

Theoretical prerequisites for substantiating the parameters of a rotary ripper for interrow potato cultivation

*Vladimir Pervushin*¹, *Marat Salimzyanov*, *Alexey Ivanov*, *Alexander Kostin*, and *Konstantin Shklyayev*
Udmurt State Agrarian University, Izhevsk, Russia

Abstract. The article is devoted to the study of the process of interaction of the rotary ripper's working bodies with the soil. The classification of rotary machines and implements according to the energy transmitted to the working body and the location of the rotation axis is outlined. The article notes that the main characteristics of the rotor work body motion are the trajectory type, the magnitude and direction of velocity of its most characteristic point, and in some cases, the magnitude and direction of acceleration. The article presents the results of theoretical research in the field of kinematics of interaction of rotary working tools with the soil. The design of the rotary ripper is presented and the description of the trajectory of its working bodies is made, the value of movement of the scraper plate in the contact area with the soil is established. We analyzed the segment of the path from the beginning of contact with the soil (the beginning of dragging the surface layer of soil) and the end of contact (the end of dragging the surface layer of soil), on the line of which weed combing, loosening and destruction of soil crust occurs.

1 Introduction

The rotation of the implements is the main feature of rotary tillage machines and tools. The set of the rotating working elements and the device on which they are attached is called a rotor.

The energy from the engine to the rotor can be supplied through the traction device of the tractor, with the rotor receiving rotation as a result of the passive interaction of the tools with the soil (passive channel). When energy is transferred from the motor to the rotor through the driveshaft, hydraulic drive, or electric drive, the rotation of the rotor becomes active (active channel). Energy can also be supplied to the rotor via two channels at the same time. This feature allows to clearly divide rotary tillage devices into two traditional groups: machines and implements.

Rotary implements are widely used in a variety of agricultural machines. The diversity of rotary machines and implements complicates the work of scientists and engineers, so

¹ Corresponding author: pervushin54@mail.ru

now there is a need to systematize the entire existing set of rotary machines and implements.

The classification of rotary machines and implements is carried out according to two main features:

- 1) According to the energy transmitted to the working body.
- 2) According to the location of the rotation axis in space.

If the energy from the tractor to the rotary working body is transferred through the traction force of the tractor, and the working body receives the rotation from the passive interaction with the soil, i.e., from the impact of external reactive forces, then such working bodies are referred to as rotary-reactive.

When energy is transferred from the tractor to the implement through a driveshaft, hydraulic drive or electric drive, the rotation of the rotor becomes active, such implements are referred to as rotary-active.

The next important feature that characterizes rotary machines and implements is the location of the rotation axis of the working body in space, which is the most convenient for their classification and theoretical research. According to the location of the axis of rotation, rotary working bodies are divided into seven groups A; B; C; D; E; F, G.

The founder of agricultural mechanics, academician V. P. Goryachkin established that the achievement of high quality indicators of working tools is possible only with their optimal geometric, kinematic parameters and mode of operation.

Working bodies of passive working tools move on a straight path, so their intensity of loosening the soil is low. Active (rotary) working bodies meet the agrotechnical requirements of loosening the soil and destroying weeds to the fullest extent. Increased activity of interaction with the soil and, consequently, the intensity of loosening the soil by rotary working tools is determined to a greater extent by the type of path of their movement.

2 Materials and Method

The work aims to study of the process of interaction of the rotary ripper working bodies with the soil.

Research objectives:

- study the trajectory of the scraper plate in the area of its contact with the soil:
- determine the amount of movement of the scraper plate in the contact area with the soil.

According to our working hypothesis, the rotary tool rolling over and adjacent to the restbalk surface can comb out and drag the weeds along the restbalk, destroy the connection of their root neck with the soil, and dump them into the interrow. Such functionality of the provided technological process can have a rotary ripper that fits the restbalk profile and passively rolls along the circumference of the large rim 1 (Fig. 1b), the points of which describe the trajectory of an ordinary cycloid with the kinematic mode parameter $\lambda=1$. And the remaining points of smaller diameter, which are on the middle 2, the small rim 3, and the scraper plates 4, describe shortened cycloids with a kinematic mode parameter $\lambda<1$ [1-4].

The description of the kinematics of the rotary ripper is more convenient to begin by considering the motion of a point located at a distance from the axis of rotation with radius r and rotating with constant angular speed ω , around the axis in the stationary coordinate system OXY with progressive speed of the machine V_T along the axis OX .

In relative motion in time t_i any point rotates around its axis by an angle:

$$\varphi_i = \omega \cdot t_p \tag{1}$$

where ω is the angular velocity of the points of the rotary harrow, s^{-1} ; t_i – time, s; and in portable motion moves along the abscissa axis by a distance:

$$S = V_T \cdot t_i \tag{2}$$

where, V_T is the translational speed of the machine, $m \cdot s^{-1}$;

Therefore, the coordinates of points of the absolute trajectory of motion of the working body are added from the portable and relative motion (Fig. 1a).

The trajectory of any point lying on the harrow surface in a fixed coordinate system is a system of two equations:

$$x = V_T \cdot t + r_i \cdot \sin(\omega \cdot t) \tag{3}$$

$$y = r_i \cdot \cos(\omega \cdot t) \tag{4}$$

where r_i is the point rotation radius ($r..R$), m .

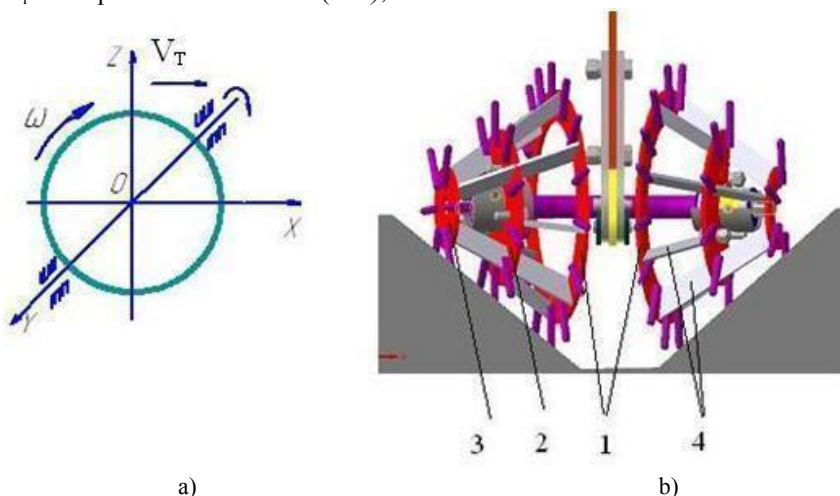


Fig. 1. Rotary ripper: a – kinematic diagram of the rotor; b – model of the rotary harrow. Compiled by the authors.

When justifying the geometrical parameters of the rotary ripper, it was assumed that the rotor rolls and performs a plane-parallel motion, the large rim 1 rotates with a kinematic mode parameter $\lambda=1$, and all other working elements as the middle rim 2, small rim 3 and scraper plates 4 rotate with a kinematic mode parameter $\lambda < 1$.

According to the results of field studies, it was found that the larger the diameter of the large rim 1 with grousers, the less the force required to roll it [5-8].

Consider the kinematics of the interaction of scraper-plate 4 during its contact with the soil. Let us analyze the segment of the path from the moment of contact of the scraper plate with the soil (the beginning of dragging the surface layer of soil) in the point θ_{in} and the end of contact with the soil (the end of dragging the surface layer of soil) in the point θ_{out} on the line which is combing out weeds, loosening and destruction of soil crust (Fig. 2).

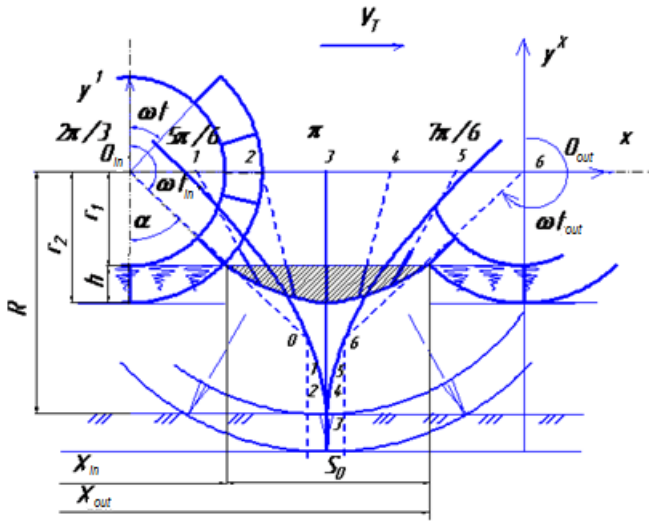


Fig. 2. To determine the segment S_0 of the forward movement of the scraper plate in the contact area with the soil. Compiled by the authors.

Graphical construction of the movement trajectory and its analysis allows establishing that the scraper plate at the contact with the soil enters the soil at an acute angle, in the middle of the working stroke takes a vertical position, and at the end of the working stroke is detached from the soil surface at an obtuse angle. Thus, on the first half of the working stroke the scraper picks up the soil and weeds on itself, and on the second – it drags them and throws them off itself, which is quite favorable for the technological process of dragging weeds and loosening the soil [9-12].

When rolling the harrow an important role is played by the trajectory described by the scraper during its contact with the soil, limited to an arc ($\theta - 6$) and conditioned by the beginning of the entry into the ridge in the point θ and the end of his working stroke in the point 6 , the line which is scraping weeds, loosening and destruction of soil crust.

Arc $\theta-6$ of the trajectory of the scraper plate corresponds to a segment of the value S_0 of the translational movement of the harrow.

Let us analyze the section of the harrow's path from the contact of the scraper plate with the soil (the beginning of dragging the surface layer of soil) in point θ and the end of contact with the soil (the end of dragging the surface layer of soil) in point 6 .

From Fig. 2 we find that at the moment when the scraper plate contacts the soil, its coordinate y takes on a value equal to r_1 . Therefore:

$$\cos\alpha = r_1 / (r_1 + h) \quad (5)$$

or:

$$\alpha = \arccos[r_1 / (r_1 + h)], \quad (6)$$

then:

$$\omega t_{in} = \pi - \alpha = \pi - \arccos[r_1 / (r_1 + h)]$$

or:

$$t_{in} = (\pi - \arccos[r_1 / (r_1 + h)]) / \omega.$$

Substituting the values of t_{in} into expression (3) and considering that $V_T = \omega r_1 / \lambda$, we obtain in the coordinate system the value of translational movement of a scraper plate at the contact of a scraper plate with the soil X_{in} (input)

$$X_{in} = r_1(\pi - \arccos[r_1 / (r_1 + h)]) / \lambda + r_1 \sin(\pi - \arccos[r_1 / (r_1 + h)]), \tag{7}$$

At the moment of scraper plate detachment from the soil, the angle α is equal:

$$\omega t_{out} = \pi + \arccos [r_1 / (r_1 + h)] \tag{8}$$

or

$$t_{out} = (\pi + \arccos[r_1 / (r_1 + h)]) / \omega \tag{9}$$

By substituting the expressions t_{out} and $V_T = \omega r_1 / \lambda$ we obtain the magnitude of movement of point A at the detachment of contact with the soil (output). Therefore,

$$X_{out} = r_1(\pi + \arccos[r_1 / (r_1 + h)]) / \lambda + r_1 \sin(\pi + \arccos[r_1 / (r_1 + h)]), \tag{10}$$

Knowing the values of the translational movement of the scraper plate X_{in} and X_{out} , it is easy to express the value of the segment S_0 movement of the scraper plate in the contact area of the scraper plate with the soil [13-16].

$$S_0 = X_{out} - X_{in}. \tag{11}$$

3 Results

The results of solving equations (2) and (3) are presented in Table 1, and the graphical dependence of the operating stroke on the kinematic mode parameter λ in Fig. 3.

Table 1. Results of solving equations (2) and (3) at kinematic mode indices λ from 0.1 to 1.0. Compiled by the authors.

$\lambda=r_2/R$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
$r_2=R \cdot \lambda, \text{ mm}$	32.5	65	97.5	130	162.5	195	227.5	260	292.5	325
$X_{in}=A_1+B_1, \text{ mm}$	352.9	649	761	828.2	875.9	913.9	943.4	969.1	991.4	1011
$X_{out}=A_2+B_2, \text{ mm}$	1688.3	1392.2	1280.2	1213	1165.2	1127.3	1097.8	1072.1	1049.8	1030
$S=X_{out}-X_{ip}, \text{ mm}$	1335.4	743.2	519.2	384.8	289.3	213.4	154.4	103	58.4	19

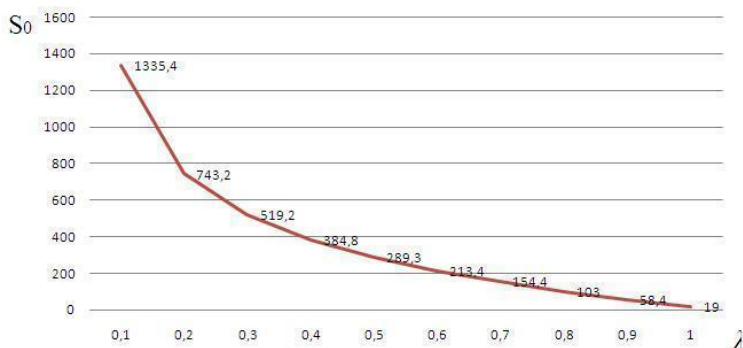


Fig. 3. Dependence of the working stroke S_0 on the kinematic mode parameter λ . Compiled by the authors.

4 Discussion

The trajectory of the rotary ripper working bodies in the area of their contact with the soil is of practical interest. It follows from the analysis of the trajectories that all points of the harrow lying in the longitudinal-vertical plane and inside the circle of the large rim describe a shortened cycloid with $\lambda < I$, therefore, in the contact area with the soil they drag the topsoil, destroying weeds, destroying and loosening the soil crust.

5 Conclusion

1. As the points of the working elements of the rotary ripper are removed from the large rim of the harrow, the length of the working stroke and, therefore, the amount of pulling of the topsoil increases.

2. Scraper plates of the rotary ripper in the contact area break the connection of the root collar of weeds with the soil, loosen the soil and thus create favorable conditions for plant development.

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