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THE PROCESS OF DIGGING CHICORY ROOTS WITH A COMBINED DIGGER

Maksym Hadaichuk

Vinnytsia National Agrarian University, Vinnytsia, Ukraine

Abstract. *The existing technical means of harvesting chicory roots do not provide the necessary indicators of the quality of digging root crops according to the agrotechnical requirements for root harvesting machines. Reduction of losses of root crops and their damage is provided by the use of a combined single-disk spherical digger, which combines a spherical disk and a loosener placed behind it and in its area of operation, which is installed on the riser of the disk. The article proposes a developed mathematical model that describes the movement of the soil layer along a spherical disc and that allows analytically determining its dynamic characteristics and technological parameters of the root crop digging process. The obtained results of the study are partially a supplement to the existing methods of substantiating the parameters of the working processes of root harvesting machines.*

Key words: *root crops, digger, spherical disk, loosener, soil layer, movement, model, parameters, speed, force, feed.*

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1. INTRODUCTION

Among many types of industrial crops, including root crops, only root chicory ensures the production of strategic raw materials from which, in the process of its processing, the raw product of inulin processing is obtained, from which an important medicinal product – insulin is subsequently produced [1, 2].

Chicory root crops are also used as fodder for farm animals in the autumn-winter period [3, 4] and for the production of renewable sources of energy – bioethanol [5, 6]. soil macrostructure [7, 8], which leads to an increase in soil fertility [9, 10].

However, in the process of harvesting chicory roots with existing technical means, certain difficulties arise in terms of such indicators of the quality of harvesting, such as the completeness of digging chicory roots and the number of damaged roots, which significantly exceed the established indicators of agrotechnical requirements for root harvesting machines [11–13]. At the same time, the average rate of loss of root crops is 3.5...7.5% depending on the harvesting conditions, and damage to chicory roots is 2.5...3.5 times the value of the index of agrotechnical requirements [14].

All this reduces the technical and economic efficiency of the production of chicory root crops, which forces farms to reduce the sown areas of this important technical crop [15].

2. EXPERIMENTAL METHODS

To increase the technological efficiency of the process of harvesting chicory root crops, we have proposed a technical tool for digging up root crops (Fig. 1), which will allow to increase the completeness of digging up root crops and reduce their damage due to the intensification of the process of destruction of the peri-fruit environment and the occurrence of additional dynamic effects that ensure an increase in the force of pushing out root crops from the ground.

The combined working body for digging chicory root crops consists of a one-sided spherical disc 2, which is located at a certain angle relative to the row of root crops.

The disk is freely seated on the axis 3 of the disk rotation, which is mounted in a riser (not shown in Fig. 1), rigidly fixed on the frame 9 of the digger.

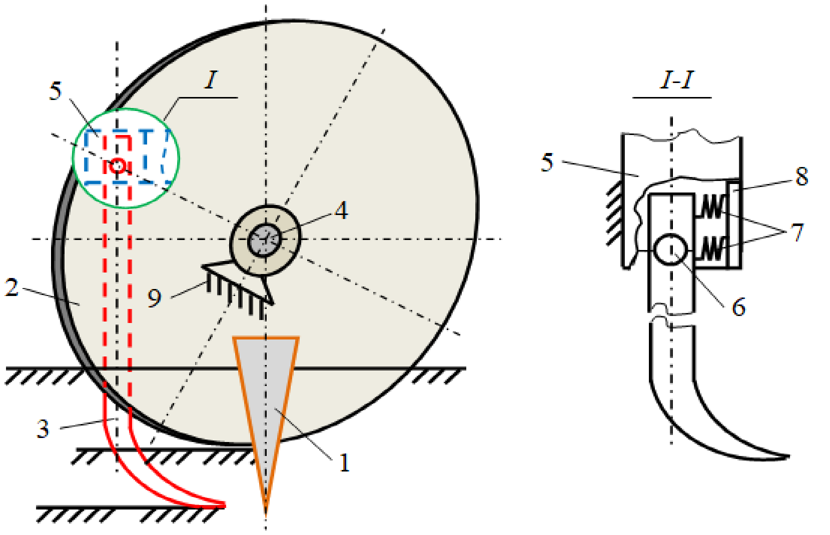

Figure 1. Construction diagram of a combined digger: 1 – root crop; 2 – spherical disc; 3 – loosened; 4 – disk rotation axis; 5 – bracket for fastening the loosened; 6 – axis of rotation of the loosened; 7 – spring; 8 – thrust plate; 9 – frame

Also, a bracket 5 is mounted on the riser, which can be moved along the riser and fixed on it with the help of fixing pairs of bolts and nuts.

The bracket has an axis 6 on which the loosened 3 is mounted. With the help of springs 7, which are connected to the loosened at one end, and rest against the stop plate 8 at the other end, the riser of the loosened is spring-loaded.

During the movement of the combined digger along the rows of chicory root crops, the loosened 3 and the spherical disk 2 destroy the surrounding soil environment and the connections of the root crop in it due to the rotation of the spherical disk with an angular velocity $\omega_d = d\vartheta_d / dt$ and the movement of the loosened (i.e. disk) with a translational velocity ϑ_d.

When this occurs such a phenomenon (process) as the movement of the excavated soil layer along the spherical surface of the disk and, accordingly, its subsequent movement to the following working organs of the root-harvesting machine.

The study of this process is an important scientific task in terms of ensuring the minimization of the supply of soil impurities by the spherical disk to the following working organs of the root harvester during the digging of chicory root crops.

The minimization of the supply of soil impurities can be achieved by studying the dynamic processes that occur during the movement of the digger along the rows of root crops and, accordingly, developing a mathematical model that describes the relationship between the technological and structural-kinematic parameters of the process of moving the digger in the soil environment.

3. RESULTS AND DISCUSSION

The process of moving the excavated soil layer along a spherical surface during the digging of chicory root crops with a spherical disc will be considered according to the diagram shown in Fig. 2.

The main parameters of a spherical disc are: sphere diameter D_s, m; disk radius R_d, m; the depth of the drive h_d, m; angle of attack of disk α, degrees; angle of inclination of the disk to the horizon ε, degrees.

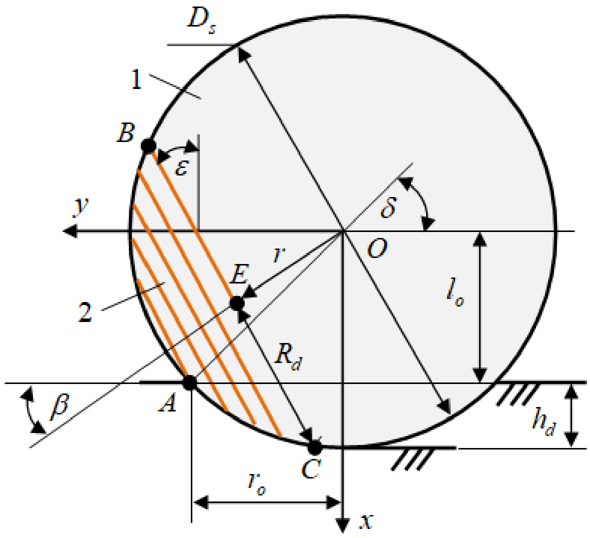

Figure 2. Scheme for calculating the dynamic interaction of a spherical disk with a soil layer: 1 – sphere; 2 – spherical disk

When considering the process of movement of the soil layer along the spherical surface of the disc during the digging of chicory root crops, it is advisable to place the selected $Oxyz$ coordinate system so that the entire $Oxyz$ coordinate system moves simultaneously with the spherical disc with a constant movement speed ϑ_d (disc movement speed, m/s) relative to the soil surface, and the excavated soil fell on the spherical disc with a constant speed $\vartheta = const$, m/s.

To ensure the condition $\vartheta = const$, we take the point O, or the point that coincides with the center of the sphere, as the reference point of the $Oxyz$ coordinate system.

We direct the Ox axis into the depth of the soil perpendicular to its surface. We direct the axis Oy so that the radius vector of the center of the disk E, or the axis of rotation of the disk, belongs to the plane of the xOy. We direct the Oz axis perpendicular to the Ox axis and the Oy axis, or perpendicular to the plane of Fig. 2.

To simplify the process of building a mathematical model of soil movement on a spherical disk, we accept the following assumptions:

- when soil particles hit the disc, a layer of soil is formed per unit of time, which moves as one solid body of mass m_s (kg) with a given angular velocity ω_s, rad/s;
- during the movement of the soil layer on the disk, we neglect the friction force, while accepting the postulate that the moment of friction forces acting on the soil layer at a constant angular velocity of the disk ω_d (rad/s) is equal to the moment of friction forces in the bearings of the axis of the disk attachment, or equal zero;
- the equations of motion are further solved for the center of gravity of the soil layer, so the rotation of the soil layer relative to its center can be neglected and it can be assumed that the angular velocity ω_s is directed along the moment of movement of the soil layer M_s, kg m/s [16, 17];
- when the soil layer is moved along the disk, we neglect the force of gravity, which is justified by sufficiently significant values of the translational speed of the disk ϑ_d, at which the kinetic energy $K_s = 0.5 m_s \vartheta^2$ (J) of the falling soil layer significantly exceeds the potential

energy $\Pi_s = m_s g h_g$ (J) of the soil layer rising up along the disk, where g – acceleration of free fall, m/s^2; h_g is the height of the soil layer on the disc, m.

In the future, after the descent of the soil layer from the disc, the force of gravity $F_g = m_s g$ (H) will be taken into account.

In addition, in the scheme of fig. 2 is marked:- $r = 2\sqrt{D_s^2 - 4R_d^2}$ is the distance to the center of the disk from the center of the sphere, or the module of the vector $|\vec{r}|$, m; l_o is the distance from the center *O* of sphere 1 to the ground surface, m; r_o is the radius of curvature of the point of contact *A* between the surface of the soil and the disk, $r_o = 2\sqrt{D_s^2 - 4l_o^2}$, m; δ is the angle between the radius vector of the point of contact *B* of the disc with the soil surface (in the xOy plane) and the Oy axis, rad.: $sin\,\delta = 2l_o / D_s$; $cos\,\delta = 2r_o / D_s$; β is the angle of inclination of the axis of the disk, or vector $\vec{r}$ relative to the axis *Oy*, degrees.

At the same time: $h_d = R_d\, cos\,\beta + r\, sin\,\beta - l_o$; the velocity vector $\vec{\vartheta}$ has components $\vec{\vartheta}_x = 0$, $\vec{\vartheta}_y = \vec{\vartheta}_n\, sin\,\alpha$, $\vec{\vartheta}_z = -\vec{\vartheta}_n\, cos\,\alpha$, m/s.

To determine the moment of the amount of movement of the soil that enters the disc per unit of time, or the moment M_s of the amount of movement of the soil layer, it is necessary to determine the average force of the reaction N_d (H) of the disc on the falling layer.

At the same time, the average force of the reaction N_d will depend on the value of the mass m_s and the velocity vector $\vec{\vartheta}$ of the falling layer of soil on the disc, as well as on the contact area (area of the disc S_d, m^2) on which the layer of soil falls.

The mass of soil m_s that falls on the disc is determined by the well-known formula $m_s = \rho_s V_s$ [18], where ρ_s is the specific mass (density) of the soil, kg/m^3; V_s is the volume of soil that falls on the disc, m^3.

The volume of soil V_s that falls on the disc can be determined according to [8], taking into account the area of the disc S_d on which the soil falls and the unit vector $\vec{n}$, which determines the instantaneous value of the thickness of the layer of soil that falls on the disc, or $V_z = \int_{S_d} n dS_d$.

Then the average reaction force N_d will be determined by the formula

$$N_d = -\int_{S_d} \rho_s \vartheta_n \left(\vec{\vartheta} \times \vec{n}\right) n dS_d , \tag{1}$$

where $\vec{n}$ is a unit vector that is directed to the point of contact (fall) of the soil layer on the disc.

The solution of the integral expression (1) relative to the axes of the $Oxyz$ coordinate system will have the form:

$$\left.\begin{aligned} N_{xd} &= -2\rho_s \vartheta_n^2 R_d^2 \theta_1 \sin\alpha; \\ N_{yd} &= -\rho_s \vartheta_n^2 R_d^2 \left(\theta_o + \theta_2\right)\sin\alpha; \\ N_{zd} &= -\rho_s \vartheta_n^2 R_d^2 \left(\theta_o - \theta_2\right)\cos\alpha \end{aligned}\right\}, \tag{2}$$

where N_{xd}, N_{yd}, N_{zd} are the average force of the disk reaction to the falling soil layer, which acts along the Ox, Oy, Oz axis, respectively.

Components θ_1, θ_2, θ_o of the system of equations (2) are determined by the formulas:

$$\left.\begin{aligned} \theta_1 &= \int_{z_1}^{z_2} z\sqrt{1-z^2}\sin\varphi_z dz; \\ \theta_2 &= \int_{z_1}^{z_2}\left(1-z^2\right)\sin\varphi_z\cos\varphi_z dz; \\ \theta_o &= \int_{z_1}^{z_2}\left(1+z^2\right)\varphi_z dz \end{aligned}\right\}. \tag{3}$$

The solution of the integral expressions of the system of equations (3) is as follows:

$$\theta_1 = \cos^2\delta\left[\frac{4R_d^2}{D_s^2} - \frac{1}{3}\left(\sin\delta - \frac{2r\sin\beta}{D_s}\right)^2\frac{1}{\cos^2\beta}\right]^{\frac{3}{2}} + \theta_3\frac{2r\sin\beta}{D_s}; \tag{4}$$

$$\theta_2 = -\theta_1 tg\beta + \frac{2\theta_3}{D_s\cos\beta}; \tag{5}$$

$$\theta_o \cong 0.5\int_{z_1}^{z_2} dz\left(1-z^2\right)\sin 2\varphi_z = \theta_2, \tag{6}$$

where $\theta_3 = \int_{z_1}^{z_2}\sqrt{1+z^2}\sin\varphi_z dz$.

At the same time, the solution of the integral expression $\theta_3 = \int_{z_1}^{z_2}\sqrt{1+z^2}\sin\varphi_z dz$ has the form

$$\theta_3 = \cos\left(\frac{\beta}{2}\right)\left(\frac{8R_d^2}{\pi D_s^2}\right) - \arcsin\left[\left(\frac{l_o - r\sin\beta}{R_d\cos\beta}\right)\right] - \left(\frac{l_o - r\sin\beta}{R_d\cos\beta}\right)\left[1 - \frac{\left(l_o - r\sin\beta\right)^2}{R_d^2\cos^2\beta}\right]. \tag{7}$$

Then, taking into account the value of expression (6), the system of equations (2) will be written in the form

$$\left.\begin{aligned} N_{xd} &= -2\rho_s\vartheta_n^2R_d^2\theta_1\sin\alpha; \\ N_{yd} &= -2\rho_s\vartheta_n^2R_d^2\theta_2\sin\alpha; \\ N_{zd} &= -\rho_s\vartheta_n^2R_d^2\cos\alpha \end{aligned}\right\}. \tag{8}$$

Let's determine the moment of movement of the soil layer using the expression

$$M_s = \frac{D_s}{2}\int_{S_d}\left(\vec{n}\times\vec{\vartheta}\right)\left(\vec{n}-\vec{\vartheta}\right)dS_d = \frac{D_s}{2\vartheta_n}\left(\vec{\vartheta}\times N_d\right). \tag{9}$$

Due to the collinearity of vectors $\vec{\omega}_s$ and $\vec{M}_s$, the angular velocity of the soil layer falling on the disk is determined by the formula

$$\omega_s = M_s \left[\int_{S_d} 0.25 \rho_s D_s^2 \left(\vartheta n \right) dS_d \right]^{-1} . \quad (10)$$

After solving the integral expression (10), it is obtained

$$\omega_s = 4M_s / m_s' D_s^2 , \quad (11)$$

where $m_s' = 0.5\vartheta_n \rho_s D_s^2 \theta_3 \sin\alpha$ is the mass of the soil layer that enters the disc per unit of time, kg/s.

The initial position of the center of gravity of the soil layer $R_{c.s} = \left| R_{c.s} \right| n_o$ on the disc can be expressed through the average reaction vector of the disc N_d, or

$$R_{c.s} = \frac{1}{2m_s'} \int_{S_d} \rho_s D_s n \left(\vec{n} \times \vec{\vartheta} \right) dS_d = -\frac{N_d D_s}{2\vartheta_n m_s'} . \quad (12)$$

The components of the vector $\vec{n}_o$, which are given by the vector $R_{c.s}$, can be determined using equations (4)–(6) and (12). After falling on the spherical disk, the soil layer comes off it due to its twisting by the surface of the disk, which rotates with an angular velocity ω_d and its subsequent rejection towards the axial line of the row of root crops.

At the same time, the movement of the soil layer, or its movement, has two characteristic features:

- free movement along the disc with angular velocity ω_s;
- free fall in the field of gravity after leaving the disk surface.

To carry out further analysis of the process of movement of the soil layer during the digging of chicory roots with a single-disk spherical digger, we will consider in more detail these two characteristic areas of movement of the soil layer.

When the soil layer moves freely along the disk surface, the direction of the vector $\vec{n}_c$, which determines the instantaneous position of the center of gravity $R_{c.s}$ of the soil layer depending on time, is determined by the expression

$$n_c \left(t \right) = n_o \cos \omega_s t + \frac{1}{\omega_s} \left[\vec{\omega}_s \times \vec{n}_o \right] \sin \omega_s t , \quad (13)$$

where $\frac{1}{\omega_s} \left[\vec{\omega}_s \times \vec{n}_o \right]$ is a unit vector directed along the initial movement of the soil layer $n \left[\vec{\omega}_s \times \vec{n}_o \right]$.

If we compare and analyze the expressions (9) and (12), we come to the conclusion that the expression is $\omega_s \cdot n_o = 0$, and the further movement of the soil layer takes place in a circle with a radius of R_s and a plane formed by the vectors $\vec{n}_c$ and $\frac{1}{\omega_s} \left[\vec{\omega}_s \times \vec{n}_o \right]$, where R_s is the radius of the sphere, m.

At the initial moment of time $t=0$, according to formulas (4)–(6), the vector $\vec{n}_c = 0$. The condition for the descent of the soil layer from the disk at the moment of time $t=t_1$ is ensured by the condition under which the cosine of the angle between the vectors $\vec{n}_c$ and $\vec{r}$ approaches the value of the expression $2\sqrt{\left(1-R_d^2\right)/D_s^2}$, i.e.

$$\vec{n}_c\left(t_1\right)\cdot\vec{r} = 2r\sqrt{\left(1-R_d^2\right)/D_s^2}\,. \tag{14}$$

Multiplying the expression (13) by r, we get

$$A\cos\omega_{г}t_1 + B\sin\omega_{г}t_1 = \sqrt{\left(1-R_{д}^2\right)}\,, \tag{15}$$

where:

$$A=\frac{1}{r}\left[r\cdot n_o\right]=\theta_1\sin\beta+\frac{\theta_2\cos\beta}{\sqrt{\theta_1^2+\theta_2^2}}\,;\; B=\left(\left[\frac{\vec{\omega}_s}{\omega_s}\times\vec{n}_o\right]\frac{\vec{r}}{r}\right)=\frac{1}{\omega_s r}det\begin{pmatrix}\omega_{xs} & \omega_{ys} & \omega_{zs}\\ n_{xo} & n_{yo} & n_{zo}\\ r_x & r_y & r_z\end{pmatrix}. \tag{16}$$

The solution of equations (15) and (16) with respect to time t_1 has the form

$$t_1=\frac{1}{\omega_s}\left[arccos\left(\frac{2}{D_s}\sqrt{\left(\frac{0.25D_s^2-R_d^2}{A^2+B^2}\right)}\right)+arccos\frac{A}{\sqrt{A^2+B^2}}\right]. \tag{17}$$

Thus, at the time of descent of the soil layer from the disc, its position and the speed of the layer are determined (or specified) by the vectors:

$$\vec{R}_{c.s}\left(t_1\right)=\vec{R}_s\left(\vec{n}_o\cos\omega_s t_1+\frac{1}{\omega_s}\left[\vec{\omega}_s\times\vec{n}_o\right]\sin\omega_s t_1\right); \tag{18}$$

$$\vec{\vartheta}_c\left(t_1\right)=\vec{R}_s\omega_s\left(-\vec{n}_o\sin\omega_s t_1+\frac{1}{\omega_s}\left[\vec{\omega}_s\times\vec{n}_o\right]\cos\omega_s t_1\right). \tag{19}$$

Further free movement of the soil layer from the disk occurs under the influence of gravity.

With

$$\vec{R}_s\left(t\right)=\vec{R}_{c.s}\left(t_1\right)+\vec{\vartheta}_c\left(t_1\right)\left(t-t_1\right)+0.5g\left(t-t_1\right)^2, \tag{20}$$

where the acceleration of free fall g is directed along the Ox axis.

The condition of the soil layer falling onto the field surface looks like this

$$R_{xs}\left(t_2\right)=l_o=0.5D_s\sin\delta\,, \tag{21}$$

where t_2 is the time of the soil layer falling to the field surface, s.

Using this condition, we find that the flight time τ (s) of the soil layer in the air is

$$\tau = t_2 - t_1 = \frac{1}{g}\left(-\vartheta_{xc} + \sqrt{\vartheta_{xc}^2 + 2g\left(l_o - R_{xc.c}\right)}\right). \tag{22}$$

At the same time, at the moment when the soil layer falls on the surface of the field during the time t_2, we have:

$$R_{yc}\left(t_2\right) = R_{yc.c} + \vartheta_{yc}\tau\,; \quad R_{zc}\left(t_2\right) = R_{zc.c} + \vartheta_{zc}\tau\,. \tag{23}$$

The distance L_n (m) from the center of the disk to the point of incidence in a plane perpendicular to the direction of the velocity ϑ of the movement of the soil layer is determined by the formula

$$L_n = \left[R_{zc}\left(t_2\right) sin\,\alpha + cos\,\alpha\left(R_{yc}\left(t_2\right) - r\,cos\,\beta\right)\right]. \tag{24}$$

The pressure force F_s (H) of the soil layer on the disk surface consists of the sum of the acting forces:

- the forces of movement of the soil layer during the fall on the disk, or the reaction forces N_d of the disk;
- centrifugal force F_τ, N

$$F_\tau = 0.5 M_s D_s \left[\omega_s \times \left(n_o - n_c\left(t_1\right)\right)\right]. \tag{25}$$

Then the pressure force F_s of the soil layer on the disk surface will be determined by the formula

$$F_s = -N_d + \frac{M_s D_s \omega_s}{2}\left\{\left(1 - cos\,\omega_s t_1\right)\frac{1}{\omega_s}\left[\omega_s \times n_o\right] + n_o\, sin\,\omega_s t_1\right\}. \tag{26}$$

Each of the three components of the pressure force vector $\vec{F}_s$ of the soil layer on the disc surface in formula (19) has its own physical meaning.

In particular, the force component F_{xs} characterizes the pressure of the spherical disk on the ground.

The component, which is parallel to the direction of movement speed ϑ_d and which is defined as $F_{1s} = F_{ys}\, sin\,\alpha - F_{zs}\, cos\,\alpha$ is equal to the traction force of the digger with a «minus» sign, or is directed in the opposite direction to the direction of movement of the digger and which ensures the movement of the digger during the digging of chicory root crops with a single-spherical disk.

The component, which is perpendicular to the direction of the speed of movement ϑ_d and the axis Ox and which is defined as $F_{2s} = -F_{ys}\, cos\,\alpha - F_{zs}\, sin\,\alpha$ characterizes the overturning moment, or lateral force.

The cross-sectional area S_k (m^2) of the groove formed by the spherical disk during its movement can be determined by the formula

$$S_k = \frac{1}{\vartheta_d} \int_{S_o} (n \cdot \vartheta_d) dS_o = 8D_s^2 \sin\alpha\theta_3 . \quad (27)$$

The volume V_k (m^3) of the soil layer, which is excavated by a spherical disc, or the second supply of the volume of soil, which subsequently enters the following working organs of the root harvester, is determined by the formula

$$V_k = \vartheta_d S_k = \frac{1}{\rho_s} M_s = 8\vartheta_d D_s^2 \theta_3 \sin\alpha . \quad (28)$$

Applying the formula (27), it is possible to determine the width of the groove formed by a spherical disc during the digging of chicory root crops according to

$$b_k = \frac{S_k}{z_o} = \frac{16\vartheta_d D_s^2 \theta_3 \sin\alpha}{D_d \cos\beta + 2(r\sin\beta - l_o)} , \quad (29)$$

where D_d is the diameter of the spherical disk, m.

According to (28), the second supply m_s' of the soil mass is determined by the formula

$$m_s' = 8\vartheta_d D_s^2 \rho_s \theta_3 \sin\alpha . \quad (30)$$

In Fig. 3 shows a graphical 3D model that characterizes the relationship between changes in the second supply of soil mass m_s' by a spherical disc depending on the speed of movement of the disc ϑ_d and the angle of attack α of the disc.

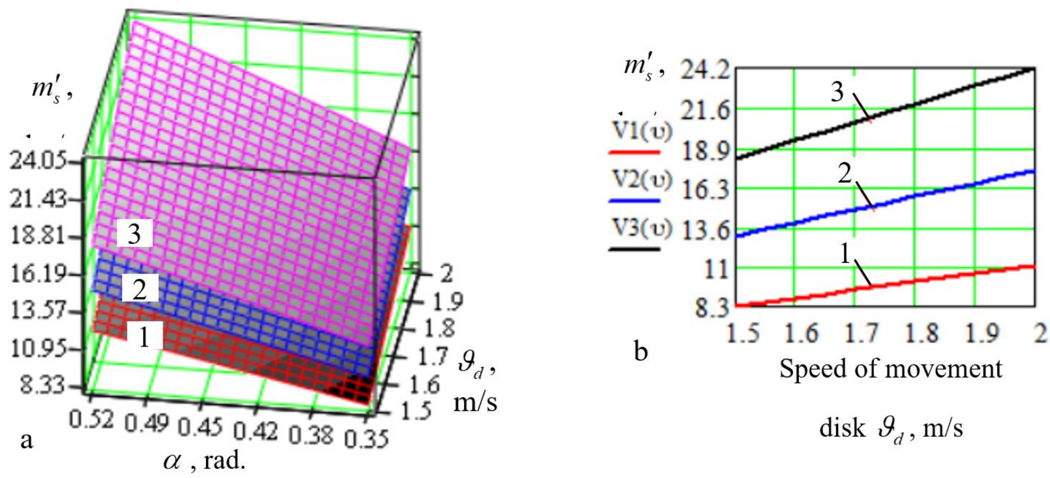

Figure 3. Dependencies of changes in the second supply of soil mass as a function: a – $m_s' = f(\vartheta_d;\alpha)$, 1, 2, 3 – respectively, $D_s = 0.4$; 0.45; 0.5 m; b – $m_s' = f(\vartheta_d)$, 1, 2, 3 – respectively, $\alpha = 20$, 30, 35 degrees

Based on the analysis of the given graphical interpretation of the dependencies $m_s' = f(\vartheta_d;\alpha)$ and $m_s' = f(\vartheta_d)$, it was established that the change in the second supply of the soil mass m_s' has a linear character – with an increase in the speed of movement of the disk ϑ_d and the angle of attack of the disk α, the second supply increases within the range from 8.3 to 24.2 kg/s.

Moreover, the dominant parameter that significantly affects the increase in the second feed m_s' P is the angle of attack of the disk α – for an increase in the angle of attack O in the range from 20 to 35 degrees the second supply of m_s' increases by approximately 1.5...1.8 times.

The given analytical dependence (30) and constructed graphic dependences (Fig. 3) characterize the second supply of soil mass from one row of root crops and without taking into account the volume of underground parts of chicory roots that lie in the soil environment.

If we accept the assumption that the depth of travel of each disk is the same, and the number of root crops in each row is constant, then the second supply of soil from k_c rows dug by a combined digger can be determined by the formula

$$M_{k_c s} = \left(V_k - V_{un.c}\right)\rho_s k_c = \left(8\vartheta_d D_s^2 \theta_3 \sin\alpha - V_{un.c}\right)\rho_s k_c, \qquad (31)$$

where $V_{un.c}$ is the volume of underground parts of chicory root crops that lie in the soil environment, m^3; k_c – the number of rows of chicory root crops, which are simultaneously dug up with a spherical disk, pcs.

4. CONCLUSIONS

1. The proposed combined digger of chicory root crops will improve quality indicators of digging root crops, which refer to indicators of completeness of digging, or reduction of losses of root crops and their damage.

2. The obtained analytical dependencies make it possible to substantiate the main parameters of the working body and the parameters of the process of digging chicory roots with a one-sided spherical disk without using numerical methods of calculation, which greatly simplifies the solution of research problems.

3. The results of analytical studies of the dynamic and technological parameters of the process of digging chicory roots with a combined single-disc digger are a further step in improving the methodology and methods of calculating the rational parameters of the spherical disk and the technological parameters of the processes of the root-harvesting machines in general.

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ПРОЦЕС ВИКОПУВАННЯ КОРЕНЕПЛОДІВ ЦИКОРІЮ КОМБІНОВАНИМ КОПАЧЕМ

Максим Гадайчук

Вінницький національний агротехнічний університет, Вінниця, Україна

Резюме. *Серед багатьох видів технічних культур, у тому числі й серед коренеплодів, тільки коренеплідний цикорій забезпечує виробництво стратегічної сировини, з якої, в процесі її переробки, отримують сировинний продукт переробки інулін, з якого в подальшому виробляють важливий лікарський засіб – інсулін. Існуючі технічні засоби збирання коренеплодів цикорію не забезпечують необхідних показників якості викопування коренеплодів згідно з агротехнічними вимогами до корензбиральних машин. При цьому середній показник втрат коренеплодів ставить 3,5…7,5%, залежно від умов збирання, а пошкодження коренеплодів цикорію в 2,5…3,5 раза значення показника агротехнічних вимог. Зменшення втрат коренеплодів і їх пошкодження забезпечується застосуванням комбінованого однодискового сферичного копача, який поєднує в собі сферичний диск і розміщений позаду нього та в зоні його дії розрихлювач, який встановлено на стояку диска. Запропоновано розроблену математичну модель, яка описує переміщення грунтового шару по сферичному диску та дозволяє в аналітичній формі визначати його динамічні характеристики й технологічні параметри процесу викопування коренеплодів. На основі аналізу наведеної графічної інтерпретації встановлено, що зміна секундного подавання маси грунту має лінійний характер – за збільшення швидкості руху диска та кута атаки диска секундна подача збільшується в межах від 8,3 до 24,2 кг/с. Причому, домінантним параметром, який значно впливає на збільшення секундного подавання є кут атаки диска – за збільшення кута атаки в межах від 20 до 35 град. секундне подавання збільшується приблизно в 1,5…1,8 раза. Результати аналітичних досліджень динамічних і технологічних параметрів процесу викопування коренеплодів цикорію комбінованим однодисковим копачем є подальшим кроком удосконалення методології та методики розрахунку раціональних параметрів сферичного диска й технологічних параметрів процесів роботи корензбиральних машин загалом.*

Ключові слова: *коренеплоди, копач, сферичний диск, розрихлювач, шар грунту, переміщення, модель, параметри, швидкість, сила, подавання.*

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