Agraarteadus
1 • XXXII • 2021 92–99

Journal of Agricultural Science
1 • XXXII • 2021 92–99

RESEARCH INTO THE PARAMETERS OF A POTATO HARVESTER'S POTATO HEAP DISTRIBUTOR, AND THE JUSTIFICATION OF THOSE PARAMETERS

Jüri Olt[1], Valerii Adamchuk[2], Viktor Korniushyn[2], Viktor Melnik[3], Hryhoriy Kaletnik[4], Yevhen Ihnatiev[5], Risto Ilves[1]

[1]Estonian University of Life Sciences, Institute of Technology, 56 Kreutzwaldi St., 51006 Tartu, Estonia
[2]National Scientific Centre, Institute for Agricultural Engineering and Electrification, 11 Vokzalna St., Glevakcha 1, Vasylkiv District, UA 08631, Kyiv Region, Ukraine
[3]Kharkiv Petro Vasylenko National Technical University of Agriculture, 44 Alchevskih St., Kharkiv, UA 61002, Ukraine
[4]Vinnytsia National Agrarian University of Ukraine, 3 Soniachna St., UA 21008 Vinnytsia, Ukraine
[5]Dmytro Motornyi Tavria State Agrotechnological University, 18B Khmelnytsky Ave., UA 72310, Melitopol, Zaporozhye Region, Ukraine

Saabunud: Received: 28.05.2021
Aktsepteeritud: Accepted: 22.06.2021

Avaldatud veebis: Published online: 22.06.2021

Vastutav autor: Corresponding author: Jüri Olt
E-mail: jyri.olt@emu.ee

Keywords: clod-crushing, distributor, harvester, heap, potato, rational parameters, rotor, soil separation.

DOI: 10.15159/jas.21.19

ABSTRACT. The low levels of efficiency and general quality when it comes to the use of potato harvesters in difficult soil and climatic conditions substantiate the relevance of the problem which is faced in terms of research by technologically advanced equipment and tools. They are looking to increase the efficiency of potato harvesters. This paper serves to justify the formation of the design and technical parameters of the V-type distributor, which directly acts on the undermined mass to increase the ability of the potato harvester to separate the soil. Preliminary experimental studies have shown that to achieve efficient technological processing in terms of the distribution of the general soil and potato heap, the distributor must possess the appropriate technological and design parameters. Calculations which have been carried out by using as a basis the theoretical dependencies that have been obtained serve to allow us to determine the optimum speed of progress through the heap, using the following design and kinematic parameters: V_{el} = 2.0 m s^{-1}, A = 0.35 m, h_v = 0.22 m, Δ = 0.08 m, b_{el} = 1.2 m. The allowable speed for heap movement will be [V] = 1.62 m s^{-1}, which will ensure the prevention of any heap clogging in front of the distributor. An analysis of the dependencies which have been obtained during the work shows that rational values for the distributor wing's fitting angle fall within the range of α = 40°.

Introduction

Experience in operating potato harvesters shows that they can satisfactorily carry out their required technological processes only when working on favourable soil and in equally favourable climatic conditions (Ruysschaert *et al.,* 2006; Bishop *et al.,* 2012; Ichiki *et al.,* 2013; Lü *et al.,* 2017; Kheiry *et al.,* 2018; Ruzhylo *et al.,* 2020). When working in difficult conditions, harvesters do not provide high-quality potato harvesting and have low levels of efficiency, plus a lack of reliability in terms of the technological processes, and increased losses amongst and damage to tubers, which leads to increased costs in terms of harvesting because the process requires significantly more labour, including the provision of labour input (Misener, McMillan, 1996; Blahovec, Židova, 2004; Bulgakov *et al.,* 2020). Therefore any study of working bodies that can increase the efficiency of potato harvesters is something of an urgent task.

It is possible to improve the quality indicators in potato harvesters by introducing intensifying equipment into the technological scheme, which additionally interacts with the digging layer (Gao *et al.,* 2011; Lü *et al.,* 2015; Wang *et al.,* 2017; Issa *et al.,* 2020). Studies (Feller *et al.,* 1987; Hevko *et al.,* 2016; Feng *et al.,* 2017; Wei *et al.,* 2017; Xin, Liang, 2017; Bulgakov *et al.,* 2018, 2019; Gulati, Singh, 2019) have shown that destroying the digging potato ridge is advisable to be able to carry out dynamic action processes in the digging zone as, in this case, the tubers are protected by the soil from any mechanical damage. One of the more promising avenues of research involves the vertical rotor (Bulgakov *et al.,* 2021). For example rod drums that have been installed between the digger shovel or two wings and the elevator, which, simultaneously to the feeding of the dug mass onto the elevator, serve to destroy the layer and sift out parts of the soil. Research which has been carried out at the National Scientific Centre, the Institute for Agricultural Engineering and Electrification, have shown that when at work (especially in conditions which involved raised humidity levels) and when fitted with digging and separating equipment which consists of a passive digger shovel and rod drums, the potato harvester has an essential area in which it is lacking: the digging layer is not evenly distributed onto the basic separating bar elevator, instead of coming in the form of a compact longitudinal windrow in the central section of the elevator. During further movement, the swathe is partially distributed across the width of the elevator surface, but not to a great enough degree for quality soil separation. As a result, due to the low level of completeness of separation, the level of clogging of tubers in the container is high, which does not meet current agrotechnical requirements. In addition, at such a distribution level of the pile on the elevator, the process of destroying soil clods by balloon-compactors is somewhat unsatisfactory (Petrov, 2004; Pshechenkov *et al.*, 2018).

Experimental studies (Wei *et al.,* 2019a, b) have shown that the intensification of the separation process utilizing uniform distribution of the heap across the width of the elevator web can improve the quality of the results seen in the use of the potato harvester.

The purpose of this study was to justify the design for and technological parameters of the potato pile distributor, which is part of the potato harvesting machine.

Materials and methods

Experimental studies into the use of the harvesting machine (Fig. 1 and 2) and an analysis of the quality of its working processes have shown that, before feeding it into the main elevator, as the digging layer is well-crushed by the rod drums – in this case for the uniform distribution of the heap – a passive operating tool is promising, with that unit being a V-type distributor which directly acts on the dug mass. It consists of two wings that have been turned at a fitting angle of 2α and are located behind the rod drums, above the main rod elevator (conveyor).

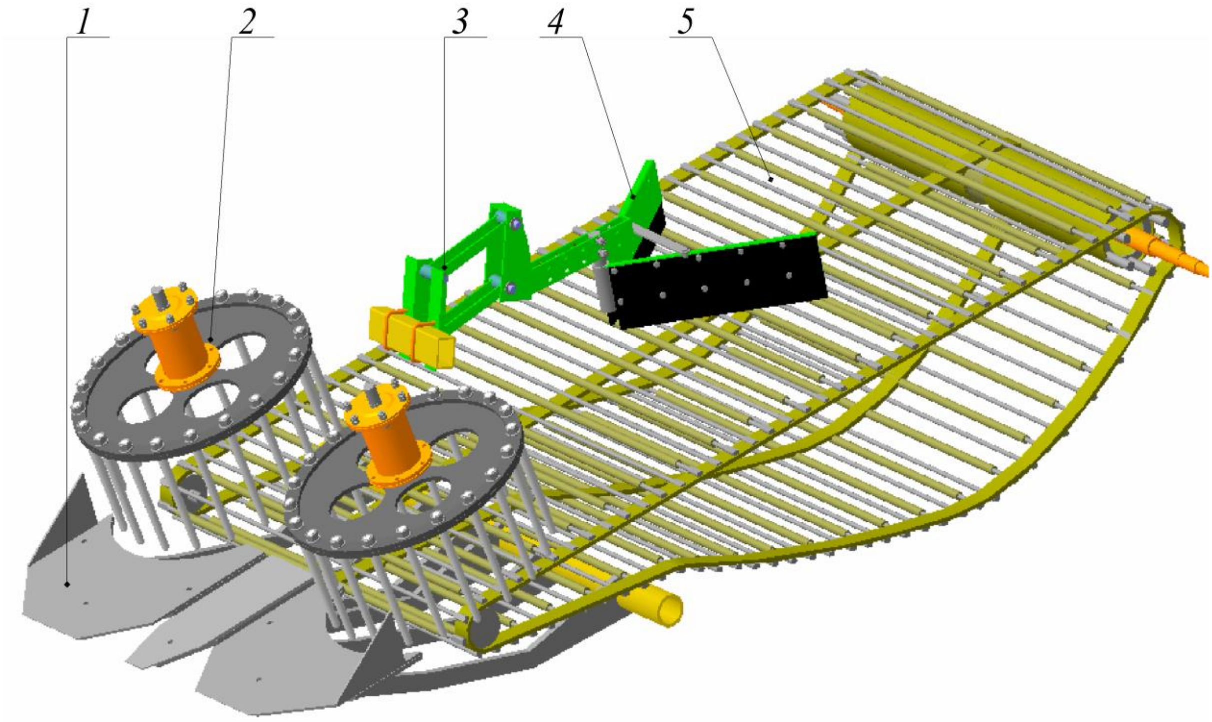

Figure 1. Digging and separating equipment for the potato harvesting machine: 1) digger shovel; 2) rod drum; 3) parallelogram mechanism; 4) distributor; 5) separating elevator

The technological process which is involved in distributor operation is as follows (Fig. 1). The soil and potato heap, undermined by the digger shovel (1), and by bar drums (2), is fed into the elevator (5) and falls onto the distributor (4). Then the flow of the crop moves along the wings of the distributor (4), while some part of the soil will always pass under the distributor because it is set so that it has a gap with respect to the surface of the elevator (5). Therefore, after the distributor (4), we get a layer of the crop that is uniform across the entire width of the elevator (5).

The distributor (4) must have the appropriate technological and design parameters to be able to qualitatively pass any test of the technological process of soil and potato heap distribution.

Figure 2. General view of the pilot potato harvesting machine

The height of the wing on the distributor h is selected based on prevailing conditions, wanting to ensure that the heap does not overshoot the heap through the distributor, while also depending upon the thickness of the layer of the heap h_b, which comes onto the conveyor after passing the rod drums. The thickness of a layer depends upon the depth of the undercutting process for potatoes h_{gr}, parity of the translation speed of the potato harvesting machine V_M, the circumferential speed of the rotation of the rod drums ωR, and the speed of the rod elevator web V_{el}, and also on the separating ability of the drums and transporter.

When considering an unfavourable case in which separation in the section up to the distributor does not occur and the entire crop is fed into the distributor, the conditions in which the height of the wing h is to be selected, taking into account the gap between the conveyor and the distributor ρ, is as follows:

$$h + \Delta > h_v, \tag{1}$$

where:

$$h > h_v - \Delta. \tag{2}$$

The size of the gap Δ is determined by taking into account the following factors: firstly, it is necessary to ensure the free passage of potato tubers between the elevator surface and the distributor; and secondly, the necessary uniform thickness of the pile flow on the elevator needs to be ensured. At the same time, it is also necessary to take into account the amplitude of oscillations in the elevator surface, which are carried out under the influence of shakers.

When taking into account the fact that potato tubers, while moving on the elevator and trying to take up a stable position when the centre of mass of a tuber takes the lowest position, ie. is placed perpendicular to the surface of the elevator thickness or width of the tuber, then the height of the gap Δ must not be less than the greatest width of the potato tuber b_b:

$$\Delta > b_b. \tag{3}$$

The height of the heap flow h_v which arrives at the distributor we can find by equating the second feed from the coulters and the second capacity of the conveyor:

$$Q_{el} = Q_p, \tag{4}$$

where Q_{el} is the conveyor capacity, kg s^{-1}; Q_p is the feed for the digging and separating equipment, kg s^{-1}.

The second feed rate for the digging and separating equipment for a two-row potato harvester can be found according to the formula:

$$Q_p = 2 \cdot S_p \cdot V_m \cdot \rho_p, \tag{5}$$

where S_p is the cross-section of the digging layer, m^2;
V_m is the speed of the harvester, m s^{-1};
ρ_p is the bulk density of the digging layer, kg m^{-3}.

If the contour of the ridge in the cross-section is taken as a parabola, then the cross-section of the digging layer can be determined as follows:

$$S_p = \frac{2}{3} \cdot h_{gr} \cdot l_{gr}. \tag{6}$$

where h_{gr} is the ridge height, m; l_{gr} is the ridge width, m; then:

$$Q_p = \frac{4}{3} h_{gr} \cdot l_{gr} \cdot V_m \cdot \rho_p. \tag{7}$$

Elevator capacity:

$$Q_{el} = S_v \cdot V_{el} \cdot \rho_p, \tag{8}$$

where S_v is the cross-section of the soil and potato heap on the elevator, also:

$$Q_{el} = h_v \cdot A \cdot V_{el} \cdot \rho_p. \tag{9}$$

where h_v is the height of the heap on the elevator, m; A is the width of the web on the elevator, m.

By equating (7) and (9), after transformations we obtain:

$$h_v = \frac{4h_{gr} \cdot l_{gr} \cdot V_m}{3 \cdot A \cdot V_{el}}. \tag{10}$$

The length of the distributor wings l must be long enough to distribute the heap across the entire width of the conveyor belt. In addition, a free zone must be provided at the point at which the heap comes off the wing. The length of the distributor wings l can be determined using the expression:

$$l < \frac{b_{el} - A}{2 \sin \alpha}, \tag{11}$$

where b_{el} is the elevator width; α – wing fitting angle.

The distance between the distributor and the drums affects the technological process because if the distance is too short, the heap will accumulate, blockages may occur, and the heap will not pass through; on the other hand, if the distance is too great, the distribution of the crop starts later, and the separation efficiency levels in the first conveyor will decrease. The greatest size of the heap will form at the beginning of the arrival of the heap onto the wings of the distributor. From Fig. 3 we have:

$$L > h_v \cdot \mathrm{ctg}\left(\varphi_v - \beta_{el}\right), \qquad (12)$$

where φ_v is the angle of the stall of the heap, β_{el} – is the angle of inclination of the elevator.

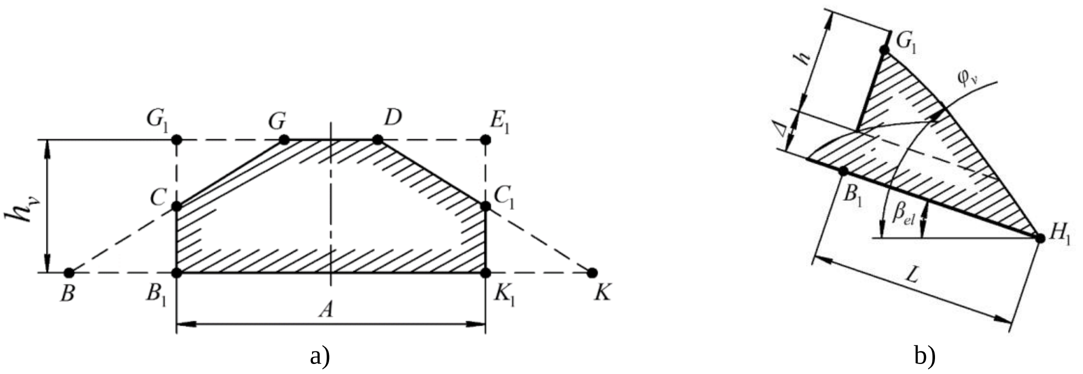

Figure 3. Diagram for calculating the parameters of the distributor: a) the shape of the heap flow coming onto the distributor; b) the shape of the heap flow which moves along the wing of the distributor: *BGDK* is the actual shape of the heap flow; and $B_1G_1E_1K_1$, $B_1G_1H_1$ is calculated from of heap flow

By substituting numerical values into expressions (10), (11), (12) we obtain the following values for the distributor parameters $h > 130$ mm, $l < 400–500$ mm, $\Delta > 80$ mm, $L > 540$ mm.

The main parameter for the distributor is the angle of the wings. Any incorrect choice of angle will lead either to a bunching of the heap in front of the distributor and, as a consequence, to a failure of the technological processes involved in automated operations, or to the fact that the crop will not be distributed across the width of the conveyor belt. To justify the angle being used in the distributor solution, a theoretical analysis needs to be carried out of crop movement on the working surfaces of the distributor and the separating conveyor.

Consider the interaction of a particle of the flow of the soil and potato heap, which moves along on the conveyor belt, with the wing of the distributor (Fig. 4). From this, a coordinate system can be drawn up, the beginning of which is connected with the nose of the distributor. The *Ox*-axis is directed in a direction that is perpendicular to the surface of the distributor; the *Oy*-axis is directed perpendicularly to the plane of the conveyor belt; the *Z*-axis is directed along the direction of flow of the crop through the distributor. On the proposed particle, the following forces will act: the gravitational force *G* (weight) of the particle on the heap, the normal reaction N_1 of the conveyor surface, the normal reaction N_2 of the spreader surface, the friction force F_1 in terms of sliding the particle along on the conveyor, the combined friction force F_2 in terms of sliding the particle on the heap along on the spreader on the axis *Oy*, and with F_3 being the combined friction-force-sliding of the heap particles on the spreader along the *Oz*-axis so that the force *P* comes from surface vibrations of the conveyor due to the shaking mechanism.

The equations regarding motion in the heap particle in vector form will be as follows:

$$m\bar{a} = \bar{G} + \bar{N}_1 + \bar{N}_2 + \bar{F}_1 + \bar{F}_2 + \bar{F}_3 + \bar{P}\,, \qquad (13)$$

where $G = mg$ is the gravity of a particle of the heap mass *m*;

$N_1 = mg \cdot \cos\beta_{el}$ is the normal reaction of the elevator surface;

N_2 is the normal reaction of the distributor surface;

$F_1 = N_1 \cdot f_1$ is the sliding friction force of the heap particle on the elevator, where f_1 is the coefficient of the sliding friction of the soil and potato heap on the elevator surface;

$F_2 = N_2 f_2$ is the component of the particle's sliding friction force on the distributor along the *Oy* axis, where f_2 is the coefficient of friction of the heap sliding along on the surface of the distributor;

$F_3 = N_2 \cdot f_2$ is the component of the sliding friction force of the heap particle on the distributor along the axis *Oz*;

$P = m \cdot \omega_{el}^2 \cdot A_{el} \cdot \sin\left(\psi_0 + \psi_f + \omega_{el} t\right)$ is the force from the vibrations of the conveyor belt when the shaking mechanism has been activated (we assume that harmonic vibrations occur perpendicular to the surface of the conveyor belt, while the amplitude of vibrations along the entire length of the conveyor belt is the same), where A_{el} is the vibration amplitude of the conveyor, and ψ_0 is the initial position relative to the zero amplitude (min); ψ_f is the phase shift (angular parameter), and ω_{el} is the frequency of elevator oscillations, rad s^{-1}.

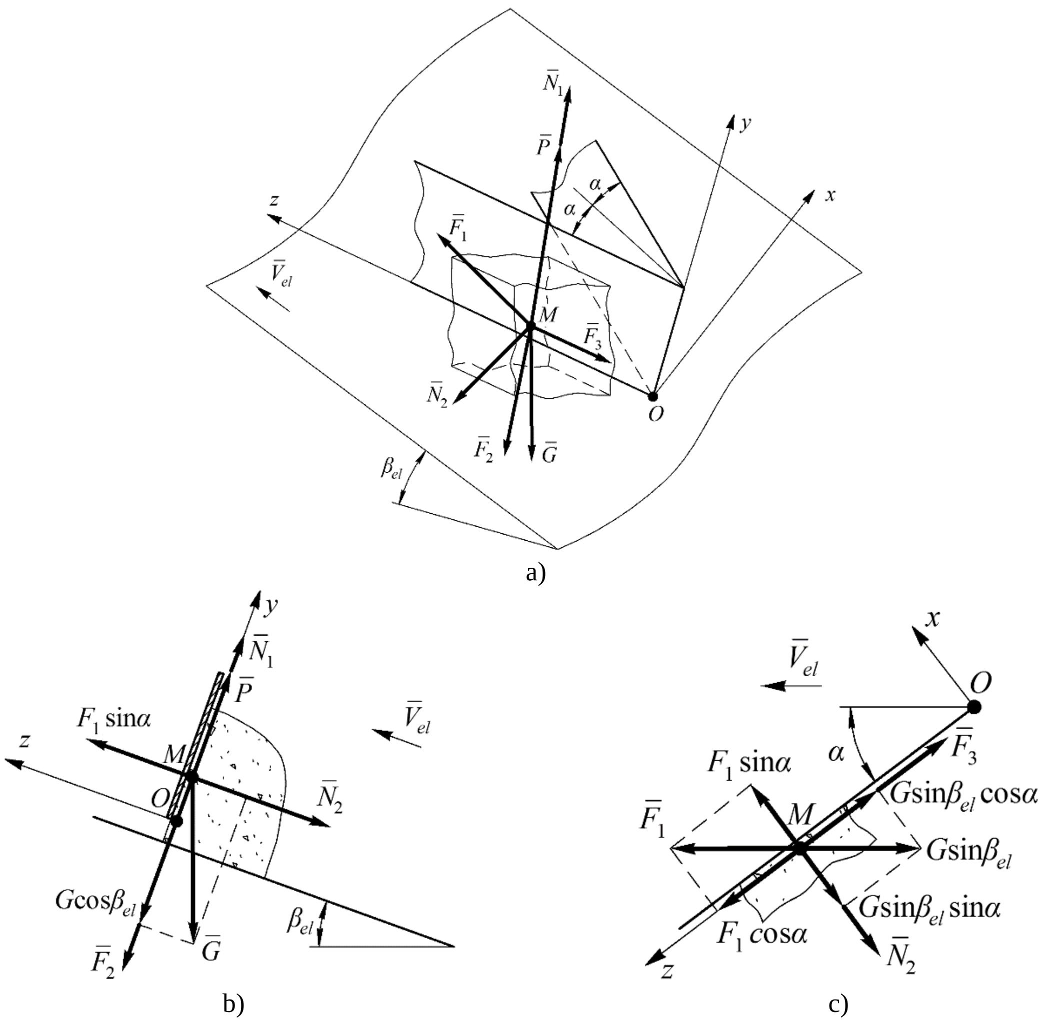

Figure 4. Schematic of interaction between the heap and the distributor: a) general view; b) view along the *yOz* plane; and c) view along the *zOx* plane

In projections onto the axes of the chosen coordinate system, the equations look like this:

$$m\ddot{x} = -N_2 + F_1 \cdot \sin\alpha - G \cdot \sin\beta_{el} \cdot \sin\alpha , \tag{14}$$

$$m\ddot{y} = N_1 + P - G \cdot \cos\beta_{el} - F_2 , \tag{15}$$

$$m\ddot{z} = -F_3 + F_1 \cdot \cos\alpha - G \cdot \sin\beta_{el} \cdot \cos\alpha , \tag{16}$$

while after the transformation the result is this:

$$m\ddot{x} = -N_2 + f_1 \cdot mg \cdot \cos\beta_{el} \cdot \sin\alpha - mg \cdot \sin\beta_{el} \cdot \sin\alpha , \tag{17}$$

$$m\ddot{y} = mg \cdot \cos\beta_{el} + m \cdot \omega_{el}^2 \cdot A_{el} \cdot \sin\left(\psi_0 + \psi_f + \omega_{el} \cdot t\right) - mg \cdot \cos\beta_{el} - f_2 \cdot N_2 , \tag{18}$$

$$m\ddot{z} = -f_2 \cdot N_2 + f_1 \cdot mg \cdot \cos\beta_{el} \cdot \cos\alpha - mg \cdot \sin\beta_{el} \cdot \cos\alpha , \tag{19}$$

In this system of differential equations, the unknown value of the reaction is N_2.
Since there is no motion along the *Ox*-axis, that is $\ddot{x} = 0$, then:

$$0 = -N_2 + f_1 \cdot mg \cdot \cos\beta_{el} \cdot \sin\alpha - mg \cdot \sin\beta_{el} \cdot \sin\alpha , \tag{20}$$

from:

$$N_2 = f_1 \cdot mg \cdot \cos\beta_{el} \cdot \sin\alpha - mg \cdot \sin\beta_{el} \cdot \sin\alpha . \tag{21}$$

After the substitution of force values, plus simplifications and transformations, the equations (14–16) look like this:

$$\ddot{x} = 0\,, \tag{22}$$

$$\ddot{y} = \omega_{el}^2 A_{el} \cdot \sin\left(\psi_0 + \psi_f + \omega_{el} \cdot t\right) - f_2 \cdot g \cdot \sin\alpha \left(f_1 \cdot \cos\beta_{el} - \sin\beta_{el} \right), \tag{23}$$

$$\ddot{z} = g\left[f_1 \cos\beta_{el} \cos\alpha - \sin\beta_{el} \cos\alpha - f_2 \sin\alpha \left(f_1 \cos\beta_{el} - \sin\beta_{el} \right)\right]. \tag{24}$$

The particle velocity projections of the heap will be found by integrating equation (22–24) under initial conditions t = 0: $\dot{x} = 0$, $\dot{y} = 0$:

$$V_0 = 0\,, \tag{25}$$

$$V_y = - f_2 \cdot g \cdot \sin\alpha \left(f_1 \cdot \cos\beta_{el} - \sin\beta_{el} \right) \cdot t - \omega_{el} \cdot A_{el} \cdot \cos\left(\omega_{el} \cdot t\right), \tag{26}$$

$$V_z = g \cdot t \left[\left(\cos\alpha - f_2 \cdot \sin\alpha\right) \cdot \left(f_1 \cdot \cos\beta_{el} - \sin\beta_{el} \right) \right] + V_{el} \cdot \cos\alpha\,. \tag{27}$$

The particle speed of the heap along the distributor's wing is:

$$V = \sqrt{V_x^2 + V_y^2 + V_z^2}\,. \tag{28}$$

The displacement of the heap particle can be found by integrating equations (25-27) under initial conditions t = 0: $x = 0$, $y = 0$, $z = 0$:

$$X = 0\,, \tag{29}$$

$$Y = - f_2 \cdot g \cdot \sin\alpha \left(f_1 \cdot \cos\beta_{el} - \sin\beta_{el} \right) \cdot \frac{t^2}{2} - \omega_{el} \cdot A_{el} \cdot \sin\left(\omega_{el} \cdot t\right), \tag{30}$$

$$Z = \frac{g \cdot t^2}{2} \left[\left(\cos\alpha - f_2 \cdot \sin\alpha\right) \cdot \left(f_1 \cdot \cos\beta_{el} - \sin\beta_{el} \right) \right] + V_{el} \cdot \cos\alpha \cdot t\,. \tag{31}$$

Results

Using the obtained expressions (25–27) and (29–31), we can describe the motion of the heap on the distributor's wing.

Using expression (28), we plotted the time dependence of the heap speed V on the distributor's wing at different values of the wing fitting angle α (Fig. 5).

An analysis of graphic dependences shows that the speed of the soil and potato heap movement along the wing decreases with an increase of the angle α. When speed V decreases less than the permissible value $[V]$, the heap will unload onto the distributor, which will result in a violation of the machinery's technological process, that is, the condition must be fulfilled $V \geq [V]$.

The allowable speed of rotation of the heap, taking into account the process of the distribution of the heap across the width of the elevator web, can be found from the condition of equality in the heap flow into the distributor and its descent from the distributor:

$$\Delta \cdot b_{el} \left[V\right] = A \cdot h_v \cdot V_{el}\,, \tag{32}$$

where $[V]$ is the allowable speed of heap movement along the distributor's wing, m·s^{-1}.

Consequently, the speed of the soil and potato heap along the distributor's wing should not be less than the value:

$$\left[V\right] = \frac{A \cdot h_v \cdot V_{el}}{\Delta \cdot b_{el}}\,. \tag{33}$$

At the given V_{el} = 2.0 m·s^{-1}, A = 0.35 m, h_b = 0.22 m, Δ = 0.08 m, b_{el} = 1.2 m the permissible speed of soil and potato heap movement is $[V]$ = 1.62m·s^{-1}.

An analysis of the obtained dependencies shows that the rational values of the distributor's wing fitting angle fall within the range α = 40°.

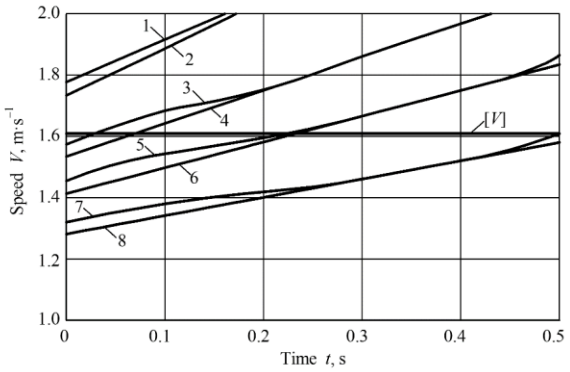

Figure 5. Dependence of heap speed along the distributor's wing V on time t at different values of the wing fitting angle α (at $f_1 = f_2 = 0.55$, $\beta_{el} = 22°$):
1 – $\alpha = 30°$ ($\omega_{el} = 4$ rad s^{-1}, $A_{el} = 0.05$ m);
2 – $\alpha = 30°$ ($\omega_{el} = 0$, $A_{el} = 0$);
3 – $\alpha = 40°$ ($\omega_{el} = 4$ rad s^{-1}, $A_{el} = 0.05$ m);
4 – $\alpha = 40°$ ($\omega_{el} = 0$, $A_{el} = 0$);
5 – $\alpha = 45°$ ($\omega_{el} = 4$ rad s^{-1}, $A_{el} = 0.05$ m);
6 – $\alpha = 30°$ ($\omega_{el} = 0$, $A_{el} = 0$);
7 – $\alpha = 50°$ ($\omega_{el} = 4$ rad s^{-1}, $A_{el} = 0.0$ m);
8 – $\alpha = 50°$ ($\omega_{el} = 0$, $A_{el} = 0$)

Conclusions

1. The analytical dependences are obtained, which allow a determination to be made of the basic design and technological parameters of the distributor which is part of the digging and separating equipment of a potato harvesting machine.
2. Modelling the processes of soil and potato heap movement concerning the real design and kinematic parameters made it possible to determine the allowable speed of heap movement $[V] = 1.62$ m s^{-1}, which ensures the prevention of heap clogging in front of the distributor.
3. As a result of the application and analysis of the graphical dependencies for the mathematical model which has been obtained, it was determined that the rational values for the wing fitting angle of the distributor fall within the range of $\alpha = 40°$.

Conflict of interest

The authors declare no conflict of interest, financial or otherwise.

Author contributions

VA, JO, VK – study conception and design;
JO, VK – drafting of the manuscript;
VA, VK, JO, RI – analysis and interpretation of data;
VK, VM, HK, YI – acquisition of data;
JO – critical revision and approval of the final manuscript.

References

Bishop, C., Rees, D., Cheema, M.U.A., Harper, G., Stroud, G. 2012. Potatoes. – In Crop Post-Harvest: Science and Technology: Volume 3: Perishables. (Eds. D. Rees, G. Farrell, J. Orchard). Wiley-Blackwell: Chichester, West-Sussex, UK, pp. 334–359.

Blahovec, J., Židova, J. 2004. Potato bruise spot sensitivity dependence on regimes of cultivation. – Research in Agricultural Engineering, 50(3):89–95. DOI: 10.17221/4932.RAE

Bulgakov, V., Bonchik, V., Holovach, I., Fedosiy, I., Volskiy, V., Melnik, V., Ihnatiev, Ye., Olt, J. 2021. Justification of parameters for novel rotary potato harvesting machine. – Agronomy Research, 19(S3): 984–1007. DOI: 10.15159/AR.21.079

Bulgakov, V., Holovach, I., Ruzhylo, Z., Fedosiy, I., Ihnatiev, Ye., Olt, J. 2020. Theory of oscillations performed by tools in spiral potato separator. – Agronomy Research, 18(1):38–52, DOI: 10.15159/AR.20.058

Bulgakov, V., Nikolaenko, S., Adamchuk, V., Ruzhylo, Z., Olt, J. 2018. Mathematical model of cleaning potatoes on surface of spiral separator. – Agronomy Research, 16(4):1590–1606, DOI: 10.15159/AR.18.173

Bulgakov, V., Pascuzzi, S., Nikolaenko, S., Santoro, F., Anifantis, A.S., Olt, J. 2019. Theoretical study on sieving of potato heap elements in spiral separator. – Agronomy Research, 17(1):33–48, DOI: 10.15159/AR.19.073.

Feller, R., Margolin, E., Hetzroni, A., Galili, N. 1987. Impingement angle and product interference effects on clod separation. – Transactions of the American Society of Agricultural Engineers, 30(2):357–360.

Feng, B., Sun, W., Shi, L., Sun B., Zhang, T., Wu, J. 2017. Determination of restitution coefficient of potato tubers collision in harvest and analysis of its influence factors. – Nongye Gongcheng Xuebao/ Transactions of the Chinese Society of Agricultural Engineering, 33(13):50–57.

Gao, G., Zhang, D., Liu, J. 2011. Design of a new soil-tuber separation device on potato harvesters. – CCTA 2010: Computer and Computing Technologies in Agriculture, IV:604– 612. DOI: 10.1007/978-3-642-18354-6_71

Gulati, S., Singh, M. 2019. Design and development of two row tractor operated potato combine harvester. – Potato Journal, 46(1):81–85.

Hevko, R.B., Tkachenko, I.G., Synii, S.V., Flonts, I.V. 2016. Development of design and investigation of operation process of small-scale root crop and potato harvesters. – INMATEH-Agricultural Engineering, 49(2):53–60.

Ichiki, H., Nguyen Van, N., Yoshinaga, K. 2013. Stone-clod separation and its application to potato in Hokkaido. – Engineering in Agriculture Environment and Food, 6(2):77–85.

Issa, I.I.M., Zhang, Z., El-Kolaly, W., Yang, X., Wang, H. 2020. Design, ANSYS analysis and performance evaluation of potato digger harvester. – International Agricultural Engineering Journal, 29(1):60–73.

Kheiry, A.N.O., Elssir, A., Rahma, A.E., Mohamed, M.A., Omer, E.A., Gong H.J., Liwei, Y. 2018. Effect of operation variables of potato digger with double chain conveyors on crop handling and machine performance. – International Journal of Environmental & Agricultural Research, 4(6):87–101.

Lü, J.Q., Sun, H., Dui, H., Peng, M.M., Yu, J.Y. 2017. Design and experiment on conveyor separation device of potato digger under heavy soil condition. – Transactions of the CSAM, 48(11):146–155. (In Chinese)

Lü, J.Q., Tian, Z.E., Yang, Y., Shang, Q.Q., Wu, J.E. 2015. Design and experimental analysis of 4U2A type double-row potato digger. – Transactions of the CSAE, 31(6):17–24 (in Chinese).

Misener, G.C., McMillan, L.P. 1996. A belt-roller mechanism for soil clod reduction on potato harvester. – Canadian Agricultural Engineering, 38(4):311–314.

Pshechenkov, K.A., Maltsev, S.V., Smirnov, A.V. 2018. Technology of potatoes combine harvesting on loamy soils in the Central region of Russia. – Potato and Vegetables, 4:19–21. (In Russian)

Petrov, G. 2004. Potato harvesting machines. – Mashinostroenije / Mechanical Engineering, Moskow, Russia, 320 pp. (In Russian)

Ruysschaert, G., Poesen, J., Verstraeten, G., Govers, G. 2006. Soil losses due to mechanized potato harvesting. – Soil & Tillage Research, 86(1):52–72. DOI: 10.1016/j.still.2005.02.016

Ruzhylo, Z., Bulgakov, B., Adamchuk, V., Bondarchuk, A., Ihnatiev, Y., Krutyakova, V., Olt, J. 2020. Experimental research into impact of kinematic and design parameters of a spiral potato separator on quality of plant residues and soil separation. – Agraarteadus, 31(2):202–207. DOI: 10.15159/ jas.20.26

Wang, X., Sun, J., Xu, Y., Li, X., Cheng, P. 2017. Design and experiment of potato cleaning and sorting machine. – Nongye Jixie Xuebao/Transactions of the Chinese Society for Agricultural Machinery, 48(10):316–322 and 279.

Wei, Z., Li, X., Sun, C. 2017. Analysis of potato mechanical damage in harvesting and cleaning and sorting storage. – Journal of Agricultural Science and Technology, 19(8):63–70. DOI: 10.6041/j.issn.1000-1298.2019.01.014.

Wei, Z., Li, H., Sun, C., Li, X., Su, G., Liu, W. 2019a. Design and experiment of potato combined harvester based on multi-stage separation technology. – Nongye Jixie Xuebao/Transactions of the Chinese Society for Agricultural Machinery, 50(1):129–140. DOI: 10.6041/j.jssn.1000-1298.2019.01.014

Wei, Z., Li, H., Sun, C., Su, G., Liu, W., Li, Z. 2019b. Experiments and analysis of a conveying device for soil separation and clod-crushing for a potato harvester. – Applied Engineering in Agriculture 35(6):987–996. DOI: 10.13031/aea.13283

Xin, L., Liang, J. 2017. Design of potato harvester. – Journal of Mechanical Engineering Research and Developments, 40(2):380–384.