THEORETICAL INVESTIGATION OF MOVEMENT OF ROUND-SHAPE TABLE BEET ROOTS INSIDE SPIRAL VIBRATION TYPE CLEANER

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Abstract. An urgent issue in the technological process of table beet production is the cleaning of root crops from adhered soil, loose impurities, and plant residues after harvesting. This study develops a mathematical model for the movement of a table beet root along the working channel of a newly designed spiral vibrating cleaner. During such movement, the cleaning of root crops from the aforementioned impurities occurs. Based on the equivalent scheme, developed in this article, there was constructed a system of differential equations, describing the movement of the table beet roots along the working surface of the spiral cleaner. A key feature of the design is that the contact between the root crop and the spiral coils occurs at two points, ensuring stable movement and cleaning. The solution of the system of differential equations, obtained on a computer, enables the study of the impact of the structural and kinematic parameters of the cleaner upon the speed of the root crop movement along the working channel until it exits the spirals. The identified structural and kinematic parameters will improve the cleaning quality of the table beet root crops from the soil impurities and plant residues. This article examines a novel design of a spiral vibrating cleaner for cleaning table beet roots. There is proposed a mathematical model of the process of the root crop movement in the working channel of the cleaner, formed by cantilever spiral springs. There was obtained a system of differential equations, describing the movement of the table beet roots under the impact of the spiral coils, allowing for the determination of the effect of the cleaner's structural and kinematic parameters on the transportation speed of the mass along the working surface. It was established that the proposed model enables the calculated determination of optimal structural parameters and operating modes of the spiral cleaner, as well as predictions regarding its performance and cleaning quality. The research conducted provides the foundation for further improvement of separator designs and increased efficiency of the root crop cleaning process.

Keywords: mathematical model, vibrational cleaner, beet root, spiral movement, cleaning process, differential equations, design parameters, kinematic parameters.

Introduction

Table beet root is an indispensable food product and has significant medicinal properties, proven by centuries of experience. It occupies one of the leading places among the agricultural crops in terms of a nutrient content [1]. Beet roots are characterized by high shelf life, which allows them to be used fresh all year round. Table beets contain many useful substances, vitamins and microelements that promote metabolism, cell growth and haematopoiesis [1; 2]. The production of table beets should be expanded in all developed agricultural countries.

One of the main problems in high-tech cultivation of beet roots is harvesting. Despite the fact that table beets are a root crop and there are some specially designed combines (mainly of the top-lifting type) for its harvesting; however, the beet harvesting machines for digging sugar or fodder beet roots from the soil can also be successfully used for this process [3]. These harvesting machines are used due to the fact that, as a rule, at the time of harvesting table beets, although their tops may be juicy and green, most of the leaves may be dry and lodged, especially on the lateral parts of the root heads. Therefore, the most common type of harvesting is one in which, from the very beginning, a separate top-harvesting machine cuts off the green mass of the tops from the heads of root crops. After this a separate root harvesting machine is used to harvest the table beet roots by digging them out of the soil and then cleaning them from impurities inside this root harvesting machine.

However, the beet roots have a number of specific features that require appropriate approaches when harvesting. The main peculiarity of the table beet roots is their weight and shape, the shape being one of the most important varietal features of the table beet root. Many years of special research have shown that, generally, the root crops of smaller weight have the highest nutritional properties, as well as the presence of a significantly greater number of vitamins than root crops of increased weight. As for the shape of the root crops, the most common shapes are oval-cylindrical (in the form of oblong cylinders with hemispheres at the ends), as well as round, in most cases in the form of regular spherical ones. There are also other shapes, such as conical, which is more typical of sugar beets. Figure 1 shows the most typical shapes of the table beet roots that they reach at the time of harvesting [1].

a) b) c)

Fig. 1. **Most common shapes of table beet root bodies before harvesting:**
a – oval-cylindrical; b – round; c – sample of a root crop of a regular geometric shape

As for the weight of the table beet roots, to be dug out of the soil for industrially grown varieties, it is, on average, within the range of 0.15-0.80 kg. Sometimes bigger root crops also grow. The average length of the root crop (cylindrical shape) reaches 12-15 cm, diameter – 5-10 cm. The yield of the table beet per hectare reaches 35-50 t.

Further research is needed to determine the conditions under which the movement of the table beet roots occurs within their cleaning channels when additional vibrations are applied to them, which will generally make it possible to select the most favourable kinematic modes for vibratory cleaning of the root crops from impurities.

The purpose of the investigation: using mathematical modelling, to determine the conditions for guaranteed movement and cleaning of round-shaped table beetroots inside the cleaning channels of the new spiral cleaner.

Materials and methods

The use of a separated method of harvesting beet roots requires the use of special cleaners when cleaning the root crops dug out of the soil, which would ensure the best performance in capturing and removing large soil lumps, fine soil, rhizomes and other plant residues from the cleaner. In addition, it is important that the spherical surfaces of the table beet roots of this shape must be efficiently cleaned of the adhering soil, which must then also be removed outside the cleaner. Besides, such cleaning should be provided for root crops of the above-mentioned shapes (oval-cylindrical and round). It may seem that the round shape of the beet roots is very similar to the shape of the potato tubers, and the potato peelers may be quite suitable for cleaning beet roots from impurities [3-8]. However, it is necessary to keep in mind that in most cases the outer surfaces of the potato tubers contain depressions of various (rather irregular) sizes, and locations on the outer parts themselves, in which the remains of "eyes" may be located, i.e. the remains of rhizomes, whereas the roots of table beets, which are precisely round in shape, shown in view c, Fig. 1, have a perfectly smooth surface. It is also necessary to ensure conditions under which, when cleaning round beet roots from impurities, damage does not occur, which may be in the form of mechanical destruction of the outer surfaces, i.e. scratches, chips, abrasions, strong impacts, which, even without destruction of the outer surface, can deform the body of the root crop to a significant depth. This is necessary to ensure long-term storage of the harvested beet table roots.

It was established by our numerous experimental investigations that the most suitable cleaner for removing impurities may be a spiral vibration cleaner. This cleaner demonstrated a good ability to capture and remove any impurities from a dug-up pile of potato tubers without damaging the tubers themselves [9; 10]. This is explained by the fact that the use of helical springs for cleaning, i.e. the spirals, provide high transport capabilities when part of the tuber gets into the inter-turn space, and the springs themselves have significant separating gaps (i.e. the distance between the turns of the spirals) through which the soil impurities and plant residues fall freely downwards under the action of their own weight beyond the cleaner. If the adjacent spiral springs are placed in such a cleaner close enough to one another, or even with a slight mutual overlap (when the spring windings touch or enter the outer inter-turn spaces for short distances), then self-cleaning of the cleaning spirals from adhering soil is ensured. If, in addition, we add the vibration of the cleaning spirals themselves, the advantages of this cleaner are more than obvious. However, the use of a spiral-vibration cleaner for round-shaped table beet roots requires some changes in both design and technical and technological parameters [11].

Previously a design of a spiral-vibration cleaner for various root crops was developed, which has a number of design improvements. Besides, this design has undergone comprehensive testing and laboratory investigations. Based on the results of further theoretical studies, the kinematic operating modes were refined. Similar studies were conducted to clean potatoes from the soil and plant impurities and are presented in [12; 13]. Previously theoretical studies were conducted on the movement of the table beet root crops, which have an oval-cylindrical shape, inside a spiral-vibration cleaner [14].

Results and discussion

A team of authors designed and manufactured an experimental prototype of a cleaner for removing the soil impurities and plant residues from the table beet roots dug out of the soil, taking into account that the root crops will have a round shape. Fig. 2 shows the structural diagram of this cleaner, which is a spiral vibration type impurity separator, and which is inserted inside an experimental setup used to conduct the laboratory research.

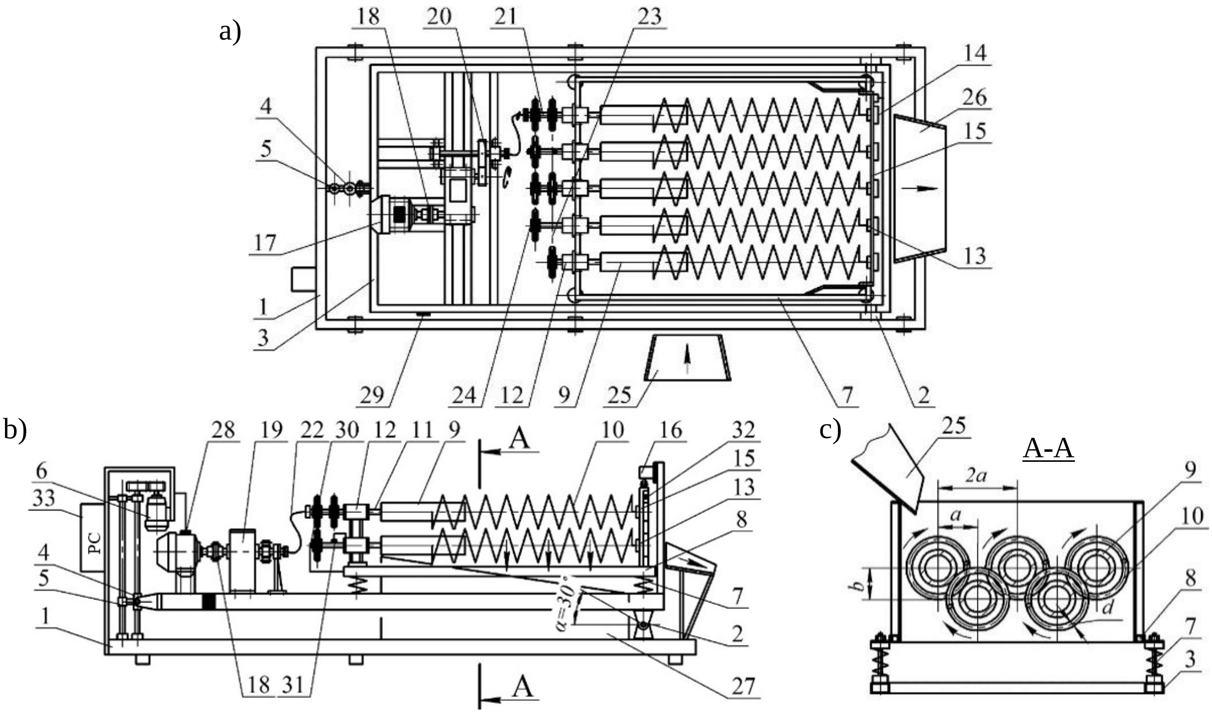

Fig. 2. **Structural diagram of a vibrational spiral type cleaner for removing soil impurities and plant residues from table beet roots dug out of the soil:** a – top view; b – lateral view; c – view of the cross section, labeled A-A in view b; 1 – supporting frame; 2 – pivotal axis; 3 – additional frame; 4 – adjusting screw connection; 5 – vertical stand for moving the screw connection; 6 – electric motor for driving the cleaning spirals; 7 – springs: 8 – base for the cleaning spirals; 9 – spiral drive shafts; 10 – cleaning spirals, forming two upper cleaning channels; 11 – shanks on which the spiral drive shafts are fixed; 12 – bearing units of the spiral drive shafts; 13 – shanks of the ends of the cleaning spirals; 14 – supports for the ends of the spirals; 15 – movable connecting bracket; 16 – mechanism of the vibration drive; 17 – electric motor for driving the vibration mechanism; 18 – connecting device; 19 – gearbox; 20 – toothed connection; 21 – drive shaft of the vibration mechanism; 22 – connecting shaft in the form of a flexible element; 23, 24 – drive elements; 25 – container, used for feeding root crops for cleaning; 26 – container for collecting cleaned root crops: 27 – containers for collecting admixtures; 28-32 – electronic devices (sensors) for recording the movements and vibrations; 33 – personal computer

In addition, *a* and *b* are the horizontal and vertical distances between the centres of the adjacent cleaning spirals 10, which allow having two cleaning channels on top 2, a is the width of the upper part of the cleaning channel; *d* is the thickness of the windings of the cleaning spirals 10; $\alpha = 30°$ is the maximum angle by which it is possible to change the position of the cleaning spirals in the longitudinal-vertical plane. The directions of rotational movements of the cleaning spirals 10, as well as the forward movements of the bodies of the root crops and impurities are shown by arrows.

The cleaning of the table beet root crops takes place inside the longitudinal cleaning channels, formed by the cleaning spirals 10, which are set in motion by the vibrator 16 (Fig. 2). To construct a mathematical model of the movement of the root crop along the axis of the spiral, it is necessary to develop an equivalent circuit, considering the probable location of the root crop in the working channel (Fig. 3). In this case, the root crop contacts the lower spiral 1 at two points K_1 and K_2, and spirals 2 and 3 do not contact it until a root crop of a larger diameter appears. The rotation of the spiral 1 causes the root crop to move along the working surface, ensuring the separation of impurities through the gaps between the windings under the action of the gravity force and vibration. The vibration processes enhance the removal of impurities outside the cleaner.

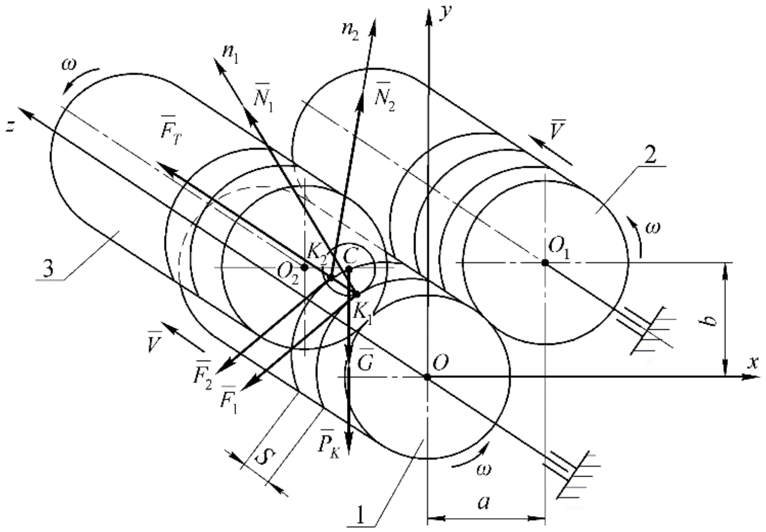

Fig. 3. **Equivalent diagram of interaction of a round table beet root with the windings of the cleaning spirals of the vibration cleaner**

The process of transporting a round-shaped table beet root by the cleaning spiral occurs in such a way that the windings of the spiral 1 at the contact points K_1 and K_2 slide along its surface, dragging the root crop into progressive movement along the working channel until it leaves it. The cleaning of root crops from the soil and plant residues is carried out by separating the impurities through the inter-winding space of the spirals due to the vibrations of the cantilever springs. These vibrations briefly throw up the root crops, effectively knocking off the stuck soil. The main movement of the root crop is a progressive movement along the axes of the spirals, which ensures transportation of the heap. The main movement of the root crop is progressive movement along the axes of the spirals, which ensures transportation. It is necessary to theoretically investigate the process of movement of the root crop along the axis of the spiral to ensure its passage through the cleansing working body. As shown in the equivalent diagram, the lower part of the root crop is located between two windings of the spiral 1. The first winding (point K_1) pushes the root crop, and the second (point K_2) supports it. Next, all the forces that act upon the root crop during its movement due to the cleaning spiral were determined and shown on the equivalent diagram. At each point of contact K_1 and K_2, there act normal reactions, directed along the normals to the surface of the windings. At the centre of mass of the root crop (point *C*) its gravity is applied, directed vertically downwards. There are also shown the friction forces that arise when the spiral windings slip along the surface of the root crop. These forces are directed in the direction of rotation of the spiral.

To ensure the movement of the root crop along the axis of the spiral, a driving force is applied at the contact point K_1. This force is directed parallel to the axis of the spiral. There is also shown the active force, applied to the spiral cleaner, causing transverse vibrations of the spirals.

To compile differential equations of the root crop movement, a fixed spatial Cartesian coordinate system *xOyz* was chosen, the origin of which is located on the longitudinal axis of the spiral 1 (Fig. 3).

Considering the force diagram, shown in the equivalent diagram, using the fundamental law of the dynamics of a material point, the equation of the movement of a round table beet root was written in the form of the following vector equality:

$$m \cdot \frac{d\bar{V}}{dt} = \bar{F}_1 + \bar{F}_2 + \bar{F}_T + \bar{N}_1 + \bar{N}_2 + \bar{G} + \bar{P}_K, \tag{1}$$

where m – mass of the round table beet root;

$\frac{d\bar{V}}{dt}$ – acceleration with which a root crop of a particular shape is moving inside the spiral cleaner;

$\bar{F}_1$, $\bar{F}_2$, $\bar{F}_T$, $\bar{N}_1$, $\bar{N}_2$, $\bar{G}$ and $\bar{P}_K$ – forces, applied to the body of a round root crop causing it to move along the cleaning spiral.

Vector equation (1) in projections onto the axes of the Cartesian coordinate system *xOyz* was presented in the form of the following system of differential equations:

$$\left.\begin{aligned} m \cdot \frac{d^2x}{dt^2} &= N_1 \cdot \cos\alpha_{1x} + N_2 \cdot \cos\alpha_{2x} - F_1 \cdot \cos\beta_{1x} - F_2 \cdot \cos\beta_{2x}, \\ m \cdot \frac{d^2y}{dt^2} &= N_1 \cdot \cos\alpha_{1y} + N_2 \cdot \cos\alpha_{2y} - F_1 \cdot \cos\beta_{1y} - F_2 \cdot \cos\beta_{2y} - G - P_K, \\ m \cdot \frac{d^2z}{dt^2} &= N_1 \cdot \cos\alpha_{1z} + N_2 \cdot \cos\alpha_{2z} - F_1 \cdot \cos\beta_{1z} - F_2 \cdot \cos\beta_{2z} + F_T, \end{aligned}\right\} \tag{2}$$

where α_{1x} – angle between normal $\bar{n}_1$ and axis x;

α_{2x} – angle between normal $\bar{n}_2$ and axis x;

α_{1y} – angle between normal $\bar{n}_1$ and axis y;

α_{2y} – angle between normal $\bar{n}_2$ and axis y;

α_{1z} – angle between normal $\bar{n}_1$ and axis z;

α_{2z} – angle between normal $\bar{n}_2$ and axis z;

β_{1x} – angle between the velocity vector $\bar{V}_1$ and axis;

β_{2x} – angle between the velocity vector $\bar{V}_2$ and axis;

β_{1y} – angle between the velocity vector $\bar{V}_1$ and axis y;

β_{2y} – angle between the velocity vector $\bar{V}_2$ and axis y;

β_{1z} – angle between the velocity vector $\bar{V}_1$and axix z;

β_{2z} – angle between the velocity vector $\bar{V}_2$ and axis z;

$\bar{V}_1$ and $\bar{V}_2$ – vectors denoting the velocities in the relative motion of the body of the round root crop, which are also applied at the contact points K_1 and K_2 and have directions along each tangent, which is drawn relative to the surface of the winding in the direction opposite to the linear velocity of the winding itself at these same contact points.

In addition, $\bar{n}_1$ and $\bar{n}_2$ are normals that are drawn to the outer surface of the spiral windings, the beginning of which coincides with points K_1 and K_2 of contact of the root crop with the spiral.

For further transformation of the system of differential equations (2), it is necessary to find the unknown values, which in this case are the direction cosines. This can be accomplished by using the recommendations given in [15]; it was convenient to present them in a parametric form. For this purpose, parametric equations of the helical line were used [16].

Having performed the necessary transformations, the values of all direction cosines were obtained under these conditions in the spatial Descartian coordinate system, in the following parametric form:

$$\cos\alpha_{1x} = \cos\alpha_{2x} = \left(M \cdot \cos\omega t \cdot \sin 2\omega t + L \cdot \sin\omega t\right) \cdot \left(\sqrt{L^2 + \left(2ML + M^2\right) \cdot \sin^2 2\omega t + Q^2 \cos^2 2\omega t}\right)^{-1}, \tag{3}$$

$$\cos\alpha_{1y} = \cos\alpha_{2y} = \left(M \cdot \sin\omega t \cdot \sin 2\omega t + L \cdot \cos\omega t\right) \cdot \left(\sqrt{L^2 + \left(2ML + M^2\right) \cdot \sin^2 2\omega t + Q^2 \cos^2 2\omega t}\right)^{-1}, \tag{4}$$

$$\cos\alpha_{1z} = -\cos\alpha_{2z} = Q\cos 2\omega t \cdot \left(\sqrt{L^2 + \left(2ML + M^2\right)\cdot \sin^2 2\omega t + Q^2 \cos^2 2\omega t}\right)^{-1}. \tag{5}$$

where ω – speed of rotation of the cleaning spiral, rad·s^{-1};
t –current time,
s – speed of rotation of the cleaning spiral, current time s.

In expressions (3), (4) and (5) the following notations are used:

$$L = -\frac{S^2}{4\pi^2 R}\cdot \cos\left(\frac{S}{2\pi R}\right) \tag{6}$$

$$M = \frac{S^2}{4\pi^2 R}\cdot \cos\left(\frac{S}{2\pi R}\right) - \frac{S^3}{8\pi^3 R^2}\cdot \sin\left(\frac{S}{2\pi R}\right) \tag{7}$$

$$Q = \frac{S}{2\pi}\cdot \cos\left(\frac{S}{2\pi R}\right) \tag{8}$$

where S – distance between adjacent turns of the cleaning spiral, m;
R – radius of the spiral twist line, m.

After that the values of the direction cosines were determined. This was reduced to the determination of the cosines of the angles between the vectors of relative velocities of the movement of the root crop along the windings of the spiral at contact points K_1 and K_2 and the coordinate axes Ox, Oy and Oz, that is: $\cos\beta_{ix}$, $\cos\beta_{iy}$ and $\cos\beta_{iz}$, (i = 1, 2).

It was taken into account that the vectors $\bar{V}_1$ and $\bar{V}_2$ are collinear. Therefore, the following equalities took place:

$$\cos\beta_{2x} = \cos\beta_{1x};\ \cos\beta_{2y} = \cos\beta_{1y};\ \cos\beta_{2z} = \cos\beta_{1z}. \tag{9}$$

The direction cosines $\cos\beta_{ix}$, $\cos\beta_{iy}$ and $\cos\beta_{iz}$, (i = 1, 2) in the Cartesian coordinate system were found according to [15] and presented in parametric form, using the parametric equations of the helical line [16]. As a result, the following was obtained:

$$\cos\beta_{2x} = \cos\beta_{1x} = \frac{2\pi R\cdot \sin\omega t}{\sqrt{4\pi^2 R^2 + S^2}} \tag{10}$$

$$\cos\beta_{2y} = \cos\beta_{1y} = -\frac{2\pi R\cdot \cos\omega t}{\sqrt{4\pi^2 R^2 + S^2}} \tag{11}$$

$$\cos\beta_{2z} = \cos\beta_{1z} = \frac{S}{\sqrt{4\pi^2 R^2 + S^2}} \tag{12}$$

After substituting expressions (3)-(5) and (10)-(12) into the system of differential equations (2) and a number of transformations, the following system of differential equations was obtained in parametric form:

$$\left.\begin{aligned}
& m\cdot\frac{d^2x}{dt^2} = \left(M\cdot\cos\omega t\cdot\sin 2\omega t + L\cdot\sin\omega t\right)\cdot\left(N_1 + N_2\right)\times \\
& \times\left(\sqrt{L^2 + \left(2ML + M^2\right)\cdot\sin^2 2\omega t + Q^2\cos^2 2\omega t}\right)^{-1} - \left(F_1 + F_2\right)\cdot\frac{2\pi R\cdot\sin\omega t}{\sqrt{4\pi^2R^2 + S^2}}, \\
& m\cdot\frac{d^2y}{dt^2} = \left(M\cdot\sin\omega t\cdot\sin 2\omega t + L\cdot\cos\omega t\right)\cdot\left(N_1 + N_2\right)\times \\
& \times\left(\sqrt{L^2 + \left(2ML + M^2\right)\cdot\sin^2 2\omega t + Q^2\cos^2 2\omega t}\right)^{-1} + \left(F_1 + F_2\right)\cdot\frac{2\pi R\cdot\cos\omega t}{\sqrt{4\pi^2R^2 + S^2}} - mg - P_K, \\
& m\cdot\frac{d^2z}{dt^2} = Q\cos 2\omega t\cdot\left(N_1 - N_2\right)\times \\
& \times\left(\sqrt{L^2 + \left(2ML + M^2\right)\cdot\sin^2 2\omega t + Q^2\cos^2 2\omega t}\right)^{-1} - \left(F_1 + F_2\right)\cdot\frac{S}{\sqrt{4\pi^2R^2 + S^2}} + F_T.
\end{aligned}\right\} \tag{13}$$

The system of differential equations (13) models the movement of a round-shaped table beet root under the action of rotating spiral windings along the working channel, where it is cleaned of impurities. Double integration of the system (13), taking into account the initial conditions, allows obtaining the laws of movement of the root crop along the working channel as a function of time *t* and other parameters.

Using a program for numerical calculations, calculations were carried out, which made it possible to construct graphs of the kinematic parameters of the movement of the root crop when it comes into contact with the windings of the spiral at two points. There were obtained graphs of the displacements and speeds of the progressive movement of the root crop over time. A comparison of these parameters was also made with the parameters of the movement of an oval-cylindrical root crop, presented earlier in [14].

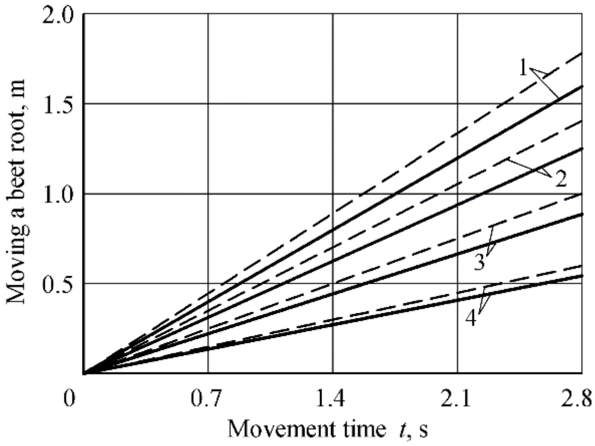

Fig. 4. **Dependences of movement of a beet root along the spiral bed on time *t* at:** 1 – ω = 45 rad·s^{-1}; 2 – ω = 35 rad·s^{-1}; 3 – ω = 25 rad·s^{-1}; 4 – ω = 15 rad·s^{-1}

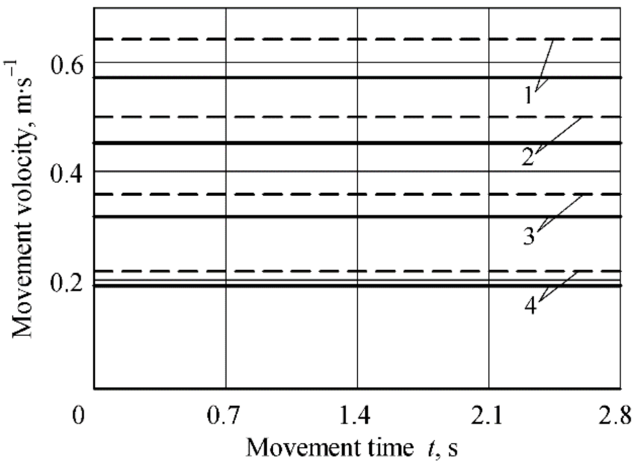

Fig. 5. **Dependences of the speed of movement of beet root crops along the spiral bed on time *t* at:** 1 – ω = 45 rad·s^{-1}; 2 – ω = 35 rad·s^{-1}; 3 – ω = 25 rad·s^{-1}; 4 – ω = 15 rad·s^{-1}

Fig. 4 shows graphs of the movement of a round root crop along the axes of spiral springs upon contact at two points. For comparison there are provided graphs of the movement of an oval-cylindrical root crop upon contact at four points (a dash-dotted line). A comparison of the graphs shows that the movement of the oval-cylindrical root crop is more intense since it is subject to the forces of two spirals, while the round root crop is subject to one.

The graphs in Fig. 5 show that the speed of the movement of the oval-cylindrical root crop with contact at four points is higher than that of the round root crop with contact at two points. Analysis of the data (Fig. 4 and Fig. 5) shows that the speed of the movement of the root crop depends on the rotation frequency and pitch of the spirals.

The solution of the model established a link between the separator parameters and the movement of the root crop. For example, the time of being of a round root crop on a 0.5 m long separating surface was 2.6 s, 1.6 s, 1.1 s and 0.88 s at a rotation frequency of 15, 25, 35 and 45 rad·s^{-1}, respectively, with a spiral pitch of 0.08 m. The speed of the movement of a root crop was 0.19, 0.32, 0.43 and 0.57 m·s^{-1}. For the oval-cylindrical root crop its residence time was 2.3 s, 1.4 s, 0.9 s, 0.74 s, and the speed was 0.22, 0.38, 0.52 and 0.64 m·s^{-1}.

Conclusions

1. A system of differential equations for the movement of a round-shaped beet root along the working channel of a spiral vibration cleaner has been obtained, which is a mathematical model of this technological process.
2. Based on this mathematical model, it is possible to determine the rational design parameters and kinematic operating modes of the specified cleaner by means of a calculation method, using PC.
3. The solving result of the system of differential equations was graphical dependencies of the influence of the kinematic parameters of the separator upon the speed of the movement of the root crops along the working channel.
4. The time of being of a round beet root on a 0.5 m long separating surface was 2.6 s, 1.6 s, 1.1 s and 0.88 s at a spiral rotation frequency of 15, 25, 35 and 45 rad·s^{-1}, respectively, if the spiral winding pitch S = 0.08 m. In this case, the speed of the movement of the root crop coming off the separating springs was equal to 0.19, 0.32, 0.45 and 0.57 m·s^{-1}, respectively. When an oval-cylindrical root crop came into contact at four points, the corresponding parameters had the following values: the time the root crop spent on the separating surface was 2.3 s, 1.4 s, 0.9 s, 0.74 s, the speed of the progressive movement of the root crop coming off the cleaning springs was equal to 0.22, 0.38, 0.52 and 0.64 m·s^{-1}, respectively.

Author contributions

Conceptualization, V.B.; methodology, I.H. and V.N.; software, Y.I.; validation, A.A. and V.B; formal analysis, V.B and J.O.; investigation, V.B., A.R., A.A. and J.O.; data curation, A.A., V.B. an J.I.; writing–original draft preparation, V.B.; writing–review and editing, A.A. and A.R.; visualization, Y.I., V.M.; project administration, A.R.; funding acquisition, A.R. All authors have read and agreed to the published version of the manuscript.

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