RESEARCH OF CONSTRUCTIVE AND REGULATORY PARAMETERS OF THE ASSEMBLY WORKING PARTS FOR POTATO HARVESTING MACHINES
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ДОСЛІДЖЕННЯ КОНСТРУКТИВНИХ ТА РЕЖИМНИХ ПАРАМЕТРІВ ПІДКОПУВАЛЬНИХ РОБОЧИХ ОРГАНІВ ДЛЯ КАРТОПЛЕЗБИРАЛЬНИХ МАШИН

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ABSTRACT
The problem of improving the quality of potato tuber separation by improving the digging working parts from the construction of potato harvesters is investigated. Based on the analysis of the theoretical and experimental studies on the existing working parts, the design scheme was established and the optimum values of the parameters and operation modes of the digging working parts were established, for potato harvesting machines, which would allow improving the quality performances of the potato harvester as a whole. According to the research results, an experimental sample of digging working parts for potato harvesting machines was developed and manufactured, whose verification in operation confirmed their workability and efficiency.

РЕЗЮМЕ
Досліджується проблема підвищення якості сепарації картопляного вороху за рахунок удосконалення підкопувальних робочих органів для картоплезбиральних машин. На основі аналізу існуючих робочих органів, теоретичних і експериментальних досліджень визначено конструктивну схему та встановлено оптимальні значення параметрів та режимів роботи елементів підкопувальних робочих органів для картоплезбиральних машин, які дозволять підвищити якісні показники роботи картоплезбиральної машини в цілому.
За результатами досліджень розроблено та виготовлено експериментальний зразок елементів підкопувальних робочих органів для картоплезбиральних машин, виробнича перевірка яких при роботі на картоплезбиральній машині підтвердила його працездатність та ефективність.

INTRODUCTION

Ukraine has a unique natural potential, which allows it to become a leader in the production of agricultural products in Europe. However, in order successfully enter the western markets it is necessary to ensure, first of all, the competitiveness of its own products, which is achieved by the complex mechanization of technological processes, reducing labour costs, increasing the yield and quality of the products (*Hrushetsky S.M., 2016*). Potato cultivation in our country is carried out according to the technology of the last century, and if earlier potato cultivation was mechanized, now it is performed in most farms manually. With the reforms in the village, potato growing scattered over small peasant, farmer and garden lands, where about 95% of this crop is located.

Machines for growing potatoes in Ukraine were imported mainly from the Russian Federation, Belarus and Germany. Potatoes producers on all scales often take the example of neighbouring Belarus, where the technological cycle is fully provided by the state, the corresponding factories operate.

There is a problem of improving the existing and inventing new promising technologies and working parts of potato harvesting equipment, justifying the optimal modes of their work and, ultimately, providing this crop sector with modern, high-performance and reliable harvesting equipment.

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MATERIALS AND METHODS

The problem of growing and collecting potatoes is tackled in a lot of published works. Increasing the technological level of modern potato harvesting machines, the criteria for assessing loss ratio, contamination and damage of the products to their mass, remain a scientific and actual problem for the further development of domestic machinery for tubers harvesting.

An analysis of the evolution of the design and layout and technological schemes of potato harvesting equipment shows that, at present, powerful self-propelled bunker combines are increasingly used for harvesting, which annually collect crop on up to 70% of world's land (*Pogorel'y L.V. & Tatianko M.V., 2004*).

Further deepening and development of the general concept of modern machines rational outlines are possible based on world experience analysis of phased improvement of harvesting root crops process, or based on a more detailed analysis of the working parts functioning of the main transport and technological systems for digging and cleaning root crops.

The efficiency of root crops harvesting depends to a large extent on the construction and layout scheme and the work quality of the heap purifier, which must separate at least 92% of impurities according to the initial requirements for potato harvesting machines, while adhering to the allowable values of losses and damage to the root crops (*Dubrovin V., Golub G., Baranovsky V. & Teslyuk V., 2013*).

A significant variation in the working conditions of potato harvesting machines and the lack of adaptation of existing constructions of digging and especially cleaning working parts to these changes in the working conditions do not allow obtaining stable agrotechnical parameters, especially for dry and wet soil, field's weeds, etc. With an increase in soil moisture to 22-28%, the quality of machines deteriorates by 2-6 times, and on solid soils there is observed a significant (up to 20-40%) amount of root heap with lumps of soil (*Ramsh V.Y., Baranovsky V.M. & Pankiv M.R., 2011*).

Despite the rather complex transport and technological systems of the working parts for cleaning the remaining root heap, after clearing by the energy-intensive multi-stage systems for cleaning the excavated amount of ground of soil impurities from the fields, the amount of fertile soil which is extracted, is the equivalent of 10...15 cm of the arable layer on the harvesting area equal to 100 ha, in spite of the fact that the total length of the treatment surfaces reaches 8...10 m (*Baranovsky V.M., Onishchenko V.B. & Solomka V.O., 2002*).

The aim of the work is to systematize and synthesize the research of modern technologies of cultivating and harvesting potatoes and create a new design of a sub-cultivating working body that would collect the minimum amount of soil together with the tubers and provide the possibility of better fragmentation of the formation to facilitate separation with increased operational efficiency, technological reliability of the sub-cavern body and reduction of its traction support.

To achieve this goal, you need:

1. To analyse the existing designs of the sub-cultivating working parts of potato harvesting machines, the results of experimental and theoretical studies of the digging working parts and to improve the design on their basis;

2. Theoretically explain the improvement of the parameters and modes of operation of the digging machines for potato harvesting;

3. Based on the results of laboratory-field experimental studies specify the optimal parameters and work modes of the investigated working body and determine the agronomic indicators according to the performance of the potato harvesting machine;

4. To determine the effectiveness of the use of combined digging working parts.

Well known digging working parts according to the type of needed work are divided into the passive ones, active ones and mixed ones (*Hrushetsky S.M., Zbaravskaya L.Y. & Semenishena I.V., 2017*). Depending on the shape, they are flat, sectional and cylindrical, where the shape of the curved front is similar to the shape of the nest of the root tubers, the cylindrical surface is flat, and the back side - is convex (*Hrushetsky S.M., Bendera I.M. & Belous S.V., 2008*).

The technical result depends on reducing the time spent on stopping the harvesting unit and cleaning the digging working body from the plant residues, as well as in reducing the energy costs of digging the potato tuber. Fig. 1 shows tubers zone of placement: B_r - row width, B - the capture width of the border front undercut part is equal to the width of the nest bug placement of tubers, taking into account the transverse deviations of the line from the axial line 2δ; h_d - digging depth; h - depth of occurrence of extreme tubers. The width of the final part of the potato cutter's digging is equal to the width of the separating part.

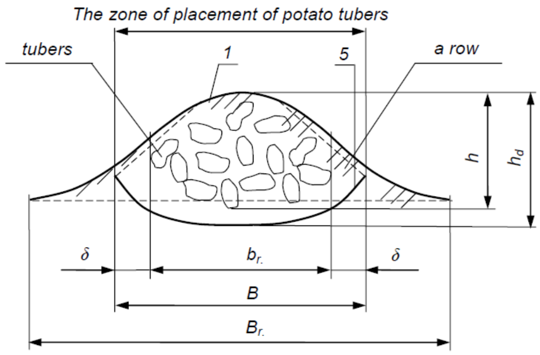

Fig. 1 – **Zone of tuber placement**

The proposed digging working body for potato harvesting machines is shown in Fig. 2 (*Hrushetsky S.M., Horodinsky V.O., Stavruk D.V., Gromik B.I. & Dudar M.O., 2015; Hrushetsky S.M., Zbaravskaya L.Y. & Semenishena I.V., 2018*) – side view of potato harvesting: V_M – speed of the machine; Q_o – filing of the general amount of potato's soil mass which has $r(t_i)$ – the amount of small particles of soil at the time t, $k(t_i)$ – the number of tubers at the time t, $m(t_i)$ – amount of plant residues at the time t, $q(t_i)$ – the number of large lumps at the time t; α_p – angle of inclination of a cylindrical catcher to the horizon; fig. 3 – top view of a cylindrical catcher: γ – the sloping angle of the slice with the excavated bunch of tubers down the blade; fig. 4 – a view of the catcher in the cut position *A-A*, *B-B*, *C-C* and *D-D* – fig. 3; fig. 4 – view *E* above the flat triangle – fig. 2.

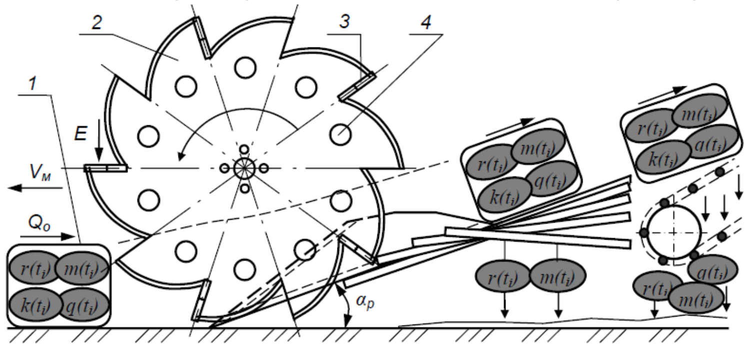

Fig. 2 − Working body for potato harvesting machines (side view)

The technological scheme of the digging process consists of a potato's soil mass *1,* on both sides of which there are two vertical toothed gears *2,* with soil compactors *3*. The disc has a series of openings *4* with centres which are located concentrically on the axis of rotation of the toothed disc, while the distance between the outer edge of the disc tooth to the axis of the opening is permissible to 140...250 mm. The diameter of the hole in the toothed disc can be made within the limits of 30...37 mm. A root heap harvesting part which has a cylinder surface shape *5* (fig. 3)*,* of the potato harvesting machine, on which the potato's soil mass *1* moves, which after a certain change in shape and deformation on the separation rods *6,* in the longitudinal vertical surface, enters the separator *7*, followed by the subsequent technological process - separation.

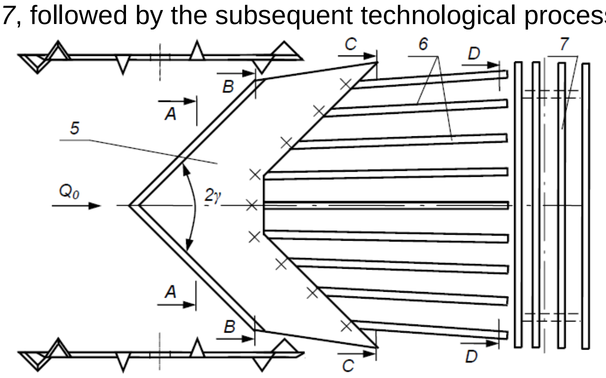

Fig. 3 − Working part for potato harvesting machines (top view)

The digging working part of the potato harvesting machine works in the following way. When moving the machine along the rows of potato fields due of the tractor traction, the working part gets deeper into the potato tuber, while there is a trimming of the reservoir from the bottom of the heap harvesting part which has a cylinder surface shape *5*. Due to the gradual movement of the potato digger and the grip of the toothed wheels *2* with soil, which are provided by the friction forces on the lateral surfaces, directly by soil harvester *3* turn discs on their axis. In this case happens the cutting of plant residues by the working edge of the toothed disc *2* and by the cutting edges of the soil tillers *3*, as well as cutting the potato layer on the sides occurs. Due to jamming between the discs *2* and the cylindrical surface of the potato harvesting machine, the reduced layer of the potato's total left mass *1* is applied along the curved forward part, further along the median flat bar *6* of the longitudinal and vertical surface and, upon approaching it, by the convex rod-separating surface in the transverse vertical surface, gets to the separation working part *7* partially crushed, separated and evenly distributed for further separation.

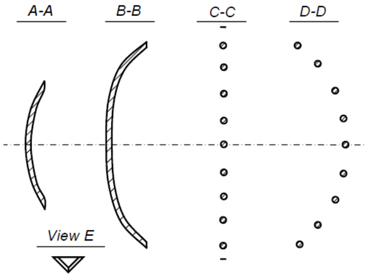

Fig. 4 − The heap harvesting part which has a cylinder surface shape

The best separation of tubers from the soil will occur due to:

a) cutting off the potato layer on the sides of the teeth gears and the cutting edges of the soil cultivators with partial destruction of it;

b) reduction of the amount of potato's soil mass of the reservoir during the movement on the cylindrical surface of the potato harvesting machine;

c) the transverse deformation of the soil layer and partial separation during its movement on the middle flat net bars surface of the potato harvesting machine;

d) the transverse deformation of the soil layer and partial separation during its movement on a convex rod net surface at the output of the potato harvesting machine;

e) the equal distribution of the potato's soil mass at the output from the rod net surface of the potato harvesting machine on the separating surface.

To determine the area of the soil tiller it is necessary to know its height and width. The soil tiller's height, considering the technological feature of the disc, cannot exceed the height of the gear tooth, therefore we accept the following parameters $h_r = h_a$.

The width and shape of the soil tiller should ensure rational working conditions of the toothed disc.

To find out the optimal shape and width of the toothed discs of the gear disc, we will carry out studies of soil-blades having the shape: *1* – rectangle*; 2* – rectangular trapezoid*; 3* – a rectangular triangle.

To verify the rational form and geometrical parameters of the cutting edge, several forms of soil tillers were considered and their comparison was made on the following indicators: metal capacity of constructions of a disc with soil tillers; traction resistance of a disc with soil tillers; cutting elements of weed plants and buds.

The main element of the proposed disc is a gear tooth with a cutting edge, executed on a logarithmic curve. In our case, the logarithmic curve equation has the form (fig. 5) (*Stavruk D.V. & Hrushetsky S.M., 2015*):

$$r = \frac{1}{2} r_0 (1 + e^{\psi ctg\tau}), \tag{1}$$

where r – value of the radius vector, *m*; r_0 – initial value of the radius vector, *m*; $r = r_v$ – the final value of the radius vector, *m*; ψ – the angle of the blade's edge, *rad*.; τ - sliding angle, *rad*. In this case, $\tau = const.$

From the scheme (fig. 5):

$$r_v - r_0 = h_a = \frac{1}{2} r_0 (e^{\psi ctg\tau} - 1). \tag{2}$$

Then the formula to determine the length of the cutting edge is the following (*Horodinsky V.O., Hrushetsky S.M., 2016*):

$$c = \frac{r_0}{2\sin\tau}\int_0^{\psi}\sqrt{\sin^2\tau + 2\cdot\sin\tau\cdot e^{\psi ctg\psi} + e^{2\psi ctg\tau}}\cdot d\psi = \frac{1}{2} r_0\left(\psi + \frac{e^{\psi ctg\tau}}{\cos\tau}\right). \tag{3}$$

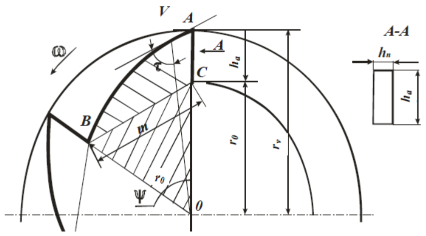

Fig. 5 − Scheme for determination of metal capacity of a toothed disc with soil tillers, the gear teeth of which have a cutting edge in the form of a logarithmic curve

Then the formula to determine the length of the cutting edge is the following:

$$S_a = (S_t + S_n)\cdot Z\ , \tag{4}$$

where: S_n – area of the soil tiller, *m*²; S_t – area of the gear tooth, limited by the radii r_0 in the low curves, *m*²; Z – number of gear teeth, *pcs*.

Determine the area of the gear tooth:

$$S_t = S_{OAB}\ , \tag{5}$$

$$S_{OAB} = \frac{S_a}{Z}\ . \tag{6}$$

In general view, we can write:

$$S_{OAB} = \frac{1}{2}\int_{\psi^1}^{\psi^2} r_0^2 d\psi\ , \tag{7}$$

$$S_{OAB} = \frac{1}{2}\int_0^{\psi}\left(\frac{1}{2}r_0 + \frac{1}{2}r_0\cdot e^{\psi ctg\tau}\right)^2 d\psi = \frac{1}{2}\int_0^{\psi}\frac{1}{4}r_0^2\left(1+e^{\psi ctg\tau}\right)^2 d\psi = \frac{r_0^2}{4}\left(\psi + \frac{e^{2\psi ctg\tau}}{ctg\tau} + \frac{e^{2\psi ctg\tau}}{2ctg\tau} + \frac{5}{2ctg\tau}\right). \tag{8}$$

The area of the soil tiller will be determined as the area of the rectangle:

$$S_n = h_a\cdot k_n\ , \tag{9}$$

where k_n – width of the heap harvesting part which has a cylinder surface shape, *m*.

Ultimately, we obtain a formula for determining the area of the gear toothed disc with the rectangular shape of the soil tillers:

$$S_a = 10\left(\frac{r_0^2}{8}\left(\psi + \frac{e^{2\psi ctg\tau}}{ctg\tau} + \frac{e^{2\psi ctg\tau}}{2ctg\tau} + \frac{5}{2ctg\tau}\right) + h_a\cdot k_n\right), \tag{10}$$

$$\begin{aligned} S_{заг.} &= \frac{5}{4}r_0^2\left(\psi + 2\cdot e^{\psi ctg\tau}\cdot tg\tau + \frac{1}{2}e^{\psi ctg\tau}\cdot tg\tau + \frac{5}{2}tg\tau\right) + 5r_0\left(e^{\psi ctg\tau} - l\right)\cdot k_n = \\ &= \frac{5}{4}r_0^2\left(\psi + 2\cdot tg\tau\cdot e^{\psi ctg\tau} + \frac{1}{2}\cdot tg\tau\cdot e^{2\psi ctg\tau} + \frac{5}{2}tg\tau\right) + 5r_0\left(e^{\psi ctg\tau} - l\right)\cdot k_n \end{aligned}\ . \tag{11}$$

The area of the soil cultivator having the shape of a rectangular trapezoid is determined:

$$S_n = h_a\cdot k_n - \frac{1}{2}k^2\cdot tg\alpha_n\ , \tag{12}$$

where α_n – angle of inclination of the working edge of the soil tiller to the trapezium height, *degrees*.

The area of a gear toothed disc with soil tillers, executed in the form of a rectangular trapezoid is equal to:

$$S_a = \frac{5}{4}r_0^2\left(\psi + 2\cdot ctg\cdot e^{\psi ctg\tau} + \frac{1}{2}\cdot tg\tau\cdot e^{2\psi ctg\tau}\right) + 5r_0\left(e^{2\psi ctg\tau} - l\right)\cdot k_n - 5r_n^2 tg\alpha_n\ . \tag{13}$$

The area of the ground tiller, which has the shape of a rectangular triangle, will be determined:

$$S_n = \frac{1}{2}h_a\cdot kj_n. \tag{14}$$

The area of a toothed disc with soil compactors, executed in the form of a rectangular triangle is:

$$S_a = \frac{5}{4}r_0^2\left(\psi + 2\cdot tg\tau\cdot e^{\psi ctg\tau} + \frac{1}{2}\cdot tg\tau\cdot e^{2\psi ctg\tau}\,\frac{5}{2}tg\tau\right) + \frac{5}{2}r_0\left(e^{\psi ctg\tau} - l\right)\cdot k_n\ , \tag{15}$$

With the help of formulae (11), (13), (15) you can find the hard disc volume:

$$Q_a = p_{cm}\cdot S_a\cdot b_{\partial}\ , \tag{16}$$

where p_{cm} – specific gravity of steel, kg/m³; b_{∂} – disc thickness, m; S_a – area of the toothed disc, m².

As a result of the calculation, we came to the conclusion that the metal capacity of the disc with steel blades in comparison with the disc without steel blades has increased by a magnitude from 1.7% to 3.4%.

Depending on the shape of the soil harvester, its area is:

- rectangle
$$S_n = h_a \cdot k_n\,, \tag{17}$$

- rectangular trapezoid
$$S_n = h_a \cdot k_n - \frac{1}{2}k_n^2 \cdot ctg_n\,, \tag{18}$$

- triangle
$$S_n = \frac{1}{2}h_з \cdot k_n\,. \tag{19}$$

The length of the working edge of the tooth is determined by the height of the tooth, the length of its cutting surface, the width of the soil cultivator, the number of teeth per segment of the blade which are immersed in the soil, namely (*Stavruk D.V. & Hrushetsky S.M., 2015*):

$$l_{kp} = Z'\left(h_a + c_a + k_n\right), \tag{20}$$

where:

h_a – height of the tooth, m; c_a – length of the curvilinear side of the tooth, m; k_n – width of soil harvester, m;

Z' – the number of teeth that are on the segment of the blade which is immersed in the ground, pcs.

It is necessary to determine the number of teeth on the segment of the blade which is immersed in the soil. To do this, use the scheme presented in fig. 6.

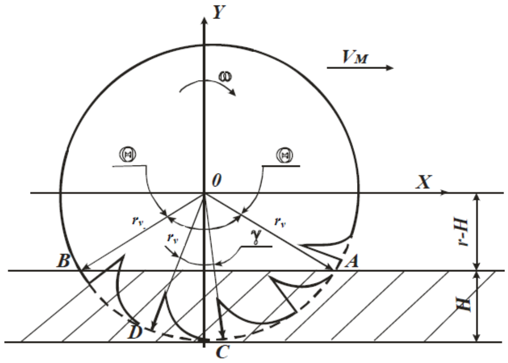

Fig. 6 − Scheme to determine the number of a disc teeth which are immersed in the soil

The length of the arc l_{AB} is determined by the formula (*Stavruk D.V. & Hrushetsky S.M., 2015*):

$$l_{AB} = r_v\left(\pi - 2\arcsin\frac{r_v - H}{r_v}\right). \tag{21}$$

The length of the arc l_{DC} which corresponds to the placement of one of the gear teeth on the arc AB is determined as follows:

$$l_{DC} = r_v \cdot y\,, \tag{22}$$

where r_v – radius of the disc at the tops of the teeth, m; y – central angle for one tooth, degrees.

With a known number of teeth Z we define:

$$\gamma\,\frac{2\pi}{Z}\,. \tag{23}$$

The number of teeth which are immersed in the soil is equal to (*Stavruk D.V. & Hrushetsky S.M., 2015*):

$$Z' \approx \frac{l_{AB}}{l_{DC}} = \frac{Z \cdot \left(\pi - 2\arcsin\frac{r_v - H}{r_v}\right)}{2\pi}. \tag{24}$$

We obtain the length of the cutting edge immersed in the soil:

$$l = \frac{\left(h_a + c_a + k_n\right)\cdot\left(\pi - 2\arcsin\frac{r_v - H}{r_v}\right)}{2\pi}. \tag{25}$$

Let us consider the effect of the forces of resistance of soil on a toothed disc with soil compactors, for which we will use the scheme represented in fig. 7.

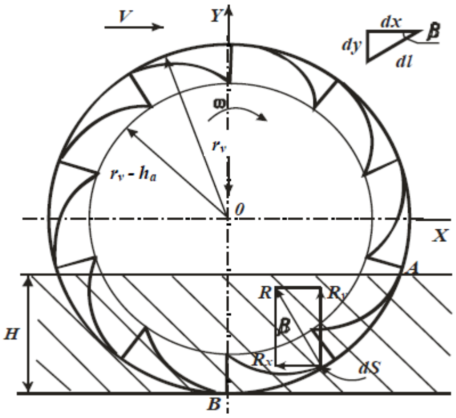

Fig. 7 − Scheme for determining the traction resistance of a disc with soil compactors, the teeth of which have a cutting surface in the form of a logarithmic curve

After transformation, the formula for determining the traction resistance of a disc with a logarithmic gear cutting edge and soil tillers without taking into account the friction forces will look as follows (*Stavruk D.V. & Hrushetsky S.M., 2015*):

$$R_x = \frac{Q_{г.ч.}\left(b_{\partial} \cdot H + \sum\limits_{i=Z'} S_n \cdot \cos\beta_i\right)}{\frac{2 \cdot Z \cdot b_{\partial} \cdot r_0}{2 \cdot 2\pi}\left(\psi + \frac{2k_n}{r_0} - 1 + e^{\psi ctg\tau}\left[1 + \frac{1}{\cos\tau}\right]\right) \cdot \left(\pi - 2\arcsin\frac{r_v - H}{r_v}\right) + \sum\limits_{i=Z'} S_n \cdot \sin\beta_i} =$$

$$= \frac{Q_{г.ч.}\left(b_{\partial} \cdot H + \sum\limits_{i=Z'} S_n \cdot \cos\beta_i\right)}{Z \cdot b_{\partial} \cdot r_0\left(\psi + \frac{2k_n}{r_0} - 1 + e^{\psi ctg\tau}\left[1 + \frac{1}{\cos\tau}\right]\right) \cdot \left(\pi - 2\arcsin\left[1 - \frac{2PH}{r_0\left(1 + e^{\psi ctg\tau}\right)}\right]\right) + \sum\limits_{i=Z'} S_n \cdot \sin\beta_i}. \quad (26)$$

According to the performed calculations results was done a comparative analysis of the digging working part disc elements of the following types: a disc with teeth, made on a logarithmic curve, a disc with soil-cutters having the shape of a rectangle, a disc with soil-cutters having the shape of a rectangular trapezoid, and a disc with soil compactors that have the form of a rectangular triangle (Table 1).

Table 1

Comparative characteristics of discs with soil compactors of different shapes

Benchmarks	Disc without steel blades	Tiller disc with soil compactors		
		Rectangular shape	Rectangular shape	Rectangle triangle
1. Increase in metal content, %	0,0	3.4	3.3	1.7
2. Increase of traction resistance, %	0,0	14.5	11.2	8.7

Let's consider the effect of the soil tiller working edge on the plant remains and the weed. First, let's assume that the soil tiller has the shape of a rectangular trapezoid. We use the scheme presented in fig. 8.

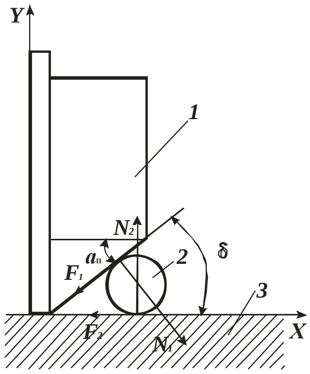

Fig. 8 – Scheme of the working edge of the soil tiller on the element of the plant

1 – disc tiller; 2 – an element of the plant; 3 – the surface of the field

Let the element of the plant act with forces N_1 and N_2, normal to the working edge and the surface of the soil. If it is pushed out from the solution of the working edge and the surface of the soil, then the strength of friction forces will affect F_1 and F_2 on it, the values of which we can find from the formulae (*Stavruk D.V. & Hrushetsky S.M., 2015*):

$$F_1 = N_1 \cdot tg\phi_1 \quad (27)$$

$$F_2 = N_2 \cdot tg\phi_2 \quad (28)$$

where: $tg\varphi_1$ and $tg\varphi_2$ – coefficients of friction of the element of the plant, respectively, to the steel and to the soil adjustment.

To prevent plant residues from being pushed away from the aforementioned substance, the force F_2 must be greater or equal to the sum of projections of all forces acting on the stalk along the *OY* axis, i.e., the condition must be met:

$$F_2 \geq N_1 \cdot sin\delta - F_1 \cdot cos\delta, H \quad (29)$$

Then the condition of plant elements jamming by the working edge of the soil tiller will have the following form (*Stavruk D.V. & Hrushetsky S.M., 2015*):

$$a_n \leq \phi_1 + \phi_2 \quad (30)$$

The angles φ_1 and φ_2 are known and, therefore, the angle of inclination of the soil cultivator working edge, which determines the cutting of the elements of plants and weeds, must be less or equal to 63° (*Stavruk D.V. & Hrushetsky S.M., 2015*):

$$a_n \leq 27° + 36° = 63° \quad (31)$$

Analysing the formula (31), we can conclude that the ground-tiller which is made in the form of a rectangular trapezoid is the most rational solution for the cutting of plant residues. So, when cutting blades have a rectangular triangle shape, for preserving the condition of the blades for fixing state, they must have width of at least 50 mm to ensure the condition of jamming, which negatively affects the metal capacity and traction resistance. The rectangular form of the soil tillage is the cutting of vegetable residues by cutting without slipping (that is, δ = 0), which is more energy-efficient than cutting with slipping (*Stavruk D.V. & Hrushetsky S.M., 2015*).

RESULTS

The tests were carried out on loamy soils at a yield of potatoes of 13.2 tons/ha. Experimental potato diggers which are based on KST-1,4A participated in the harvesting of potatoes along with serial potato diggers KST-1,4A. Experimental potato diggers had a changed undercut part consisting of a sectional passive bench steel blades and vertical discs mounted on the outside of the working body.

The disc element has steel blades, made in the form of a rectangular trapezoid. The tread depth was set with the help of a support wheel, which goes along the inter-row.

In fig. 9 and 10 are shown the results of field experiments of the experimental potato digger compared to the serial loss and damage of potato tubers depending on the machine working speed.

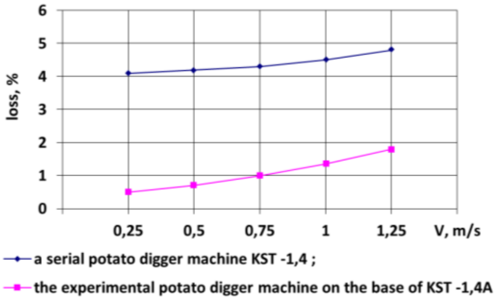

Fig. 9 − Loss of potato tubers depending on working speed and constructions of potato digger working parts

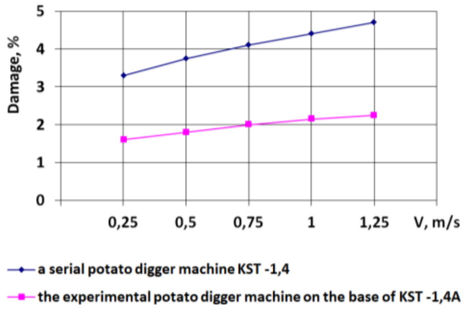

Fig. 10 − Damage of potato tubers is depending on working speed and constructions of potato digger working parts

The conducted studies showed the following:

1. The digging working part of the experimental potato digger, with a reduction of traction resistance by 18%, has an improved buckling rate of the potato soil level to 19%.

2. The completeness of digging with an experimental potato digger machine based on KST-1,4A amounted to 99.1%, compared to 97.6% with the serial digger KST-1,4. The obtained data can be explained by the more advanced design of the digging working parts.

3. Increasing the purity of residues amount of the experimental potato digger by 30.8% compared to the serial KST-1,4A is due to a decrease in the taken amount of "free" soil from the inter-row, as well as better soil cracking by the digging working parts.

4. As a result of the application of the disc sidewalls with the steel blades in the digging working part, the technological reliability of the experimental potato digger has increased and the downtime decreased by 33%.

5. The use of a potato digger machine with an experimental digging working part has allowed increasing productivity by 22%.

A potato digger machine allows harvesting potatoes with the determined quality level of working speed from 2.2 to 4.7 km/hour.

Research was performed to find out the capacity level of metal vertical cutting discs which have steel blades on potato harvesting machines for advanced digging performance.

The study of the capacity of metal vertical cutting discs with steel blades was conducted during the field trials. The deterioration value was determined by decreasing the sample weight by weighing on the analytical scales before and after the tests. The results of the tests were expressed as a measure of specific capacity level of *J* (g/ha), which is equal to the ratio of the difference in mass of the toothed disc before and after the test *m* (g) to the area of the field treated area S_n (ha).

$$J_n = \frac{m_n}{S_{\Pi n}}. \tag{32}$$

$$m_n = m_{2n} - m_{1n}. \tag{33}$$

Weighing was subjected to all toothed discs, after which the average specific capacity level is calculated:

$$J = \frac{J_1 + \ldots + J_n}{n}. \tag{34}$$

Also, during the study, the control of the intensity level of the steel blades in width and thickness was carried out. Thickness measurement was carried out using an indicator head with an accuracy of 0.01 mm; width measurement was made using a calliper with an accuracy of 0.05 mm.

The results of the capacity level study of the toothed discs with steel blades and the soil tillers by weight and according to the linear indicators are presented in Table 2.

It should be noted that studies on sandy soils were carried out on an area of 17 hectares and on loamy soils - 10 hectares.

Based on the study results, it can be concluded that for the entire term of the improved potato harvesting machine work it is not necessary to replace the vertical cut-off toothed discs with soil compactors due to their excessive capacity level.

Table 2

Research results of capacity level of toothed discs with soil compactors by weight and soil compactors according to the linear indices

Indicator	Units of measurements	Type of soil	
		Sandy	Loamy
Number of discs	unit	2	2
Average specific capacity level	g/ha	1.34	0.61
Changing linear indicators soil compactors during the study:			
– average in length	mm	1.36	0.71
– average in width	mm	0.25	0.61
– average in thickness	mm	0.19	0.11

CONCLUSIONS

A combined digging working part, which contains a passive blade and cutting discs with soil compactors, provides work at speeds up to 4.7 km/h. The use of new digging working parts has allowed increasing the purity of the residues amount by 30.8% compared to the base version.

Installation in the undercut part of the discs with the steel blades compactors on the lateral surface allows, compared with the basic variant to improve the fracture of the layer formation by 19%.

Comparative tests of experimental potato-diggers equipped with a developed digging part with a serial potato-digger KST-1,4A showed that its application yields positive results: the completeness of the harvesting is 99.1% versus 97.6%, no tubers that are not dug out.

The use of cutting discs in the underside reduces the traction resistance of the experimental digging working part by 15% compared to the basic version of their operation, improves the crumbling of the potato soil layer by 11%, increases the purity of the residues amount by 16%.

The study of the capacity level of developed gear discs during the research period showed that in the absence of production shortage, the capacity term of the discs will be equal to the term of the potato harvesting machine for 8 years.

The direction of further research in this area may be a wide range of issues of theoretical justification of the parameters of digging and separation working parts of potato harvesting machines, and also the calculation and explanation of the joining parts and body parts of the developed construction to its capacity level (*Kutsenko A., Bondar M.* & *Pryshliak V., 2018*).

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