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Modeling the operation process of the unit for processing row-spacings of fruit plantings

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Abstract. The reserves for expanding areas for fruit plantations in the mountainous regions of Russia are limited. One of the ways to solve this problem is to engage in agricultural circulation and, in particular, for fruit plantations, sloping lands. At present, for foothill and mountain areas, scientifically based technologies for growing gardens on slopes have been developed for zones. One of the problems faced by fruit producers is the lack of technology for the care of the row-spacings of fruit plantations. Mechanized technologies of plain gardening are ineffective in the specific conditions of mountain and foothill agriculture, where soil fertility is the main limiting factor. At the same time, there is an urgent need to accelerate the creation of a humus layer in the near-stem stripes, to improve the water and food regimes of fruit plantations on sloping lands. The analysis of the soil maintenance system in the gardens showed that the most rational is the sod-humus system, which involves mowing the vegetation, leaving it on the soil surface in the form of mulch. However, commercially available technical means have a relatively low rotational speed of a rotary working body, do not provide high-quality tillage. In this regard, the proposed design of the unit for processing row-spacings of fruit plantations. As a result of the theoretical studies, rational values of the main parameters and modes of operation of the proposed unit have been established.

1. Introduction

One of the important elements of increasing the productivity of fruit plantations is to conduct high-quality row spacing, which is carried out by disking [1-3]. The most common tools are technical equipment with passive working bodies, which provide a relatively satisfactory quality of loosening only when the soil is ripe [4-6]. As a result, lumps are formed, the disking depth is reduced, etc. All this leads to the fact that the soil moisture evaporates intensively, as a result of which the normal conditions for the development of fruit plantations deteriorate. This can be avoided by the use of milling tools.

2. Research results

The shape of the working body, its geometrical parameters and the type of movement of the knives determine the intensity of soil loosening [7-11]. In the process of movement, rectilinearly and uniformly with the unit and at V_A speed and evenly rotating with ω_F angular velocity (Fig. 1), the working body describes the trajectory that is a cycloid.



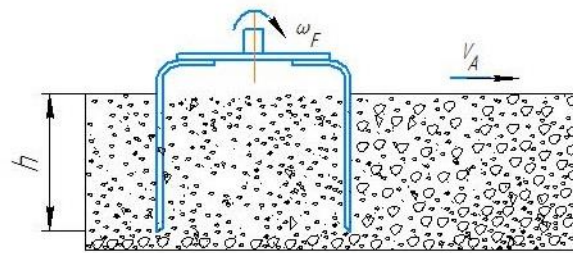


Figure 1. The process of the milling work body.

The equation of motion of the knife point most distant from the axis of the milling tool of the knife point in a parametric form is:

$$\begin{cases} X = V_A t + r_N \cos(\omega_F t) \\ Y = r_N [1 - \sin(\omega_F t)] \end{cases}, \quad (1)$$

where t – time, s; r_N – knife radius, m; ω_F – angular speed of cutter rotation, s^{-1} .

Eliminating the time from these equations, after some transformations we get:

$$t = \frac{1}{\omega_F} \arcsin \frac{r_N - y}{r_N}. \quad (2)$$

Substituting the time value from expression (2) into equation (1) for X , we get:

$$X = \frac{V_A}{\omega_F} \arcsin \frac{r_N - y}{r_N} + \sqrt{2r_N y(1 - y)}. \quad (3)$$

The type of cycloid depends on how the circumferential speeds of the cutter and the translational speed of V_A unit, called the kinematic indicator:

$$\lambda = \frac{V_{OKR}}{V_A} \quad (4)$$

where V_{OKR} – circumferential rotational speed of the mill around the vertical axis, m/s.

Usually rotary tillage machines have $\lambda > 1$. Consequently, there is an elongated cycloid (figure 2).

When turning the cutter through 360° , the knife moves successively in either solid or loosened soil. The parameters of the cut chips and the soil lumps formed at the same time are determined by the shape of the cutter, the depth of processing and the thickness of the chips.

The experience of using milling machines has shown that the energy and agrotechnical indicators of their work are determined mainly by the process of cutting soil chips, which occurs at a certain turn of the milling drum, equal to $\omega_F t = 180^\circ$. The energy performance of the tillage cutters depends on the direction and magnitude of the cutting speed, cutting effort, as well as on the shape and size of the cutting chips.

Determine the cutting speed and the absolute speed of the cutter. To do this, we differentiate expressions in system (1):

$$\begin{cases} V_X = \frac{dX}{dt} = V_A - r_N \omega_F \sin(\omega_F t) \\ Y = \frac{dY}{dt} = -r_N \omega_F \cos(\omega_F t) \end{cases}. \quad (5)$$

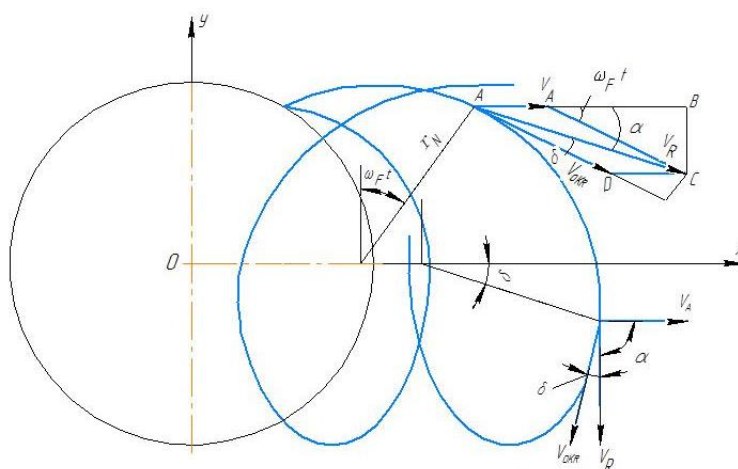


Figure 2. Scheme to determine the kinematic indicators of the cutter.

Taking into account the expression (5), the magnitude of the absolute speed of the knife can be calculated from:

$$V_R = V_A \sqrt{1 + \lambda^2 - 2\lambda \sin(\omega_F t)}. \quad (6)$$

Analyzing expressions (6) it can be concluded that the magnitude of the cutting speed and its direction determine the angle of rotation of the milling tool $\omega_F t$ and the kinematic mode λ .

In order to guarantee the qualitative loosening of the soil, it is necessary that the value of the minimum absolute speed of the knife beats to be equal to or exceed the critical rate of destruction of the soil lumps. Thus, the peripheral speed cutters can be calculated from the dependencies:

$$V_R \succ \sigma_K \sqrt{\frac{J_P + m_K r_N^2}{3E_J \rho_K (1 - k^2)}} + V_A, \quad (7)$$

where σ_K – tensile strength of soil lump, Pa; J_p – moment of inertia of the working body, $\text{kg} \cdot \text{m}^2$; m_K – mass of soil lumps, kg; E – the modulus of elasticity of the soil lump, Pa; k – soil lump recovery coefficient; ρ_K – density of soil lump, kg/m^3 .

As a result of calculations using the expression (7), it was established that the soil is qualitatively loosened at a circumferential speed of the cutter of 4.77 m/s and a rotational speed of 387 rpm.

The direction of the cutting speed (fig. 2) is determined by the value of the angles α and δ . It is easy to notice that

$$\alpha + \delta = \omega_F t. \quad (8)$$

It can be seen from the triangles ABC and ACD that:

$$\alpha = \arctg \frac{\sin(\omega_F t)}{\frac{1}{\lambda} + \cos(\omega_F t)}, \quad (9)$$

$$\delta = \arctg \frac{\sin(\omega_f t)}{\lambda + \cos(\omega_f t)}. \quad (10)$$

Analysis of expressions (9), (10) and dependencies constructed from them $\alpha = f(\omega_F t, \lambda)$ and $\delta = f(\omega_F t, \lambda)$ (figure 3) shows that when the angle of rotation changes from $\omega_F t$ 0 to 180° , α angle changes in the same range.

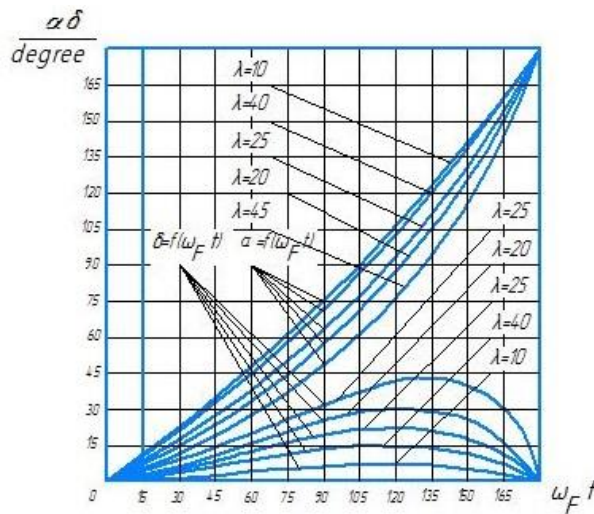


Figure 3. Dependence of α and δ angles from changing the angle of rotation $\omega_F t$ at different values of λ .

Moreover, α angle reaches 90° with strictly defined boundary values of $\omega_F t = \omega_F t_1$ angle of rotation (this is achieved when the projection of V_R cutting speed on X axis is zero), depending on λ indicator.

At $\lambda > 10$ values $\alpha = f(\omega_F t, \lambda)$ dependence is close to linear.

δ angle reaches a maximum value with $\omega_F t = \omega_F t_1$ and for any values of $\omega_F t$ angle of rotation is always $< 90^\circ$. With an increase in the value of λ the value δ tends to zero.

To determine the values of $\omega_F t$ boundary angle, we will use the expression (4). In this case, we consider that $\omega_F t = \omega_F t_1$. In this case, at $\alpha = 90^\circ$, the projection of the peripheral speed of the cutting edge of the cutter on X axis will be equal to the translational speed of the unit and they will have opposite directions. Then we have:

$$\omega_F t_1 = \frac{\pi}{2} + \arcsin \frac{V_A}{V_{OKR}}. \quad (11)$$

As $\frac{V_A}{V_{OKR}} = \frac{1}{\lambda}$, after we substitute $\omega_F t_1$ value into the expression (9) the later will take the following form:

$$\alpha = \arctg \frac{\sin\left(\frac{\pi}{2} + \arcsin \frac{1}{\lambda}\right)}{\frac{1}{\lambda} + \cos\left(\frac{\pi}{2} + \arcsin \frac{1}{\lambda}\right)}, \quad (12)$$

i.e. $\alpha = 90^\circ$.

Taking into account the expression (11) from the expression (8) we will have:

$$\delta = \arcsin \frac{1}{\lambda}. \quad (13)$$

The dependence $\omega_F t_1 = f(\lambda)$, shown in figure 4, shows that in range of change λ from 2 to 8 (range of greatest interest for practical use) the values $\omega_F t_1$ change in the range from 120 to 97° .

The feed to the knife is one of the main parameters of the rotary working bodies, which determine qualitatively the crumbling of the soil and energy costs. It is determined according to the expression:

$$S_H = 2\pi \frac{r_N}{\lambda z_N}, \quad (14)$$

where z_N – number of knives, pcs.

Analysis of the expression (14) shows that the amount of feed to the knife is determined by the cutter radius, the number of knives and the kinematic mode of operation.

The dependence of the change on the knife feed on the number of knives and the kinematic mode when the cutter radius is 0.1175 m (figure 5) shows that increasing the kinematic mode of the cutter and the number of zeros leads to a decrease in feed and vice versa.

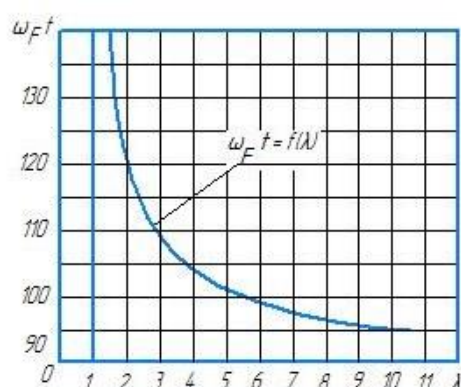
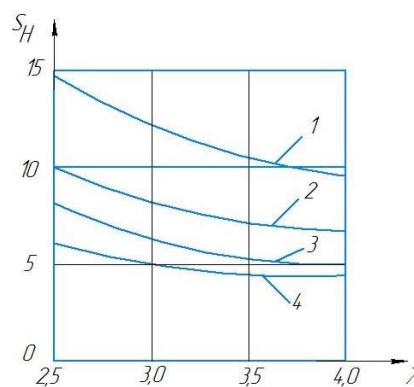


Figure 4. The dependence of the boundary angle from the kinematic index.



1 – $z_N = 2$; 2 – $z_N = 3$; 3 – $z_N = 4$; 4 – $z_N = 5$

Figure 5. The dependence of the filing of the knife on the number of knives and kinematic indicator.

The angle of the knife can be calculated by the expression:

$$\alpha = \arccos\left(\frac{1}{\lambda} + \frac{b_N}{2r_N}\right), \quad (15)$$

where b_N – width of the knife, m.

According to the expression (15) when $z_N = 2$ pcs; $\lambda = 2,96$; $b_N = 0,004$ m; $r_N = 0,1175$ m we will get that $\alpha = 60^\circ$.

3. Conclusion

As a result of modeling the process of operation of the unit for processing pristvolnyh bands of fruit trees, its rational parameters and modes of operation have been established, which have the greatest impact on the quality and energy indicators of tillage.

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