of absolute motion of any point of apparatus after differentiating them by t we get:

$$dx/dt = V_{\text{м}},$$
$$dy/dt = V_{\text{м}}\, \lambda. \quad (3)$$

Absolute speed is given by formula:

$$V_{a1} = \sqrt{\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2} = \sqrt{V_{\grave{\imath}}^2 + V_{\grave{\imath}}^2 \lambda^2} = V_{\grave{\imath}} \sqrt{1+\lambda^2}\,. \quad (4)$$

It should be noted that in the apparatus of this design are used mainly steel kinematic and geometrical parameters, namely the speed of the machine $V_{\text{м}} \approx 1$ m/s, rotary machine kinematic parameter $\lambda = 0.5$, the height of the ascending branch of the conveyor $y' = 1.5$ m. The first stage ends at the point A'_h, i.e. at the start point of the junction of the ring-scoop with the sprocket. You can take that first stage lasts for the time of capture of potato by the ring-scoop at point O' to its movement to the point A'_h (Fig. 1). This time can be determined by using of equation (2):

$$t_{y'} = \frac{y'}{V_{\grave{i}}\, \lambda}\,. \tag{5}$$

Substituting the data, we obtain the value $t_{y'} \approx 3$ s, which characterizes the duration of the first stage.

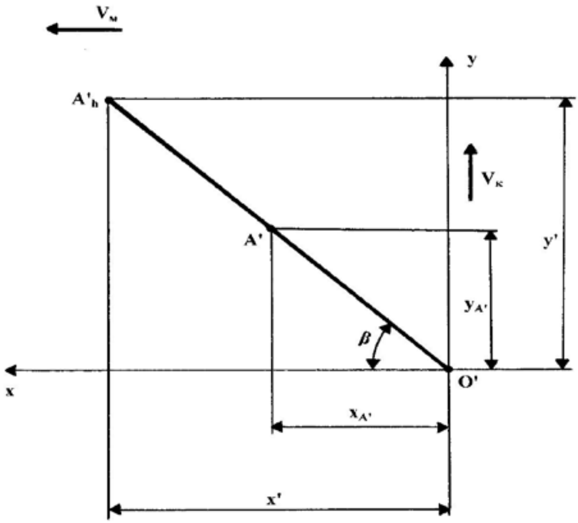

Fig. 1. Plan of motion of ring-scoop points of conveyor potato-planter apparatus in the first stage

The second stage is characterized by curvilinear motion of the ring-scoop in the area of the top sprocket. It begins with the contact of the ring-scoop with an sprocket, namely at the point A'_h, and ends at the time of release of the contact. We determine the trajectory of the characteristic point of the potato-planter apparatus at this stage. After a moment of the contact at the point A'_h (starting point of the ring-scoop in the second stage) ring-scoop begins its curvilinear motion to the moment of release of its contact at the point O''', which is the end point of the second stage (Fig. 2).

As in the first stage here carried out the complex movement: translational motion with the speed $V_М$ and relative motion around the axis O'' with angular velocity of the sprocket ω. We take the origin on the axis O'' of the apparatus sprocket. x axis will direct the course of the machine, and the axis y - up. After a certain period of time $t_{A''}$ the axis will moved to position O''_1 and will path the way $V_М t_{A''}$. By this time the sprocket with a ring-scoop will turn at an angle $\varphi_{A''} = \omega t_{A''}$. Point A'_h will take a position A'', then the coordinates of this point expressed by the equation:

$$x_{A''} = V_м t_{A''} - R \cdot \cos \omega t_{A''},$$
$$y_{A''} = R \cdot \sin \omega t_{A''}. \tag{6}$$

where R – distance from the axis of the sprocket to the characteristic point.

Given that the angular velocity of the characteristic point (equal to the speed of the conveyor) is $V_к = \omega R$ and substituting on λ the value in the expression (6), we obtain:

$$x_{A''} = R\,(\omega\, t_{A''}/\lambda - \cos \omega t_{A''}),$$
$$y_{A''} = R \cdot \sin \omega t_{A''}. \tag{7}$$

Equations (7) express the trajectory of absolute motion of characteristic point, which is geometrically - cycloid. Cycloid shape depends on the value of λ. When $\lambda < 1$ the cycloid has no loops - shortened cycloid, and when $\lambda > 1$ - cycloid trajectory is extended.

As for the first stage, for the most complete description of this process in the second stage we will determine the value of the absolute velocity V_{a2} of characteristic point. Assuming that the expressions (7) describe the trajectory of absolute motion of any point of apparatus after differentiating them by t we get:

$$dx/dt = R\omega(1/\lambda + \sin \omega t),$$
$$dy/dt = R\omega \cos\omega t. \tag{8}$$

Absolute speed is defined by formula:

$$V_{a2} = \sqrt{\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2} = \frac{R\omega}{\lambda}\sqrt{\lambda^2 + 2\lambda \sin \omega t + 1}\,. \tag{9}$$

For this second stage, we again us a steel kinematic and geometrical parameters, and that the maximum height that characteristic point is achieved is the height y'', which is equal to the radius of the sprocket, i.e. $y'' = 0.07$ m. The radius of the sprocket (equate to the distance from the axis of the sprocket to the characteristic point) $R = 0.07$ m, the speed of the conveyor $V_к \approx 0{,}5$ m/s, the angular velocity of the sprocket $\omega \approx 7$ rad/s. You can take that second stage lasts for time of the path of characteristic point from point A'_h to point O'', i.e. during the period of moving of characteristic point up from the X-axis at height y'' and then it moving down from this height again to the X-axis (Fig. 2). This time can be determined by using of equation (7):

$$t_{y''} = \frac{1}{\omega} \arcsin \frac{y''}{R}\,. \tag{10}$$

Substituting the data, we obtain the value $t_{y''} \approx 0.224$ s. Thus, the duration of the second stage is $2\,t_{y''} \approx 0.45$ s.

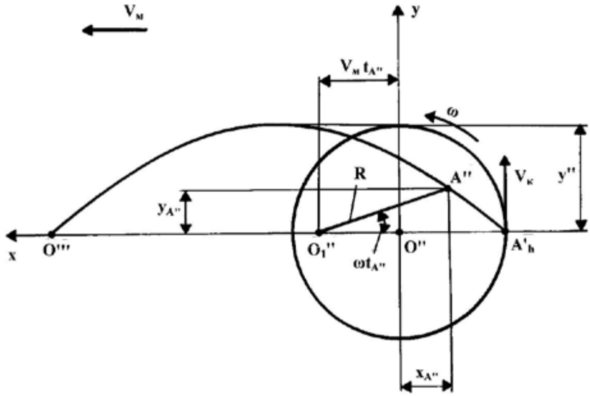

Fig. 2. Plan of motion of ring-scoop points of conveyor potato-planter apparatus in the second stage

The third stage is characterized by the movement of the ring-scoop from top point (the moment out of the contact with the sprocket) down until it reaches the lowest point (moment of release of potatoes by ring-spoon).

For the third stage we take origin, which coincides with the center O''' of the ring-scoop that comes out of contact with the sprocket, X-axis - directed toward the motion of machine and the Y-axis - down (Fig. 3). So, let the center point of the ring-scoop located at the initial time at the origin (point O'''). After a certain period of time $t_{A'''}$' she moves from point O''' to the point A''', which coordinates are determined by the equation:

$$x_{A'''} = V_{м}\, t_{A'''},$$
$$y_{A'''} = V_{к}\, t_{A'''}, \qquad (11)$$

Replacing on λ the value in the expression (11), we obtain:

$$x_{A'''} = V_{м}\, t_{A'''},$$
$$y_{A'''} = V_{м}\, t_{A'''}\, \lambda. \qquad (12)$$

Similarly to the first stage the equation (12) expressed the trajectory of absolute motion of characteristic point, which is geometrically is a straight line with a certain angle β to the X-axis, depending on the value of λ (β = arctg λ). By lower values of λ the angle β of the trajectory line to the X-axis is smaller and, respectively, by higher values of λ - given angle β is greater.

To define the absolute speed we are using the formula (4) from the first stage.

Using the similar to the first stage kinematic and geometrical parameters and equation (5) we obtain the value $t_{y'''} \approx 3$ s, which characterizes the duration of the third stage.

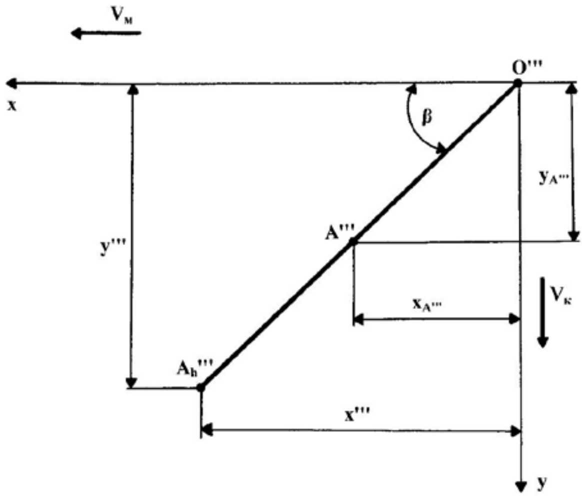

Fig. 3. Plan of motion of ring-scoop points of conveyor potato-planter apparatus in the third stage

Thus, taking into account all three stages the total time from the capture of potato by ring-scoop until her release of this ring is t = 0.45 + 3 + 3 = 6.45 s.

In terms of the work of this potato-planter device such period of time is not a long. And considering the fact that during this short period of time the potato passes through three stages during which the direction and nature of its movement varies substantially, the essential value becomes to ensure a good stoppage of potatoes in the ring-scoop that can be achieved by applying of this apparatus with additional structural elements.

Conclusions. This theoretical analysis makes it possible to determine the trajectory of absolute motion of characteristic point of ring-scoop for three stages of the work of conveyor potato-planter apparatus and duration of these stages in time.

The calculation procedure can be used as a single methodology for important calculations and as a basis for further study of the entire unit.

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Определение кинематических параметров машины для высаживания картофеля

АППАРАТ, НАКАЛЫВАЮЩЕЕ УСТРОЙСТВО, СОШНИК, КОЛЬЦО-ЛОЖЕЧКА, ИГОЛКА, ПОЧВА, КАРТОФЕЛЬ, ТРАЕКТОРИЯ

Резюме. *В данной статье высветлены конструктивные особенности конвейерного картофелепосадочного аппарата. Определена траектория абсолютного движения характерной точки аппарата на всех стадиях работы и продолжительность данных стадий по времени*

Define of kinematic parameters of potato-planter

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Summary. The paper proved that the area of agriculture in Ukraine is not quite flat, as there are lands that are located on hills and even on steep slopes. To ensure a quality work in conditions of unequal relief the existing machines to work in plain conditions are not suitable and therefore they must either convert or equip with additional devices to work in these external conditions. Disadvantages of flat machines begin to appear already on the slopes of 3º-5º. If on agricultural operations related to solid tillage

(without the presence of plants) the demerits of these machines do not lead to catastrophic consequences, on the operations related with plants (seeding, planting, harvesting etc.) these demerits may cause damage to plants and significant yield loss.

For quality work of potato-planters is very important in this aspect to ensure the accuracy of the kinematic parameters, which in turn ensure the accuracy of technical parameters and agronomic parameters, such as the exact location of potatoes in a ring-scoop without loss of potatoes from this scoop, releasing the potatoes from the scoop in time, straight trajectory of potatoes falling and, therefore, a direct hit to the bottom of the furrow that is made by coulter, any potatoes missing in a row, any injury of potatoes. The accuracy of kinematic parameters is important at all stages of potato-planters work by transport potatoes from the bunker (after its catching by ring-scoop) to the coulter.

The least negative facts at work in difficult environmental conditions occur when compact equipment is using, including small potato-planters.

In the article the trajectories of absolute motion of characteristic point of potato-planters apparatus at all work stages and duration of these stages in time are defined.