

CHICORY ROOT CROPS COMBINED HARVESTER

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КОМБІНОВАНИЙ КОПАЧ КОРЕНЕПЛОДІВ ЦИКОРІЮ

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ABSTRACT

The stages of improvement, structure and modes of digging tools of root harvesters' transport-technology systems have been described in this paper. The main ways of improvement, development principles and construction algorithm of combined digging machine for chicory root crops harvesting have been considered on the basis of research objects identification (conventional types of diggers). It was found that the construction algorithm of chicory roots combined harvester functional design must be based on mono block technological-transport systems development where digging tools are supposed to perform related technological operations simultaneously, namely: preliminary and final root crops digging, their topping. The results of experimental researches, the regression equation describing the change in loss and damage chicory root crops depending on the parameters of the combined digger are presented. It is established that the condition providing generalized criteria (root crop loss less than 2.5%, root crop damage less than 15%) performed digger combined velocity of 1.5 m/s, rotational speed of the drive shaft 500 Rpm and depth of the ripper 16 cm.

РЕЗЮМЕ

Наведено етапи удосконалення, будову та принцип функціонування викопувальних робочих органів транспортно-технологічних систем коренезбиральних машин. На основі ідентифікації об'єктів дослідження (існуючих типів копачів) зазначено основні шляхи удосконалення, принципи розробки та алгоритм побудови конструктивно-компонувальної схеми комбінованого копача, призначеного для викопування коренеплодів цикорію. Визначено, що алгоритм побудови функціонально-конструктивної схеми комбінованого копача коренеплодів цикорію повинен базуватися на розробці моноблочних технологічно-транспортних систем, робочі органи яких передбачають одночасне виконання суміжних технологічних операцій попереднього підкопування та кінцевого викопування коренеплодів і відокремлення залишків гички з їх головок. За результатами експериментальних досліджень розроблено рівняння регресії, які характеризують зміну втрат і пошкоджень коренеплодів цикорію залежно від параметрів комбінованого копача. Встановлено, що умова забезпечення узагальнених критеріїв (втрати коренеплодів менше 2.5 %, пошкодження коренеплодів менше 15 %) виконується за швидкості руху комбінованого копача 1.5 м/с, частоти обертання приводного вала 500 об/хв, глибини ходу розрихлювача 16 см.

INTRODUCTION

Modern trends of root crops machinery include the development and implementation of highly efficient, energy-saving and technologically reliable harvesting systems and facilities in the agricultural production. The main criteria for meeting these demands are the digging quality and root crops impurities separation characteristics. The analysis of conventional root crops machinery showed that chicory roots damaging and losses while digging by the existing tools are 20...30% and 4...10% respectively, which significantly exceeds the present requirements of cleaning quality (Adamchuk V. et al., 2002; Baranovsky and Skalsky, 2016). The main current feature of the general trend of big root crops harvesting, especially sugar and fodder beet, is a large-scale use of single phase technology, which is implemented on the basis of energy intensive six-row self-propelled bunker combine harvesters use, with up to 40 m³ bunker capacity (Kravchuk V.I. et al., 2004).

Self-propelled combine harvesters do all phases of root crops harvesting (main tops cutting, tops unloading on the field, remaining tops cutting of root crops heads, root crops digging, root crops cleaning from impurities, root crops transportation and loading into bunker, clean root crops unloading on the harvested field in large piles, or on a vehicle), i.e. combining all phases of root crops harvesting into one sequential technological operation.

In the EU, this type of root-harvesting machine annually harvest up to 70% of the planted acreage of sugar beet roots and in Germany and France – much more. Due to some objective and subjective factors (economic conditions, soil and climate conditions of root crops harvesting, etc.) such harvesters used in Ukraine are not always effective – root crops cleaning quality doesn't sufficiently meet the agrotechnical requirements as there are a number of defects (*Dubrovin et al., 2013*).

However, despite the rather complex multi-joints transport technological systems of tools for root crops digging and cleaning, the diggers, together with the already dug root crops, load on the mentioned cleaning systems of root crops harvesting machinery a completely unacceptable amount of soil impurities (an average of 30...50 tons per 1 hectare).

As a result, after their cleaning by energy-intensive multi-stage cleaning systems from field impurities a great amount of fertile soil is carried, which is equivalent to 10...15 cm topsoil on 100 hectares of harvesting area, while the total length (technological length) of surfaces under cleaning is 8...10 m and more (*Pogorely and Tatyanko, 2004*).

The goal of this study is to increase the technical and economic parameters of chicory harvesting by using the improved digging-cleaning systems of root crops harvesting machinery.

MATERIALS AND METHODS

Significant damage and losses of chicory roots are the results of cutting and not digging the underground parts of root crops by tools that are not adapted for brittle roots digging, which lie in the soil in great (to 15...20 cm) depths (*Humentyk M. Ya., 2003*).

In addition, these types of harvesters structurally and technologically can't combine, while harvesting, two manufacturing operations – root crops digging and remaining head tops separation.

Therefore, a simultaneous combination of head tops separating with the process of roots digging is a further step in the development, research and implementation into production of digging-cleaning systems of combined chicory root crops diggers. Under economic management conditions of multipurpose farm, agricultural enterprises in Ukraine, which are engaged in growing not only chicory but sugar, red and fodder beet and carrot root crops as well, the most urgent technical and economic problem is the payback of technically complex and costly (from 150 to 350 thousand of UAH per unit) root crops machinery due to their limited climatic performance life (about one calendar month) in a small area (especially root crops of red and fodder beet, carrots and chicory), and 90% of the root crops total area is gathered in by separate, economically inefficient technology (*Baranovsky et al., 2014*).

Significant efficiency increase of multipurpose farms economic management can be achieved primarily due to some organizational measures such as the use of a root crop machine for different root crops gathering in and determination of necessary flexible and cyclic operation due dates regarding weather and climate, root crops different agrophysical characteristics and so on.

The basis of the scientific problem solving dealing with operational and agrotechnological characteristics increase of chicory root crops harvesting is the hypothesis of possible considerable intensification of root crops digging due to the development and substantiation of parameters and general design-engineering principles and aspects of the combined carrying and cleaning diggers use.

RESULTS

A variety of design schemes of digging tools greatly depend and are closely linked both with harvest method and with the technological requirements to harvest quality indicators of different crops and root crops, the main of which are the quality indicators of root crops digging and their heads cleaning from the head tops. The most common basic disadvantage of existing and technically implemented types of diggers (blade, forklift, two-disc, vibration), which are widely installed on mounted, trailed and self-propelled root crops machinery is considerable second's supply of soil both free and adhering to the root surface (7...10 kg/s) head tops on root crops heads (0.5 to 1.5 kg/s) per one running meter at operating speeds up to 1.6 m/s, which led to an increase in length and structural complexity of cleaning-transport systems (*Bulgakov et al., 2009*).

The major drawback of existing and technically implemented types of diggers is relatively high both percentage (up to 3% relative to the root crops weight) and a mass amount of soil adhering to the roots surface and also percentage (from 0.5 to 1.5% relative to the root crops weight) and mass of head tops on the root crops heads, which significantly reduce, depending on the crop, or in one case, the quality of raw sugar and sugar yield or, in another case – products storage life. In addition, together with root crops gathered on the fields approx. 1.5...3.0% of fertile soil is removed depending on crops yield (Baranovsky *et al.*, 2014).

The objective reason of these diggers' technological imperfections is that the conventional diggers structurally and technologically can't combine two technological operations while digging – root crops digging and simultaneous removal of head tops. Algorithm for design-layout scheme constructing of transport-cleaning combined digger must be based on the use of mono block digging and cleaning combined tools in its technological scheme, the principles of which are based on common properties of multipurpose (all purposes to some degree) adapters use, their purpose and way of use while root crops gathering.

A large number of developed tools designs, assemblies and circuit layout of digging machines require a differentiated approach at the selection, calculation, design, research and implementation of new developments into production. Therefore, the ranked approach taking into consideration tools characteristics, their layout schemes and methods of operation can provide the possibility of identification (analysis and synthesis) of the necessary structural and technological scheme of digging-cleaning system for chicory root crops combined digger.

Of the whole digger variety, one-disk concave diggers, or the so-called "eurodisc" (Fig. 1a) are the simplest in design, and the least energy and metal consuming. Besides, they have a wide range of applications for the various root crops digging at satisfactory performance index. The axis of rotation 2 of concave 1 of a digger forms an angle of attack α in the horizontal plane reported to root crops row axis.

A significant drawback of their work, or the failure of simultaneous root crops digging and head tops cutting can predictably be eliminated by further structural and technological improvement of this digger type.

Operational characteristics and quality factors enhancement of conventional diggers, and all root crops machinery in general, is partly solved by using the improved digger (Fig. 1b) or by additional installation of the concave disc 1 in the front area, root guide 3 and horizontal drive cleaning shaft 4, where radial flanges 5 are fixed. Parallel axes 6 are consequently circle-wise set between the flanges, rotated relative to the cleaning shaft axis by a sharp angle. Flat elastic blades sections 7 are articulated on the parallel axes (Hurchenko *et al.*, 1991).

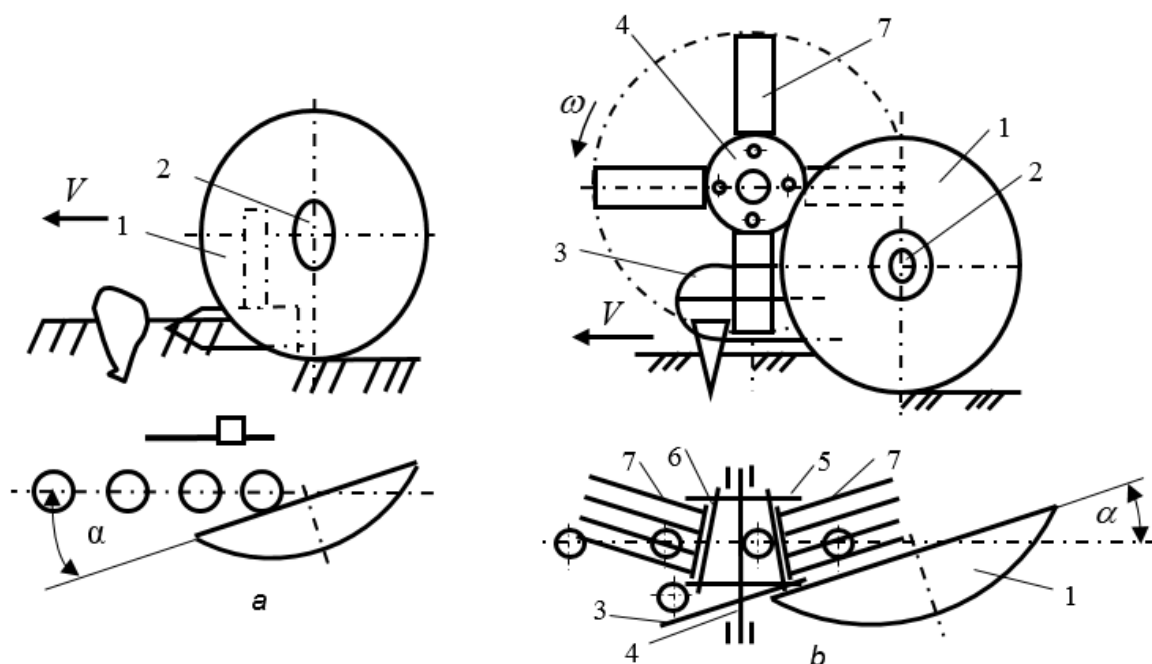


Fig. 1 – One-disc digger structural diagram

a – digger of "eurodisc" type; *b* – improved digger; 1 – disc; 2 – axis of rotation; 3 – root director; 4 – drive shaft; 5 – flange; 6 – axis; 7 – blade

When the digger is moving, root guide 3 is shifting the previously beaten root crops during crop tops cutting by toppers tools from the row to its centre, and concave disc 1 is digging the root crops. Simultaneously, while the root crops digging by a concave disk is taking place due to cleaning shaft 4 rotation, flat elastic blades 7 are in contact with the root crops heads, clean them from the head tops due to contact interaction of flat elastic blades with the head.

Parallel axes 6 rotation by a sharp angle relative to the axis of the cleaning shaft allows the flat elastic blades to strike the root heads aside of the row, which improves the roots of different height cleaning, as a high root crop doesn't cover a low one against oblique impact.

In addition, flat elastic blades simultaneously interact with soil clumps, destructing the latter and pushing the root crops to the next transportation systems, that results in enhancement of the technological potential of root crops machinery.

While root crops digging under dry hard soil conditions, root tails are damaged due to their cracking, because of lack of roots pushing vertical force and result root crops significant losses. To eliminate this cracking of root tails or their losses concave disc 1 (Fig. 2a) is set at a sharp angle φ and flange 5 – at an angle δ to the vertical plane, with the axis 6 in the lowest position on the flange, forming an angle ε equal or close to 90° with a plane passing through the concave disk blade.

Concave disc 1 digs root crops, which are in a row by lifting them up due to setting the concave disk at a sharp angle φ to the vertical and appearing additional lateral projection of lift force which is directed to a vertical plane. At the moment of flat elastic blades 7 impact on the root crop head or soil surface their rotation around their axes 6 is taking place and in the impact plane due to installing the flanges 5 at an angle φ to the vertical and rotated axes by an angle γ relative to the axis of the shaft 4. As the axes in the lower position are perpendicular to the plane passing through the concave disk blade or inclined to it at an angle close to the right, then flat elastic blades in the lower position are parallel to this plane and do not have a contact with the concave disc surface, which results in their wear reduction.

To increase the cutting degree of root crops head tops, particularly sugar beet and carrots, and the degree of soil lumps destruction by increasing the force of contact interaction (the force of direct central impact) of flat elastic blades on the root crops heads and soil lumps, parallel axes 6 (Fig. 2b) which are placed on the flanges 5 of horizontal cleaning shaft 4 and where flat elastic blades 7 are mounted, are installed parallel to the rotation axis of the cleaning shaft (Pankiv et al., 2009).

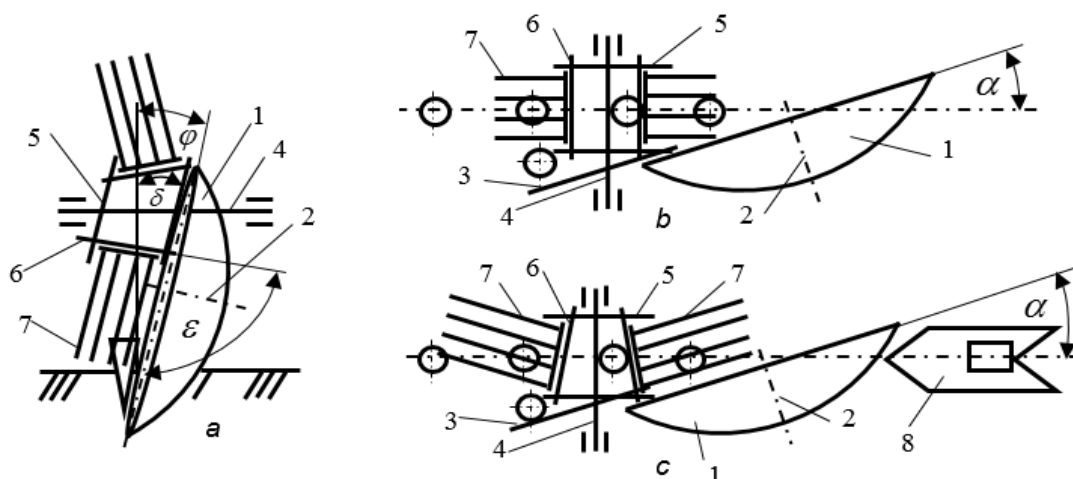


Fig. 2 – Structural diagram of one-disc digger

1 – disc; 2 – axis of rotation; 3 – root director; 4 – drive shaft; 5 – flange; 6 – axis; 7 – blade; 8 – ripper

Along with root crops digging, due to cleaning shaft 4 rotation, flat elastic blades 7 interact with root crops heads and soil lumps. In this case a direct impact of elastic flat blades takes place which results in head tops removal of root crops heads and soil lumps breaking up.

For digging root crops which are relatively deep relative to the soil surface (sugar beets, some kinds of carrots, chicory root crops) ripper 8 is used, which is set behind the concave disc 1 stroke (Fig. 2c) and can be designed as cultivating tine or chisel.

In the working process, ripper 8, while moving forward, lifts the roots a little, and the root crops-soil ties are getting damaged, i.e. the previous breaking up of soil layer is taking place. Then the root crops are easily dug from crumbled soil by the concave disc 1 and are displaced in the direction of a plane passing through the concave disk blade. In this case, we have the opportunity to dip the concave disc so as not to lose the root crops and load to transport-cleaning systems of root crop machinery the least amount of soil and plant heads.

On the basis of earlier diggers identification (analysis and synthesis) we have proposed an improved design of the two-disc (two-row) digger, which combines all positive aspects and benefits relative to the existing concave one-disc digger (Fig. 1). The structural diagram of two-row digger is shown in Fig. 3.

Two-row digger (Fig. 3a) consists of two loose concave discs 1 mounted on their axis of rotation 2 and located by angle α to the corresponding row axis of root crops. A root guide 3 is set in the front area of the attacking edge of each disc 1. Above the discs 1 the horizontal drive shaft 4 is mounted perpendicular to the digger motion operating speed V_k direction. The horizontal drive shaft includes a cylinder 5, bearing flanges 6. The horizontal shaft cylinder is divided into three sections. The axes 7, 8, 9 with flat elastic blade 10, 11 are set consequently between the flanges of the cylinder circle-wise. Axes 7 and 8 of two boundary sections 12, 13 of the cylinder form a truncated cone, and sections 12, 13 are directed to each other by smaller bases. Axes 9 of middle section 14 form a cylinder. The planes crossing the axes 7, 9 or 8, 9 of contiguous sections 12, 14 or 13, 14 form an obtuse angle.

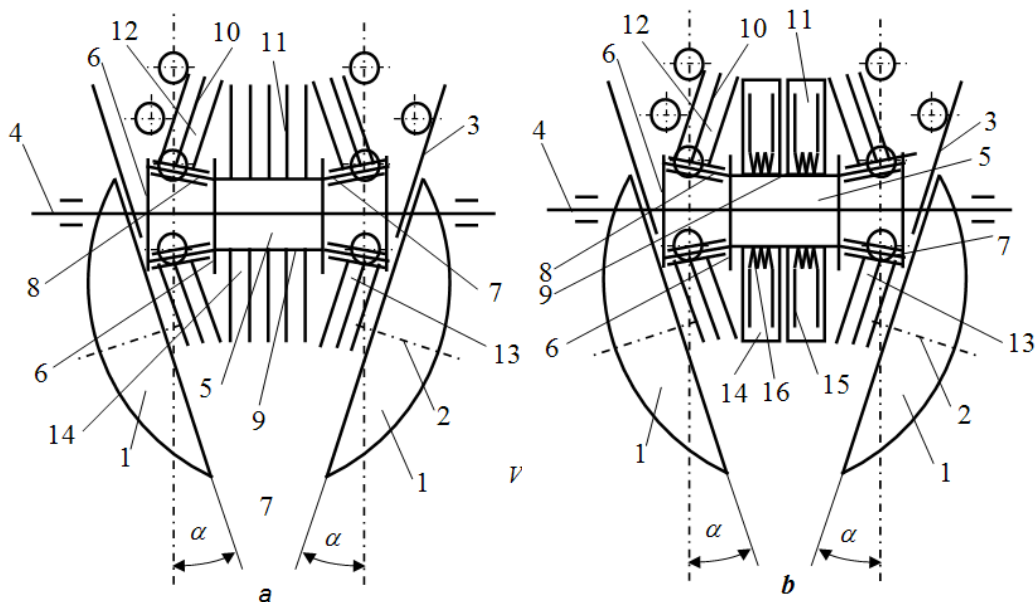


Fig. 3 – Structural diagram of two-row disc digger

1 – disc; 2 – axis of rotation; 3 – root guide; 4 – drive shaft; 5 – cylinder; 6 – flange; 7, 8, 9 – axis;
10, 11 – blade; 12, 13 – boundary section; 14 – middle section; 14 – spring-loaded; 15 – two-section spring

While the digger is moving, root guide 3 is displacing the root crops dug out of the row to its centre and concave disc 1 is digging the roots out. Along with roots digging out, due to horizontal drive shaft 4 rotation, flat elastic blades of 10 two boundary sections 12, 13 interact with the roots heads. In this case roots heads cleaning of head tops from two adjacent rows and breaking up of soil lumps take place simultaneously. In addition, flat elastic elements 11 of middle section 14 also interact simultaneously with roots and soil lumps, thus the roots surface cleaning of adhering soil and soil lumps breaking up take place together with pushing the thrashed heap in the concave discs 1 at the same time, in this way accelerating its supply to the next technological systems of root harvesting machinery.

To reduce the supply of soil contaminants during two-row digger operation under dry and hard soil conditions on the outer side of each flat elastic blade 11 (Fig. 4) of middle section 14 spring-loaded rod 15 is mounted which is designed as a two-section spring 16. Two-section spring is firmly fixed on each axis 9 of middle section 14 (Kravchenko et al., 2013).

To adjust the contact force of flat elastic blades 10 (Fig. 4) of two boundary sections 12, 13 with the head of root crops during their digging, or to provide the highest degree of root crops cleaning of head tops

and simultaneous agreement on roots damage degree that should not exceed the limit according to agrotechnical requirements, we propose to install a spring-loaded rod 17 on the outer side of each flat elastic blade of two boundary sections 12, 13 of three-section cylinder 5, which is designed as a two-piece spring 18. Two-section spring is firmly fixed on each axis 7, 8 of the three-section cylinder. The contact force of flat blades of two boundary sections is regulated by turning each section axis, which results in changing the twisting of two-section springs and spring-loaded rod pressing.

Along with roots digging due to horizontal drive shaft 4 rotating, flat elastic blades 10 of two boundary sections 12, 13 get in contact with the roots heads and flat elastic blades 11 of middle section 14 – with soil lumps dug out by concave discs 1. In this case, the cleaning root crop heads of head tops of two adjacent root rows and soil lumps intense breaking up, due to the impact contact of inner side of the flat elastic blades 11 with lumps of soil, take place simultaneously.

In addition, the flat elastic blades of middle section not only break up the soil lumps but push the thrashed heap dug out by concave disks, located in the space between them, thereby accelerating its move to the next technological systems of the machine.

On the basis of conventional diggers identification (analysis and synthesis), we have proposed an improved design of transport and cleaning system of chicory root combined digger taking into consideration all the positive aspects and advantages of concave two-disc digger (Fig. 3, 4).

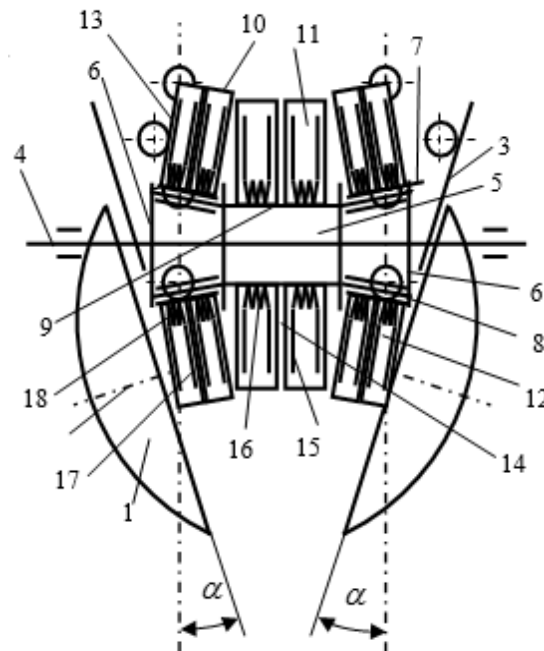


Fig. 4 – Structural diagram of two-row disc digger

1 – disc; 2 – axis of rotation; 3 – root guide; 4 – drive shaft; 5 – cylinder; 6 – flange; 7, 8, 9 – axis; 10, 11 – blade; 12, 13 – boundary section; 14 – middle section; 15, 17 – spring-loaded; 16, 18 – two-section spring

The proposed transport-cleaning system of combined digger allows intensifying the process of chicory root crops digging under considerable rooting depth conditions. The structural diagram of transport and cleaning system of combined chicory root digger is shown in Fig. 5.

Combined root crops digger consists of two adjacent concave discs 1 which are loose on their axes of rotation 2 and are mounted by angle α to the root crops row axis. In the front area of cutting edge 3 of each of the two concave disks a root guide 4 and hollow guide tube 5 are set horizontally. The latter is placed above the two concave discs and between them perpendicular to the roots row, or to the digger motion operating speed V_k direction. Bearings 6 are set inside the hollow guide tubes, where drive shaft 7 is mounted. The separate cylinders 10 and 11 are fixed on the frontal edges 8 and 9 of the drive shaft, designed as radial flanges 12 installed on the horizontal drive shaft. Between the flanges of each of the cylinders the axes 13, 14 are fixed on their generators in series and parallel, where flat elastic elements 15 are set. The axes are turned about the axis of the drive shaft by an acute angle. Two supporting plates 17 are mounted radially to the external bottom of the hollow tube 16 where horizontal finger 18 is fixed. Pivoting

slide rest 19 is hinged on the fixed horizontal finger where the ripper 20 is assembled which is placed in the space between rows. Pivoting slide rest of the ripper is made of springy type thanks to spring 21, one end of which is fixed on the top of the pivoting slide rest 22, and the second – on the digger frame 23. The pivoting slide rest rotation on the fixed horizontal finger is limited by the stop 24 fixed on the supporting plates.

The ripper running depth is more than running depth of concave disks. The drive shaft direction of rotation V_k is the same as the combined digger.

Combined root chicory harvester operating principle is as follows. While at combined harvester motion, the ripper 20 due to the soil environment resistance is stretching the spring 21 and is deviating in the opposite direction on the horizontal fixed finger 18 to the support 24. The ripper simultaneous translational motion in the soil environment and spring reverse compression create two recurring opposite acting forces the action of which causes forced oscillations around roots soil environment. These cyclic fluctuations lead to the breaking ties of chicory root crops with soil on the rooting depth, i.e. the ripping intensification of soil environment and root crops partial digging take place. Also, along with roots digging up by a ripper, two related processes take place, i.e. chicory roots final digging out by adjacent concave disks 1 due to their free rotation on their axes 2 in the soil environment and root heads cleaning of head tops of two adjacent root rows by rotating cylinders 10 and 11 of the drive shaft 7 or interactions of flat elastic elements 15 with root crops heads. Root guide 4 is shifting the chicory roots previously broken up of the row to its centre and adjacent concave disks pick up the roots dug out of soil. Besides, flat elastic elements also break up the soil lumps and at the same time push the thrashed heap, located in the space of adjacent concave disks, accelerating its supply to the next technological systems of root harvesting machinery.

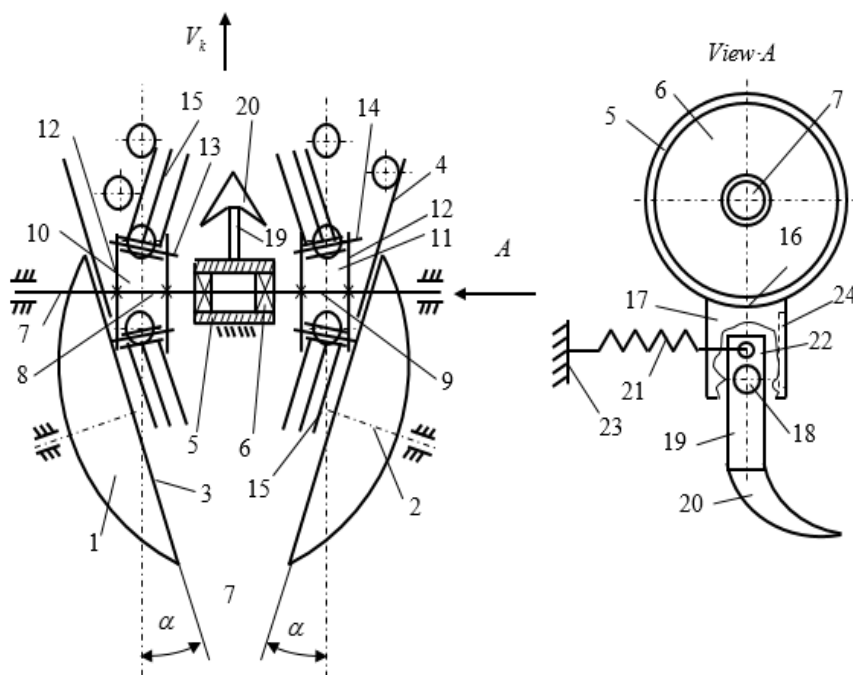


Fig. 5 – Structural diagram of combined digger transport and cleaning system

1 – disc; 2 – axis of rotation; 3 – edge; 4 – root guide; 5 – guiding tube; 6 – bearing; 7 – shaft; 8, 9 – shaft end; 10, 11 – cylinder; 12 – flange; 13, 14 – axis; 15 – spring element; 16 – low outer part of guiding tube; 17 – support plate; 18 – finger; 19 – swivel carriage; 20 – ripper; 21 – spring; 22 – swivel carriage top; 23 – frame; 24 – support

To confirm the technological efficiency of the combined digger in the composition of the root-harvesting machine (Fig. 6), field comparative experimental studies were carried out on the digging of chicory roots of the variety "Alexandrite".

The dependences of the quality indices of the work-loss w_k and damage p_k of the chicory root crops for two cases were investigated with the use of a ripper 6 (Fig. 6), which is performed in the loosening loos and without the use of a pest. The performance indicators w_k and p_k were determined according to the standard procedure and relative to the common root crop of one experiment.

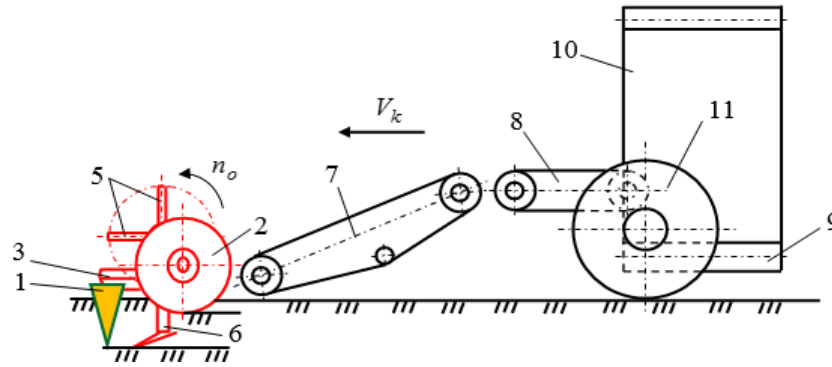


Fig. 6 – Structural diagram of field installation

1 – root crop; 2 – disc; 3 – axis of rotation; 4 – root guide; 5 – drive shaft; 6 – spring blades; 7 – ripper; 8, 9, 10, 11 – conveyors; 12 – support wheel

After processing the experimental values, final regression equations are obtained in natural quantities, that characterize the dependence of changes in losses and damages of chicory root crops on their digging out of the constructive-kinematic parameters of the combined digger:

$$\left. \begin{aligned} w_k &= 94,19 - 38,06V_k - 7,36a_k + 13,24V_k^2 + 0,15 \cdot 10^{-4} n_o^2 - 0,76 \cdot 10^{-3} n_o a_k + 0,22a_k^2; \\ p_k &= 4,51 + 1,28V_k + 1,001n_o + 1,003a_k \end{aligned} \right\}, \quad (1)$$

where V_k – speed of the root machine, [m/s];

a_k – depth of the ripper stroke, [cm];

n_o – rotational speed of drive shaft, [rpm].

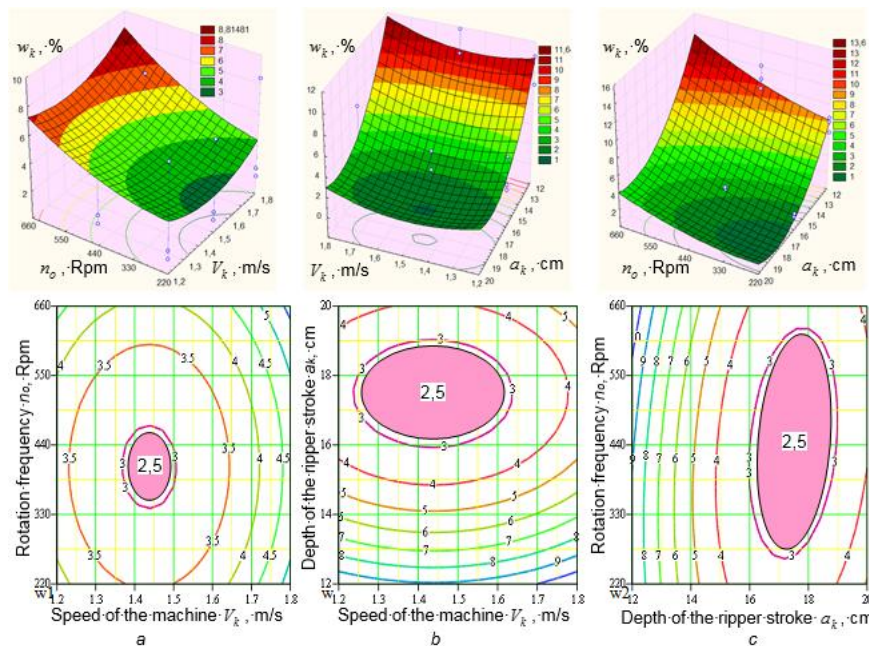


Fig. 7 – The response surface and the two-dimensional section of the response surface

$$a - w_k = f_{w_k}(V_k; a_k); \quad b - w_k = f_{w_k}(V_k; n_o); \quad c - w_k = f_{w_k}(n_o; a_k)$$

In Fig. 7, 8 is shown the response surface and the response surface two-dimensional section of losses w_k and damage p_k of chicory root crops from the movement speed of the root harvesting machine V_k ($1.2 \leq V_k \leq 1.8$ m/s), the speed of the drive shaft n_o ($220 \leq n_o \leq 660$ rpm), the depth of the ripper stroke a_k ($12 \leq a_k \leq 20$ cm), which are constructed according to the regression equations (1).

The dominant factors that functionally characterize the loss w_k of chicory root crops (Fig. 7) are the speed V_k and the ripper's stroke depth of the combined digger. The functional change w_k in root crop losses has an optimum - the minimum values of the response function $w_k = f_{w_k}(V_k; n_o; a_k)$, which are in the range of 1.5 to 2.5%, are provided for the movement speed of the root harvesting machine in the range $1.4 \leq V_k \leq 1.5$ m/s, the depth of the ripper stroke – $16 \leq a_k \leq 20$ cm, the speed of the drive shaft – $400 \leq n_o \leq 500$ rpm. It has been established that the smallest values of the chicory root crops loss ($w_k \Rightarrow \min$) correspond to the values of factors $V_k = 1.45$ m/s, $n_o = 450$ rpm, $a_k = 18$ cm. The optimization criterion for the minimum point w_k , which is calculated using the first regression equation (1), is 1.2% at this point.

The maximum permissible damage to the chicory roots ($p_k \leq 15\%$ according to agrotechnical requirements) corresponds to the rotational speed of the drive shaft not more than $n_o \leq 500$ rpm and the established limits of variation of V_k and a_k (Fig. 8).

Based on the analysis of empirical dependencies and graphical constructions (Figures 7, 8), which characterize the change in the performance indicators of the combined digger in the form of functionals $w_k; p_k = f_i(V_k; n_o; a_k)$, we can state that the condition for storing generalized optimization criteria $w_k \leq 2.5\%$ and $p_k \leq 15\%$ is fulfilled for the following constructive-kinematic parameters: $V_k = 1.5$ m/s, $n_o = 500$ rpm, $a_k = 16$ cm.

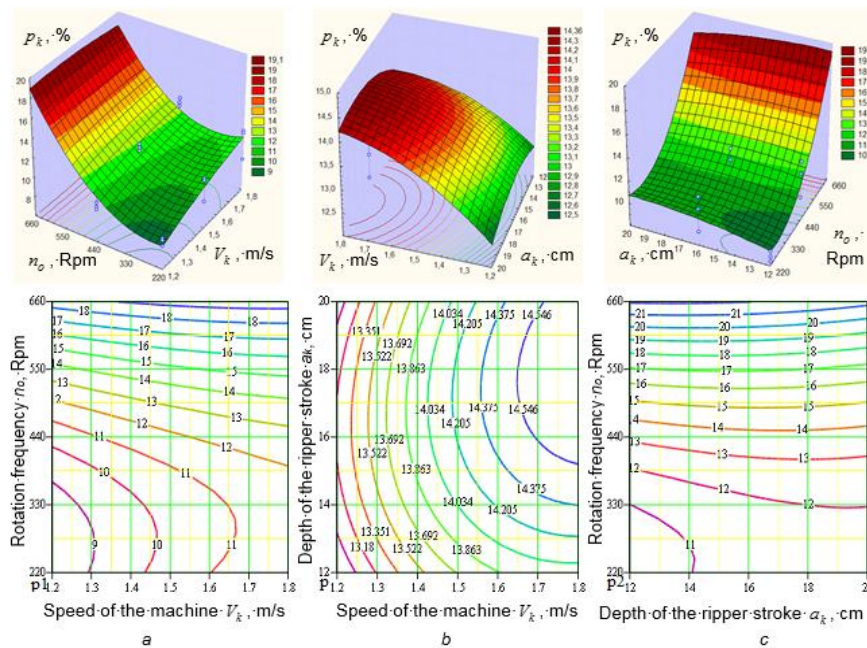


Fig. 8 – The response surface and the two-dimensional section of the response surface
 $a - p_k = f_{p_k}(V_k; a_k)$; $b - p_k = f_{p_k}(V_k; n_o)$; $c - p_k = f_{p_k}(n_o; a_k)$

The rational constructive-kinematic parameters of the combined digger in conducting comparative studies were as follows: diameter of the spherical disk 0.45 cm; the angle of attack of the disk is 30 degrees; the depth of the disc is 9 cm; the diameter of the drive shaft is 0.6 m; rotation speed of the drive shaft 500 Rpm; the depth of the ripper 16 cm.

It was found that the total losses of chicory root crops, which were excavated by a combined digger, were 1.6 times lower compared to the basic digger (without setting the ripper) - from 3.5% in the basic digger to 2.2% in the modernized digger. A significant reduction in the losses of chicory root crops is achieved due to the additional installation of the ripper, which also reserves a 2.1-fold decrease in the number of untreated (unrecovered and left in the soil) root crops – 2.9% in the base crop and 1.4% in the combined digger.

A significant reduction in the damage to root vegetables of chicory (approximately 2 times - 20.3% in the base versus 10.1% in the combined digger) also confirms the technological feasibility of its use for the rooting of roots. This allows us to improve the technological process of digging out the crumbling roots.

CONCLUSIONS

Thus, it can be stated that the mounted drive shaft with flat blades installed on it, allows two operations (root crops digging and root heads cleaning of head tops) to take place simultaneously. This provides the reducing of second supply of soil and plant impurities due to contact interaction of flat blades with thrashed heap components. Moreover, hinged ripper use mounted on a horizontal finger and made a spring-loaded, can intensify roots with soil environment ties breaking up. As a result, the losses of chicory roots are decreasing due to the number of damaged root tails reducing, energy consumption while root crops digging saving and technological reliability growth of the digger and root crop machinery in general. It has been established that chicory root losses are reduced by digging with a combined digger in 1.6, and the damage is approximately 2-fold compared to a baseline (serial) digger. In this case, the number of dug roots with a broken tail is reduced by approximately 2.6 times.

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